STATE OF THE TROPICS
2014 REPORT

Is life in the Tropics getting better?

The inaugural *State of the Tropics 2014 Report* addresses this nominally simple question. It provides the first in-depth, objective assessment of the Tropics as an environmental and geopolitical entity in its own right. Drawing on the knowledge, experience and diverse backgrounds of leading institutions across the Tropics the report assesses the state of the region and examines the implications of the immense changes the region is experiencing.

The assessment demonstrates that nations in the Tropics have made extraordinary progress across a wide range of environmental, social and economic indicators in recent decades. Rapid population and economic growth mean its influence is set to rise dramatically in coming decades.

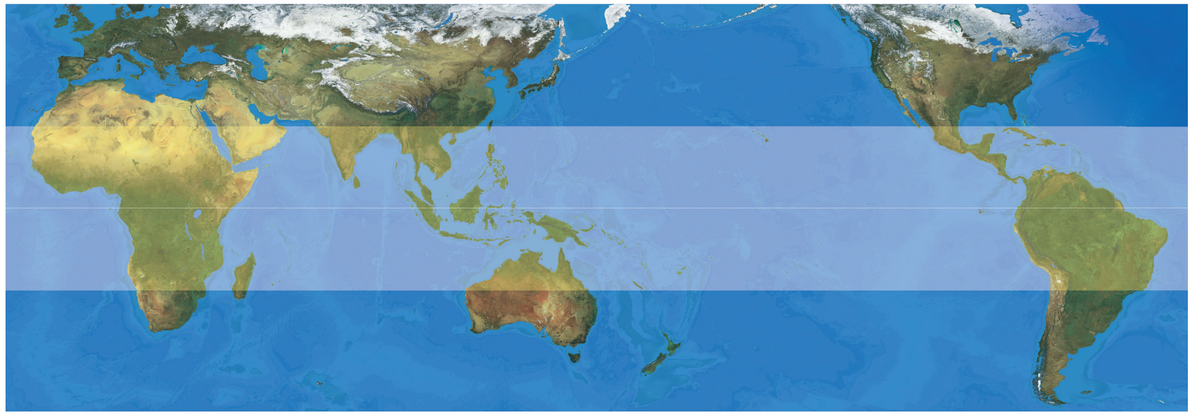
The nature of this influence will depend on how the region addresses its many challenges, and whether it realises its potential and opportunities.

A defining feature of the Tropics is its extraordinary biological, cultural and socio-political diversity, yet its people are connected by an ability to survive and thrive in this diverse and dynamic region. *State of the Tropics* explores this diversity and the inextricable link between natural systems and human health, well-being and prosperity. It provides a basis from which to work towards a prosperous, sustainable and equitable future for the Tropics and will be a valuable resource for policy makers, geopolitical analysts, researchers, students and other stakeholders interested in the Tropics.

Participating institutions:

James Cook University Australia · LSTM Liverpool School of Tropical Medicine · Mahidol University · University of Hawai'i Mānoa · USP The University of the South Pacific · OTS · Organization for Tropical Studies · Nanyang Technological University · University of Nairobi · INPA Instituto Nacional de Pesquisas da Amazônia · The University of Papua New Guinea · NUS National University of Singapore

STATE OF THE TROPICS
2014 REPORT



A comprehensive report by key research institutions exploring environmental, social and economic indicators

Published by James Cook University Townsville on behalf of the State of the Tropics leadership group.

 ISBN 978-0-9924023-4-1

This report should be cited as: State of the Tropics (2014) *State of the Tropics 2014* report. James Cook University, Cairns, Australia.

Disclaimer: The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of James Cook University or the leadership group for the State of the Tropics project.

The designations employed and presentation of material in State of the Tropics does not imply the expression of any opinion of James Cook University or the State of the Tropics leadership group concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries.

Layout and Design: Leo Schoepflin Graphic Design Studio Cover image credits: NASA

This report is printed on FSC certified paper sourced from well managed forests, controlled sources and recycled wood or fibre.

This report and associated data are available for download from **www.stateofthetropics.org**

Paperstocks used in this publication are Forest Stewardship Council (FSC) certified. Print: Lotsa Print and Design

Cover: Maine, gloss recycled, 350gsm Content: Maine, gloss recycled, 150gsm

STATE OF THE TROPICS

2014 REPORT

JAMES COOK UNIVERSITY AUSTRALIA

Cairns
Singapore
Townsville

in collaboration with

Authors and Acknowledgements

James Cook University and the State of the Tropics leadership group acknowledge the contributions made by many individuals and institutions to the preparation and publication of the inaugural State of the Tropics report.

State of the Tropics leadership group

James Cook University – Australia
Escuela Superior Politiécnica del Litorial (ESPOL) – Ecuador
Mahidol University – Thailand
The National Institute of Amazonian Research (Instituto Nacional de Pesquisas da Amazônia or INPA) – Brazil
Liverpool School of Tropical Medicine – United Kingdom and Ghana
Nanyang Technological University – Singapore
National University of Singapore – Singapore
Organisation for Tropical Studies – Costa Rica
University of Hawaii (Mānoa) – United States
University of Nairobi – Kenya
University of Papua New Guinea – Papua New Guinea
University of South Pacific – Fiji

Project management and editorial team

Sandra Harding, Rodney McComiskie, Mark Wolff, Dennis Trewin, Stephanie Hunter

Contributing authors

Alexandra Edelman, Andrea Gedling, Elena Konovalov, Rodney McComiskie, Ann Penny, Nicholas Roberts, Shelley Templeman, Dennis Trewin, Mark Ziembicki

Essay authors

Blair Trewin – *Australian Bureau of Meteorology*
Richard Corlett – *Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences*
Janet Hemingway – *Liverpool School of Tropical Medicine.*
Dennis Trewin – *Dennis Trewin Statistical Consultants.*
Dr Joanne Isaac – *James Cook University.*
Professor Steve Turton – *James Cook University.*

Advice, assistance and reviews

Norm Duke, Dean Jerry, Natkunam Ketheesan, William Laurance, Ali Mahdi, Linda Shields, Jeff Warner, Robert Bell, Reggie Carter, Chao-Ling Chien, Richard E Cibulskis, Sophia Couzos, Patricia Graves, Simon Hay, Terry Hughes, Dympna Leonard, Alex Loukas, Mary Mahy, Bill Maloney, Robyn McDermott, Meg Parsons, David Plummer, Morgan Pratchett, Scott Ritchie, Garry R Russ, Janelle Saffen, Louis Schofield, Larissa Siliezar, Natalie Stoeckl, Laura Taylor, Ryan Williams, Raman Vlayudhan, Dirk Zellar (Sea Around Us Project) and a number of anonymous reviewers.

Contents

List of Figures

List of Tables

List of Boxes

Foreword

The world's tropical region has long captivated the imagination of outsiders. Aristotle viewed the 'Torrid Zone' as an uninhabitable region of oppressive heat and pestilence; early European explorers and colonisers considered the region to be full of opportunity and ripe for discovery and exploitation; scientists have long worked to uncover its secrets; artists have been inspired by it and it has been idealised as a paradise, characterised by aqua blue seas, benign peoples and jungles teeming with exotic wildlife. The Tropics have long been defined by these views, invariably promoted and sustained by people who live outside the region: views which have shaped, and in many cases, framed policies and approaches to the region that have not necessarily been appropriate or beneficial.

In recent times, east/west, north/south, developed/developing axes of understanding have dominated our worldview, while that fundamental Aristotelian, lateral perception of the world has faded from view.

Yet, almost half the world's population call the Tropics home. People have lived, even thrived in the region for millennia. Across all parts of the region, they have mastered their tropical domains. Many peoples of the Tropics continue to live on their traditional lands, working determinedly to adapt their traditional ways to meet the challenges of a rapidly changing world, even as economic powerhouses have emerged elsewhere in the Tropics.

Despite the Tropics being a place of extraordinary biological and cultural diversity, the peoples of the Tropics across the globe share a common bond: their ability to adapt to and thrive in Aristotle's 'uninhabitable' zone. There is much the wider world can learn from the many innovative approaches to life adopted by the various peoples in the region; approaches which have served those peoples well.

Of course, the region is not without its challenges. For a variety of reasons, both imposed from the outside and born from within, the Tropics have lagged behind the rest of the world. In many ways, this makes the Tropics more vulnerable to the world's grand challenges than other regions.

At a time of increasing concern about social, environmental and economic sustainability, a different approach is long overdue. It is time to recognise and acknowledge the Tropics as a region defined from within, rather than without, to embrace the wisdom and experience of its peoples and to ensure that solutions of merit deployed in one part of the Tropics can be shared elsewhere, across the Tropics and beyond.

This is the approach taken by State of the Tropics. This report provides the first in-depth, impartial assessment of the Tropics as an environmental and geopolitical entity in its own right. It draws on the expertise, knowledge and diverse backgrounds of leading institutions across the region to assess the state of the region; to better understand the implications of the immense social, economic and environmental changes the region is experiencing and frame a pathway for a prosperous and sustainable future.

This report demonstrates that nations in the Tropics have made extraordinary progress across a wide range of environmental, social and economic indicators in recent decades. It also highlights the many significant and unique challenges the region continues to face.

There is much to learn here. And while this report shines a spotlight on the tropical world, its power and potential, the rest of the world is inevitably engaged, challenged and redefined by its findings as well.

By taking a unique perspective from within the Tropics, by and for the people that live in the region, and acknowledging the critical need to balance ongoing development and human wellbeing with environmental sustainability, State of the Tropics provides a base camp for the long, but increasingly achievable climb to a more prosperous global future.

Professor Sandra Harding

Burma/Myanmar.
Image: UN Photo.

Executive summary

In early 2011 a group of leading research institutions with an interest in tropical issues united to examine the condition of life in the Tropics. The group met in Singapore in mid-2011 to scope a project that would draw on shared expertise to report trends across a broad range of environmental, social and economic indicators. The intent was to shed light on a simple question: Is life in the Tropics getting better?

This report is the culmination of that collaboration. Across a broad range of environmental, social and economic indicators, the Tropics emerges as a critical global region with a unique set of development challenges and opportunities. The Tropics covers only 40% of the world's surface area, but hosts approximately 80% of its terrestrial biodiversity and more than 95% of its mangrove and coral reef-based biodiversity. The tropical world's economy is growing 20% faster than the Rest of the World and many tropical nations are important contributors to world trade, politics and innovation. The Tropics is home to 40% of the world's population, and 55% of the world's children under the age of five years old. By 2050, some 50 per cent of the world's population and close to 60% of the world's children are expected to reside in the Tropics. Advances in technology are providing a platform for expanding business opportunities, enhancing prospects to reduce poverty, and improving education and health outcomes. Incomes are higher, infrastructure is more accessible and life expectancy is the highest it has ever been.

While there have been rapid improvements, assessment of key indicators of wellbeing such as life expectancy and economic output per capita show that the Tropics still lags behind the Rest of the World. The region is at a critical juncture. The resources required to sustain larger populations and economic growth are putting significant and increasing pressures on the natural environment; poverty remains prevalent in many areas; many nations suffer from poor health and educational outcomes; significant investment in infrastructure is still required in many nations; and, in some cases, political and economic instability and poor governance are major constraints that limit development. Clearly, while on the right track, much remains to be done. The range and significance of shared issues facing nations and territories in the Tropics suggests it is timely to examine the characteristics and challenges facing the tropical region as an entity in itself.

By assessing a broad range of environmental, social and economic indicators the inaugural State of the Tropics Report shines a light on the people and issues of the tropical world, and contributes to efforts to improve the lives of the peoples of the Tropics and their environments.

In this report, finding are reported based on two key systems essential to assess progress and sustainability; the ecosystem and the human system. The ecosystem is recognised as providing services that underpin all life on Earth. The human system is considered a subset of the ecosystem acknowledging that ecosystem 'health' is essential to sustainable health, development and progress in the human system.

The Ecosystem

For many ecosystem indicators, the Tropics is in much better condition than the Rest of the World, although increasing population and affluence are placing greater pressures on the natural environment. Rapid growth in global trade and the exploitation of resources for export markets by more developed nations are also contributing to the ongoing and increasing risk to the ecological health of tropical ecosystems.

Key Findings:

The Atmosphere

- Across the world total and per capita greenhouse gas emissions are increasing.
- Consistent with rapid economic growth since 1980 the Tropics' share of global energy generation has more than doubled, from 7% to 15%. The Tropics produces 23% of global renewable energy, mostly through hydroelectricity generation.
- Air quality has improved in the Tropics and in the Rest of the World in the 20 years to 2010. The extent of the improvement is variable by region, and is in part dependent on climatic and geographical constraints. However, no tropical region has yet reduced PM_{10} levels (a measure of small particulate matter) to the World Health Organization's guideline of 20µg/m^3.

Land and Water

- Nearly one-third of all land in the Tropics experienced some form of degradation over the past three decades. Deforestation and poor agricultural practices are the major causes of degradation in the Tropics.
- Although the amount of land used for agriculture increased by only 2% in the Tropics between 1980 and 2009, productivity of that land has increased dramatically. Livestock production increased by almost 90% and cereal production more than doubled. However, agricultural productivity in the Tropics remains significantly lower than in the Rest of the World.
- The Tropics has just over half of the world's renewable water resources (54%), yet almost half its population is considered vulnerable to water stress. Although tropical rivers are on average less polluted than those in the Rest of the World, there is large regional variation, with South East Asia having the highest pollution discharge in the world.

Oceans

- Exploitation of wild marine food resources in the Tropics has grown rapidly over the past 60 years due to greater demand for seafood from a growing and increasingly affluent population and greater fishing effort by international fishing vessels.
- The rate of growth in marine catch has slowed considerably in recent years as more fisheries become fully exploited or overexploited.
- Threats to coral reef systems have increased markedly in recent years with over half the reefs in the Tropics now considered to be at medium or high risk of damage.
- The Tropics host nearly 95% of the world's mangrove forests by area and 99% of mangrove species. The area of mangrove forest has decreased in all tropical regions since 1980.

Biodiversity

- Biodiversity is greater in the Tropics across most taxonomic groups, with an equivalently higher proportion of threatened species. For those plants and animals for which there are adequate data, loss of biodiversity is greater in the Tropics than in the Rest of the World.
- The Tropics have a greater proportion of terrestrial area under formal protection than the Rest of the World. However, management effectiveness in these protected areas is variable, and many are still subject to illegal encroachment and exploitation.
- The proportion of marine area under formal protection is lower than for terrestrial areas, and the proportion under protection in the Tropics is lower than for the Rest of the World, although the gap is narrowing.
- Tropical biodiversity is being threatened by the rapid loss of primary forests, though since 2000 the rates of loss are reported as slowing in most – though not all – regions. New remote sensing technologies suggest losses may be under reported in some regions.

Into the future, the challenge will not only be to sustainably manage resources, but to also recognise the importance of less tangible aspects of ecosystem health and services that operate at multiple scales in both time and space. This will require cooperation at local, national and international scales to ensure that valuable ecosystems are protected and maintained.

The Human System

Society

Societies are the result of humans interacting with one another, sharing interests, cultures and traditions. Healthy, connected societies are essential for growth and wellbeing. This section of the report explores the status of tropical societies in terms of poverty, urban and slum living conditions, health, education and employment.

Outcomes are improving rapidly for the majority of Society indicators across the Tropics. A smaller proportion of people are living in extreme poverty, and more people have access to a more nutritious diet, and have better health and education outcomes than in past decades. Despite these improvements, the Tropics bears a disproportionate share of the global burden of many communicable and preventable diseases.

Key Findings:

Poverty and urbanisation

- Globally, extreme poverty has declined by almost 50% since the early 1980s, but more than two-thirds of the world's poorest people live in the Tropics. Most poverty reduction in the Tropics has occurred in South East Asia and Central America. The number of people living in extreme poverty in Central & Southern Africa has more than doubled in this time although the rate has been stable over the past five years.
- Consistent with the higher levels of poverty, more people experience undernourishment in the Tropics than in the Rest of the World. However, the prevalence of undernourishment in the Tropics has declined by one-third over the past two decades.
- In the Tropics the urbanisation rate has increased considerably faster than globally, from 31% of the population in 1980 to 45% in 2010. Despite this, a greater proportion of people in the Rest of the World (56%) live in cities compared with the Tropics.
- The proportion of the urban population living in slum conditions is higher in the Tropics than in the Rest of the World.

Health

- Life expectancy has increased across all regions of the Tropics in the past 60 years, but is still well below that of the Rest of the World. Nonetheless, the gap has narrowed from 12.1 years to 7.7 years since 1950.
- All regions in the Tropics have experienced significant decreases in maternal and child mortality rates since 1950. However, on a global scale the Tropics accounts for the vast majority

of these deaths, with 76% and 72% of mother and child under-five deaths respectively.
- The adult obesity rate in the Tropics is lower than in the Rest of the World, but is increasing at a faster rate. Non-communicable diseases are a growing cause of illness, disability and death in both the Tropics and the Rest of the World.
- HIV prevalence among people aged between 15 and 49 years is higher than in 1990 but has stabilised or declined in most regions of the Tropics after peaking in the mid to late 1990s, and the AIDS mortality rate has been declining in all regions since 2005. Compared with the Rest of the World, prevalence and mortality rates are higher in the Tropics.
- Except in Oceania, tuberculosis incidence has decreased in all regions of the Tropics since 1990. The Tropics represented 56% of new cases globally in 2010.
- There are no time series data for malaria, but in 2010 the Tropics represented 96% of cases and 99% of deaths from malaria, with Central & Southern Africa having the greatest burden.
- There are no time series data for dengue, but available data suggest 72% of infections occur in the Tropics, with South Asia and South East Asia having the highest number of cases, and the Caribbean the highest incidence rate. Other neglected tropical diseases such as soil transmitted helminthiases, schistosomiasis and lymphatic filariasis cause significant disability, disfigurement and death, especially in impoverished communities in the Tropics.

Education and Work
- Mean years of schooling of adults has almost doubled in the Tropics since 1980, but is still 2.5 fewer years of schooling than adults in the Rest of the World.
- Youth literacy rates have increased in all regions of the Tropics except in Oceania since 1990, but are consistently lower than in the Rest of the World.
- Adult literacy rates have increased faster in the Tropics than the Rest of the World but are still considerably lower. Despite the improvements, the overall number of illiterate adults in the Tropics is increasing.
- The unemployment rate is cyclical and influenced by economic growth. In the Tropics, the unemployment rate has declined steadily since the turn of the century and only showed a small increase in 2009 during the global financial crisis, before returning to pre-crisis levels.

Economy
The past 60 years has seen a dramatic rise in living standards across the world, and even nations that are relatively poor today enjoy living standards that were unprecedented 100 years ago. The reasons for this development are varied and complex, but economic growth is a useful indicator of improvements in living standards. Nations that have strong economic growth are better able to reduce poverty rates, strengthen political stability, improve the quality of the natural environment and even diminish the incidence of crime and violence.

Key findings:

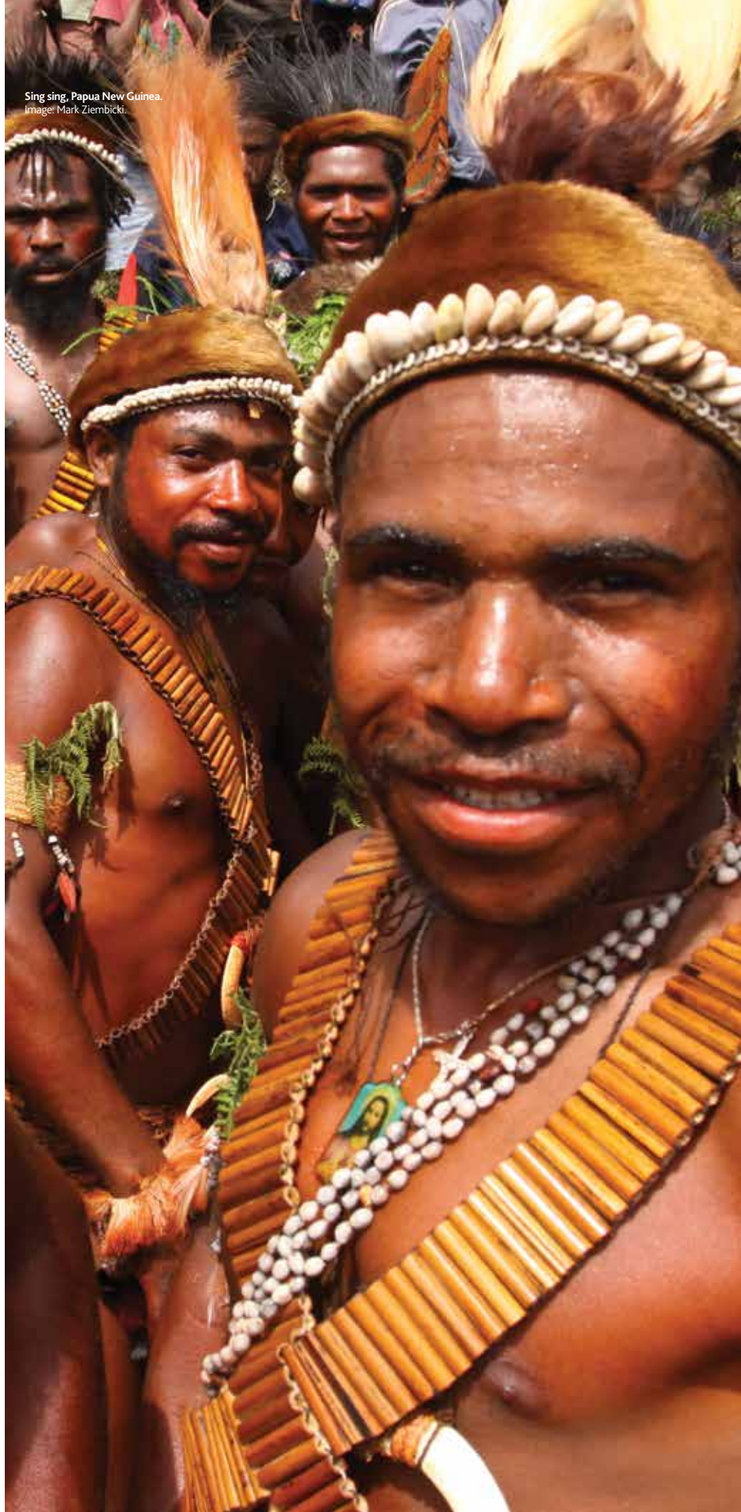
Economic output and government
- The Tropics has outperformed the Rest of the World in terms of economic growth over the past 30 years. The Tropics is now estimated to represent 18.7% of global economic activity, up from 14.5% in 1980. Despite this, available data suggests Gross Domestic Product (GDP) per capita in the Tropics is currently estimated to be only one-third that of the Rest of the World.
- The public sector debt service burden has been improving across most regions of the Tropics over the past three decades as a result of stronger economic growth and, especially for poorer nations, the impact of debt relief programs. As a proportion of GDP the debt service burden declined in the Tropics by two-thirds between 1980 and 2010.

International trade and investment
- Exports of goods and services as a percentage of GDP have grown rapidly in the Tropics in the past 30 years, increasing from 25% to 47%. Export earnings, however, are only 21% of the global total. Export earnings tend to be more important to national incomes in the Tropics than in the Rest of the world.
- Imports of goods and services to tropical nations have increased rapidly in the past 30 years from 26% to 45% of GDP. The volume of imports to the Tropics grew by 210% during this period. Nevertheless, the volume of exports continues to exceed the volume of imports.
- Foreign investment increased in all regions of the Tropics in the 30 years to 2010. Investment to tropical nations increased from 0.7% of Gross National Income (GNI) to 3.5%.

Science and technology
- In the Tropics investment in research and development is increasing modestly, while the number of published science and technical journal articles and enrolments in tertiary education are growing rapidly from a low base. There is substantial regional variation in trends.
- Despite these improvements, compared with the Rest of the World, there is less investment in research and development, fewer tertiary enrolments per capita and fewer scientific and technical journal articles produced in the Tropics. Investment in technology and innovation will be important for the tropical region as a whole to be competitive in future knowledge-based economies.

Governance
Governance is about how companies, institutions and nations are organised to manage affairs, power and responsibilities. It is the process used to implement and monitor decisions, policies and legislation.

Generally, the Tropics shows a poorer result than the Rest of the World across governance indicators. However, there has been rapid improvement in recent decades.


Sing sing, Papua New Guinea.
Image: Mark Ziembicki.

Key Findings:

Human security, crime and corruption
- Refugee numbers in the Tropics declined significantly during the 1990s, but numbers have stabilised at around 4 million over the past decade. The decline in refugee numbers in the Tropics between 1990 and 1999 was driven by the repatriation of significant numbers of refugees to Mozambique and Ethiopia. Although not reported here, refugee numbers in the Rest of the World have increased recently due to conflict in the Middle East.
- Although time series data are not available, the homicide rate in the Tropics is considerably higher than in the Rest of the World. Overall, the Tropics reported a homicide rate of 14.5 per 100,000, compared with a rate of 5.6 per 100,000 in the Rest of the World. However, within the Tropics there is great regional and national variation. For example, the homicide rate in South America was 32.9 per 100,000 compared to 5.1 per 100,000 in South Asia.
- The Tropics achieved lower scores than the Rest of the World for a range of governance indicators, indicating higher rates of corruption.

Gender equality
- Improving wellbeing across society requires people to have similar opportunities with respect to education, employment and decision-making.
- Comparing the Tropics with the Rest of the World, fewer females attend secondary education relative to males, although the gap is closing.
- Globally, the representation of women in different sectors of society is improving. The proportion of women in national parliaments worldwide increased from 12% in 1997 to 20% in 2011. The improvement is broadly similar in the Tropics and the Rest of the World, increasing from 10% to 18% and 13% to 20% respectively.

Infrastructure
- Worldwide, the rate of gross capital formation as a percentage of GDP has declined marginally since 1980, but is highly variable across nations and, in the Tropics there has been an upward

trend. The performance of the Tropics varied substantially with some regions displaying higher growth and variability than others.
- Although the gap has narrowed, the proportion of the population with access to safe drinking water is lower in the Tropics than in the Rest of the World. In the Tropics the proportion of the population with access to safe drinking water has increased from 67% to 81% since 1990.
- Poor sanitation is a major issue in many tropical nations, especially those with rising populations and increased urbanisation. However, global sanitation coverage increased from 48% of the population in 1990 to 63% in 2010, and the number of people with access to improved sanitation facilities increased from 2.5 billion to 4.3 billion. The number of people with access to improved sanitation facilities in the Tropics doubled from 0.7 billion to 1.4 billion.

Information communications and technology

- Over the past decade the mobile phone has emerged as one of the fastest growing consumer technologies ever introduced. In the Tropics, mobile telephony has become the dominant means of communication and the principal gateway to increased ICT access and use, with penetration rates reaching 68% up from almost zero in the early 1990s.
- Internet diffusion in the Tropics has grown quickly in terms of both users and penetration, though access is considerably less widespread than mobile communications. A growth rate of 30% per annum since 2000 (twice that in the Rest of the World) has seen internet users in the Tropics increase to 471 million, or 17% of the population.

This report also includes five essays, written by experts from around the world, exploring climate change, health and development in the Tropics.

Mong Kok, Hong Kong.
Image Luke Chan.

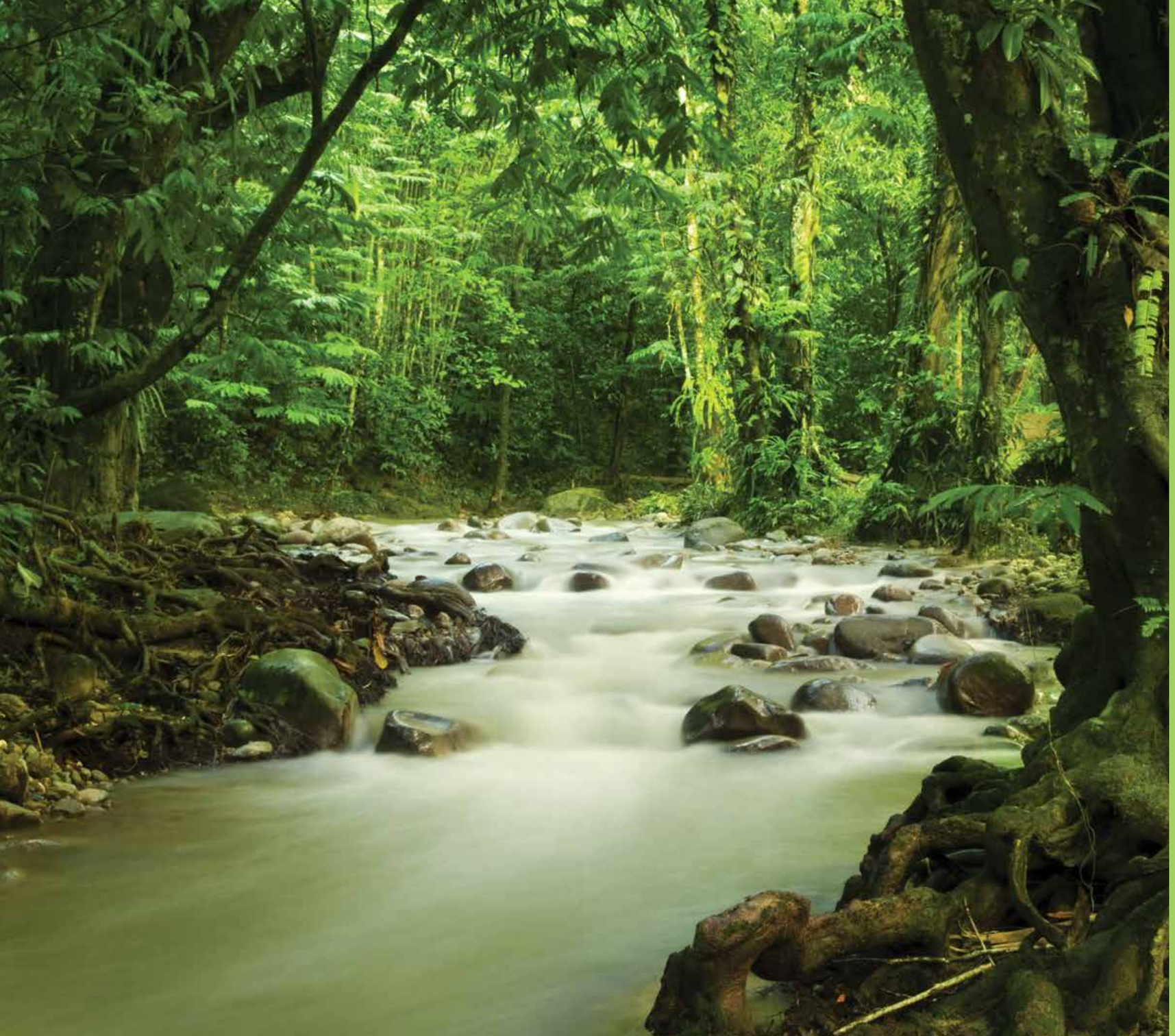
Acronyms used in this report

ACOSS	Australian Council of Social Services (Australia)
ADB	Asian Development Bank
AFMA	Australian Fisheries Management Authority (Australia)
AIDA	Interamerican Association for Environmental Defense
ALI	Australian Landcare International
APEC	Asia Pacific Economic Cooperation
ATA	Alternative Technology Association
AU-NEPAD	African Union - New Partnership for Africa's Development
BIP	Biodiversity Indicators Partnership
CBD	Convention on Biological Diversity
CDC	Center for Disease Control and Prevention
CFS	Committee on World Food Security
CIA	Central Intelligence Agency (USA)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DFAT	Department of Foreign Affairs and Trade (Australia)
ECOSOC	United Nations Economic and Social Council
EIA	Energy Information Administration (USA)
EPA	Environmental Protection Authority (USA)
FAO	Food and Agricultural Organisations of the United Nations
FIVAS	Association for International Water Studies (Norway)
GBRMPA	Great Barrier Reef Marine Park Authority (Australia)
GSMA	Global System for Mobile Communications
HEI	Hedley Environmental Index
HK EPD	Hong Kong Environmental Protection Department
IAACA	International Association of Anti-Corruption Authorities
IAEA	International Atomic Energy Agency
IBRD	International Bank for Reconstruction and Development
ICAO	International Civil Aviation Organization
ICRW	International Center for Research on Women
ICS-CERT	Industrial Control Systems Cyber Emergency Response Team
IEA	International Energy Agency
IFAD	International Fund for Agricultural Emergency
IFPRI	International Food Policy Research Institute
IHC	International Housing Commission
IIDEA	International Institute for Democracy and Electoral Assistances
ILO	International Labour Organisation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPU	Inter-Parliamentary Union
ITC	International Trade Centre
ITIF	Information Technology and Innovation Foundation
ITU	International Telecommunication Union
IUCN	International Union for the Conservation of Nature
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
NASA	National Aeronautics and Space Administration (USA)
NHMRC	National Health and Medical Research Council (Australia)
NOAA	National Oceanic and Atmospheric Administration (USA)
NSF	National Science Foundation (USA)
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-operation and Development
OTA	Office of Technology Assessment, United States Congress
SPC	Secretariat of the Pacific Community
UN	United Nations
UN AIDS	Joint United Nations Programme of HIV/AIDS
UN CCD	United Nations Convention to Combat Desertification
UN DESA	United Nations Department of Economic and Social Affairs
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UN HABITAT	United Nations Human Settlements Programme
UN REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
UN WTO	United Nations World Tourism Organisation
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Scientific, Educational and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNGEI	United Nations Girls Education Initiative
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNIFEM	United Nations Development Fund for Women
UNODC	United Nations Office on Drugs and Crime
UNPF	United Nations Population Fund
US AID	United States Agency for International Development
USIP	United States Institute of Peace
USITC	United States International Trade Commission
WB	World Bank
WCPA	World Commission on Protected Areas
WEDO	Women's Environment and Development Organization
WEF	World Economic Forum
WFP	World Food Programme
WHO	World Health Organisation
WMO	World Meteorological Association
WRI	World Resources Institute
WTO	World Trade Organisation
WWF	World Wide Fund for Nature

Haiti.
Image: Logan Abassi, UN Photo.

Section 1

The Tropics



Chapter 1

State of the Tropics

Introduction

Humanity has long sought to define the world through broad categories to help contextualise its diversity. Since Aristotle divided the world into Temperate, Torrid, and Frigid zones with the narrow view that only the Temperate region was habitable, we moved to North-South and East-West dichotomies. Other recent distinctions such as the First and Third World and developed and developing nations have also been made on the basis of socio-economic and political similarities and affiliations. Invariably such distinctions are too simplistic, and fail to recognise the inherent diversity of approaches, perspectives and realities faced by different regions and nations in relation to their own contexts and the broader global community.

The State of the Tropics report adopts a different approach. The intention here is not to add a further distinction dividing 'tropical' vs 'non-tropical' regions, but to recognise that the nations and territories within the Tropics share many unique challenges and opportunities that stem from more than their current and historical political and economic circumstances. Critically, it recognises geography and the environment as central to shaping human societies in the region, and the inextricable link between natural systems and human health, well-being and prosperity.

Occupying a distinctive geographical area between the Tropic of Cancer in the north and the Tropic of Capricorn in the south, the "Tropics" is a place of extraordinary diversity. As well as spanning a broad spectrum of socio-economic and political systems, the Tropics hosts most of the world's biological diversity, and is home to its most linguistically and culturally diverse regions. Stemming back to Aristotle, it is a region traditionally viewed by those from higher latitudes as essentially uninhabitable; hot and harsh and burdened by disease. Yet today its major biomes, including tropical savannas, deserts, rainforests and coral reefs are being increasingly transformed by human-dominated landscapes. With expanding agricultural areas, industrial infrastructure and some of the fastest growing megacities in the world, the tropical region is a long way from the inhospitable 'Torrid Zone' described by Aristotle.

The Tropics today is home to 40% of the world's population – a figure projected to rise to 50% by 2050. The region's economy is growing 20% faster than the Rest of the World; its people are more educated than ever before and new technology is an increasingly pervasive influence. Not only is the Tropics a region that is changing rapidly, but it is also a region that has much to offer, and whose influence is set to rise dramatically in the coming decades. The nature of this influence will depend on how its many significant challenges are addressed.

Many tropical nations face greater and more imminent exposure to some of the critical issues of our time. Climate change, for example, has the potential to disproportionately affect the Tropics through impacts on human and food security, renewable water availability, rising sea levels, and vector borne diseases. The resources required to sustain larger populations and economic growth will put ever-increasing pressures on the natural environment, and poverty and poor health outcomes remain prevalent in many areas.

During the period examined in this report (1950 to the present), many tropical nations have undergone immense social and political change. For many nations in the Tropics, the second half of the 20th century was characterised by decolonisation and a move towards political independence.

For many, the transition has not been smooth, and has been burdened with civil conflict, dictatorships and, in some cases, large-scale genocide. Despite this unrest, strong democracies and stable economies have emerged from this period of change.

The range and significance of shared issues facing nations and territories in the Tropics suggest it is timely to examine the opportunities and challenges facing the tropical region as an entity in itself. It is time to systematically assess the state of the region, to take stock and to develop the means to work towards a common future that recognises the potential of this dynamic and diverse region.

The environment of the Tropics

The Tropics surround the Earth's Equator within the latitudes of the Tropics of Cancer and Capricorn at ±23.5 degrees. These latitudes relate to the axial tilt of the Earth; in all areas between them the Sun reaches a point directly overhead at least once during the solar year.

Although topography and other factors contribute to local climatic variation, tropical regions are typically warm and experience little seasonal change in daily temperatures. Important features of the Tropics are the prevalence of rain in the moist inner regions near the equator, and increasing seasonality of rainfall with distance from the equator.

The Köppen-Geiger climate classification identifies the Tropics as being dominated by 'equatorial' and 'arid' climates, with the balance of the world being primarily 'warm temperate', 'snow' and 'polar' climates. Equatorial climates have a mean temperature for all months above 18°C (64°F), and arid zones are defined with reference to both temperature and rainfall, and are characterised by a general lack of water which constrains plant and animal life.

The Tropics host an estimated 80% of the world's terrestrial biodiversity and most of its marine diversity. A significant proportion of this diversity is already under threat, which climate change impacts are likely to amplify. Changes to climate are likely to have a greater impact in the Tropics than elsewhere because many species are specialised to deal with a narrow range of environmental conditions. Species in the Tropics are not as able to tolerate changes in climate as well as those accustomed to more significant changes in seasonal conditions in other parts of the world.

The people of the Tropics

The number of people living in the Tropics, their demographic characteristics and distribution are an important influence on many of the measures of progress used in this report. The Tropics is home to 40% of the world's population, or more than 2.8 billion people. This is an increase of over 2 billion people since 1950 and equates to a growth rate of 2.2% per annum, considerably higher than growth of 1.4% per annum in the Rest of the World. By 2050 more than half of the world's population is expected to live in the Tropics. According to the World Bank, 21% of the tropical population currently resides in low income nations, a further 54% in lower middle income nations and the remainder in upper middle income and high income nations. Almost 99% of the tropical population live in a nation considered to be 'developing'.

Population growth rates have in fact been declining in most regions of the Tropics during the past 60 years, mostly because of declining fertility. Fertility has declined across all tropical regions including those with the most population growth. In 1950 a woman in the Tropics could be expected to give birth to around six children in her lifetime. Sixty years later this number has declined to 3.3. Fertility rates tend to decline with growing affluence and greater access to education.

The age structure in the Tropics differs quite significantly from the Rest of the World. Higher birth rates and lower life expectancy in the Tropics mean that children under 10 make up 23% of the population compared with 15% in the Rest of the World. Longer life expectancy in the Rest of the World equates to a much greater proportion of older age groups than in the Tropics. People over 70 years make up only 3% of the population in the Tropics compared with 7% in the Rest of the World. Based on median population growth and life expectancy assumptions, by 2050 the Tropics will be home to 60% of the world's children under 10 years old. Half of these children will live in Central & Southern Africa.

Child in Papua New Guinea.
Image: Mark Ziembicki.

Irrigated fields, Nigeria.
Image: Arne Hoel, World Bank.

The State of the Tropics Project

In early 2011 a group of leading research institutions with an interest in tropical issues identified a need to examine the condition of life in the Tropics. The group met in Singapore in mid-2011 to scope a project that would draw on shared expertise to report trends across a broad range of environmental, social and economic indicators. The intent was to shed light on a simple question: Is life in the Tropics getting better?

This report is the culmination of that collaboration. By assessing a broad range of environmental, social and economic indicators it shines a light on the people and issues of the tropical world, and contributes to efforts to improve the lives of the peoples of the Tropics and their environments.

To answer the question of whether life is improving in the Tropics an evaluation of progress was made on national, regional and global scales. In this case, progress refers to an increase in the sustainable and equitable well-being of a society. It is multidimensional and includes economic, social and environmental factors along with other areas considered important to quality of life (for example the quality of governance).

Given these multiple dimensions, answers to the fundamental question are likely to be positive for some aspects and negative for others. The concept of progress is influenced by an individual's perspective; what is viewed as progress by some will be seen as regress by others.

This report is a dispassionate, statistical analysis of a range of indicators that reveal trends and areas where progress is being made or lost. Analyses were based on data collated from existing, authoritative sources and included no new data collection.

The framework of the report is based on two key systems essential to assess progress and sustainability; the ecosystem and the human system. The ecosystem is recognised as providing services that underpin all life on Earth. The human system is considered a subset of the ecosystem acknowledging that ecosystem health is essential to sustainable health, development and progress in the human system.

In the conceptual framework the ecosystem's domains are:

- Atmosphere (Chapter 2);
- Land and water (Chapter 3);
- Oceans (Chapter 4); and
- Biodiversity (Chapter 5).

These domains deliver services to the human system for a broad range of economic, social and aesthetic purposes.

In the conceptual framework the human system's domains are:

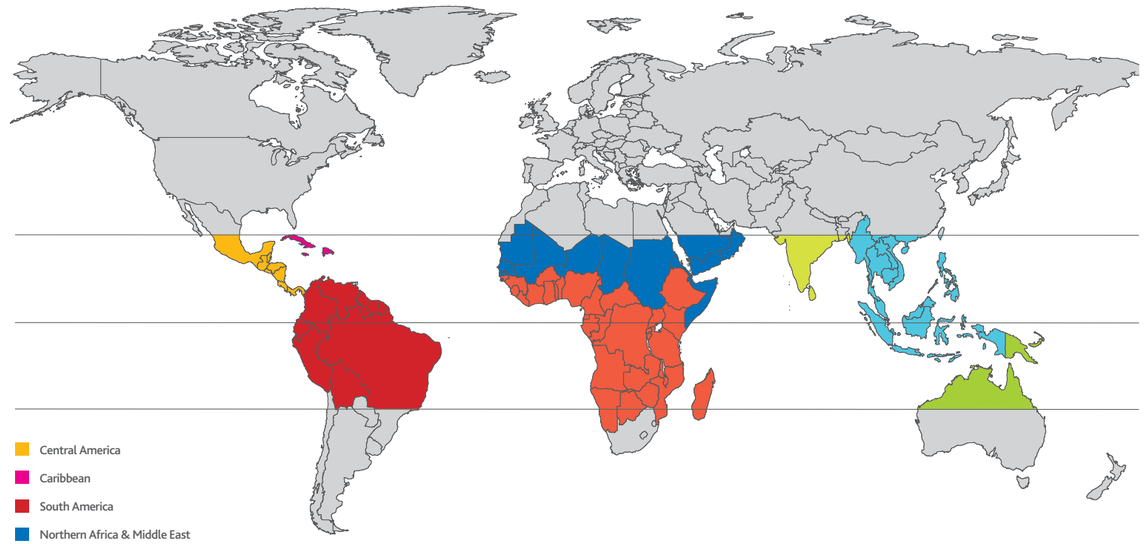
- Society (Chapter 6);
- Economy (Chapter 7; and
- Governance (Chapter 8).

These domains are recognised as critical in assessing societal progress. The human system's domains were further defined by dimensions, and indicators were identified to assess progress in each dimension. The indicators allow quantitative assessment of the domains and dimensions. It is through analysis of the indicators that the question of whether 'life in the tropics is getting better' is assessed. A full list of the indicators, data sources and coverage, is found in **Appendix A**.

The report also includes five essays by experts on climate change, health and development who provide comment on the current challenges and opportunities for the Tropics.

Regions of the Tropics

Figure 1.1 **Tropical regions of the world**



The Tropics is diverse in terms of climate, environment and culture. To aid with analysis and reporting, the region was sub-divided into regions based on general geographical similarities to develop groupings that have some degree of commonality. There are a number of ways that this could be undertaken, including by climate (e.g. wet and dry Tropics) and by national borders.

As the majority of data are reported on a national basis, individual nations are the primary basis for these regional aggregations. The regional groupings used in this report are:

- Central & Southern Africa;
- Northern Africa & Middle East;
- Caribbean;
- Central America;
- South America;
- Oceania;
- South East Asia; and
- South Asia.

Analysis in the Report focusses on comparisons of regions rather than nations.

Nations of the Tropics

To assess which nations and territories should be included in the Report two processes were applied. The first used a population-based decision tool to assess whether nations partially in the Tropics should be included in the Report, and the second reviewed data availability to assess whether sufficient data were available to warrant a nation's inclusion in the Report. Generally only very small nations were excluded.

The geographic area that is the Tropics is clearly defined as the region between the Tropics of Cancer and Capricorn. However, national borders do not align neatly with these latitudinal lines and there are a number of nations and territories that straddle the zone.

The following practical approach was applied to select nations and territories for inclusion in the Report:

- Nations that are wholly within the Tropics are included;
- Nations partially within the Tropics are included if:
  - The majority of the population (i.e. more than 50%) lives in the Tropics (e.g. Brazil, India); or
  - The proportion of the population living in the Tropics is 5% or more of the region's population living in the Tropics.

Using this decision tool 134 nations and territories were assessed as being in the Tropics (See **Appendix B**).

Large nations which straddle the Tropics (Mexico, Brazil, Saudi Arabia, India, Bangladesh, China, Australia and United States) were investigated at a sub-national level and divided into tropical and non-tropical regions (See **Appendix C**). Sub-national estimates were calculated using regional data where it was available or applying assumptions to national level data.

Reflecting the broad international scope of the project are the key institutions involved. These include: Escuela Superior Politiécnica del Litorial (Ecuador), Instituto Nacional de Pesquisas da Amazônia (Brazil), James Cook University (Australia), Liverpool School of Tropical Medicine (England), Mahidol University (Thailand), Nanyang Technological University (Singapore), National University of Singapore, Organization for Tropical Studies (Costa Rica), University of Hawaii – Manoa (USA), University of Nairobi (Kenya), University of Papua New Guinea and University of the South Pacific (Fiji).

Fishing Boats.
Image: Chris Chancellor.

Section 2

The Ecosystem

Chapter 2

Atmosphere

'You can't see it; yet the sky is blue. You can't touch it; yet you can feel its movement. It is very light and easily moved; yet it can support weights of hundreds of tons, destroy buildings and even move the Earth. It has no voice; yet conversation and music are impossible without it. It won't stop a bullet; yet it protects us from cosmic missile attack. It dries the washing; yet it brings us rain. It doesn't generate heat; yet it keeps the earth from freezing. It is non-flammable; yet it allows us to make fire. It lacks life; yet it sustains it. These are a few of the multitude of attributes of the wonderful material that is 'Air'.'

Frank Fahy

Image: Mark Ziembicki.

Summary of Atmosphere Indicators

Indicator		The Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Carbon Dioxide & Greenhouse Gas Emissions	CO_2 emissions* 1950 to 2008	**177-4,593**	15-227	3-214	43-901	30-2,026	9-111	24-401	41-659	13-53.7	**5,525-25,381**	**5,891-29,986**
	Greenhouse gas emissions – per capita** 1990 to 2006	**2.4-2.9**	2.3-1.9	3.05-3.15	1.2-1.6	2.3-3.6	3.7-3.9	4.1-4.7	4.7-5.3	7.9-7.0	**7.66-7.75**	**5.6-5.7**
Electricity Generation 1980 to 2010	Total Electricity Generation#	**542-2,927**	56-126	11-108	75-543	106-1,140	31-66	60-242	185-664	18-38	**7,471-17,286**	**8,013-20,213**
	Renewable Electricity Generation#	**270-954**	46-83	0.6-5	30-84	19-189	2.3-2.7	21-64	149-520	2.6-5.5	**1,484-3,198**	**1,754-4,152**
	% Electricity Generated from Renewables	**50-33**	83-66	5.4-4.7	40-15	17.7-16.6	7.4-4.1	34-27	81-78	14.4-14.4	**19.9-18.5**	**21.9-20.5**
Air Pollution 1990 to 2010	PM_{10} Air Quality^	**77-39**	80-35	164-78	81-65	82-41	48-28	48-33	53-28	39-22	**73-34**	**76-36**

Red: Situation is deteriorating
Green: Situation is improving

* CO_2 emissions in millions of tonnes of carbon dioxide; **emissions in tonnes of CO_2 equivalent;
# net generation (gross electricity generation less electricity required for power station operations) in billion kilowatt hours;
^ measured in micrograms/cubic metre (µg/m³)

Image: Mark Ziembicki.

Is it getting better?

Carbon dioxide and greenhouse gas emissions
Carbon dioxide (CO_2) emissions have increased worldwide in the past 200 years. The Tropics region emits less CO_2 and greenhouse gases than the Rest of World, although its share of global emissions is increasing. Despite accounting for around 40% of the global population the Tropics only contributes 15% of current greenhouse gas emissions. Regionally, emissions from South-East Asia and South Asia are increasing rapidly but are still small relative to the contribution from the Rest of the World, particularly on a per capita basis.

Electricity supply
Since 1980 global electricity production has increased by 150%, with the relative contribution to global electricity generation from the Tropics increasing from 7% to 15% in the 30 years to 2010. The Tropics produced 23% of global renewable energy in 2010, mostly through hydro-electricity although other sources such as biofuels, solar and wind power are being increasingly utilised.

Air pollution
Globally air quality has improved in the 20 years to 2010. The extent of improvement is variable and is in part dependent on climatic and geographical constraints. Despite major improvements, no tropical region has yet reached the World Health Organization's PM_{10} guideline of 20 g/m³.

Despite its critical importance to life on Earth the atmosphere is amongst the least known and appreciated of our global systems. It plays a vital role in the provision of essential ecosystem services, including protecting life from damaging solar radiation, providing the air we breathe, regulating climate and being integral to the hydrological cycle. The atmosphere is being increasingly impacted by human activities at multiple scales which affect the broader environment and human health and well-being. For example, increased atmospheric concentrations of greenhouse gases are causing the world's climate to change. Climate change has a wide-ranging impact on habitats, species distributions, human health, agriculture, sea levels and the frequency and intensity of extreme weather events. Emissions of ozone-depleting substances have decreased over the past two decades but the "hole" in the ozone layer over Antarctica is now larger than ever. Human and environmental health suffers and millions of people are affected adversely by outdoor and indoor air pollution. Such impacts are global in their nature but are likely to be felt more strongly in the world's most vulnerable communities – most of which are in the Tropics.

Headline indicator

Carbon dioxide and greenhouse gas emissions: Carbon dioxide and other greenhouse gases (GHG) are critical components of the earth's atmosphere and their concentrations strongly influence the planet's climate at local, regional and global scales. Human-caused increases in emissions of these gases threaten the environment and our relationship with it. Measuring emissions of GHGs is a good indicator of progress towards responding to climate change.

Supplementary indicators

Electricity supply: Electricity generated from coal and gas is the largest sectoral contributor to carbon dioxide and greenhouse gas emissions. Conversely, electricity generated from low carbon technologies and renewables may be regarded as low impact with regard to climate change effects. In this regard, how energy is created, distributed and used is an important indicator of future climate change risks and sustainable development.

Air quality (PM_{10}): Air pollution has both human and environmental impacts from short or long term exposure. Air quality indicators reflect a combination of industrial output, economic growth and environmental governance. From a public health perspective an important measure of air quality is the concentration of particulate matter less than 10 micrometres (µm) in diameter. Particulate air pollutants are measured as the mass of particles that are less than 10 µm in diameter divided by the volume of air sampled in cubic metres (PM_{10}).

Links to other dimensions

Land degradation, corals, mangroves, agriculture, water supply, health, economic output, biodiversity.

Carbon dioxide emissions

The earth's atmosphere is primarily composed of nitrogen, oxygen and argon, but it is the greenhouse gases (GHG) – which comprise less than 1% of atmospheric gases – that play a key role in maintaining an optimal temperature on the earth's surface for sustaining life by absorbing and emitting infrared radiation. That is, GHG's such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), fluorinated gases and water vapour play a critical role in the energy budget of the earth (Baede et al. 2001). This energy balance is complex, with surface temperatures and weather conditions influenced by the patterns and flow of GHG's, aerosols and clouds in the lower and upper atmosphere.

Carbon dioxide (CO_2) is the most common GHG, and is primarily generated through respiration in living organisms and the combustion of fuels. It is also the carbon source for photosynthesis in plants. Natural emissions of CO_2 from respiration and decomposition are approximately twenty times greater than anthropogenic (or human-induced) emissions, but are balanced through the natural uptake of CO_2 by plants and marine plankton (Sabine et al. 2004). Anthropogenic emissions of CO_2 have been the major cause of increased concentrations of atmospheric CO_2 since industrialisation (Sabine et al. 2004).

Over the past 400,000 years, atmospheric GHG levels have fluctuated, with CO_2 concentrations ranging from 180 to 300 parts per million (ppm) (Petit et al. 1999). However, since industrialisation atmospheric CO_2 emissions have increased from around 285 ppm in 1750 (Forster et al. 2007) to 394 ppm in 2010 (NOAA 2013). Critically, the rate of increase during this period has been much greater than in the past and is primarily due to the burning of fossil fuels and deforestation. Current atmospheric concentrations of CO_2 are at their highest levels for the past 650,000 years (Siegenthaler et al. 2005).

The relationship between increased CO_2 emissions and a warming climate was first suggested over a century ago (Field et al. 2004), but it has only been in recent decades that the weight of scientific evidence has led to increased public awareness and political action. The first World Climate Conference was held in 1979, which resulted in the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988; the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992; and the Kyoto Protocol in 1997 (see Box 2.1).

Trends

According to World Resources Institute estimates, global anthropogenic CO_2 emissions increased by 400% between 1950 and 2008 from 5,892 to 29,986 million tonnes (Mt) (see Figure 2.1). In 1950, the Tropics accounted for 3% of reported CO_2 emissions. By 2008, emissions had risen to 15% with increases at 5.8% per annum from 177 Mt to 4,600 Mt. Over that period annual CO_2 emissions in the Rest of the World increased from 5,500 Mt to 25,000a Mt at a rate of 3.0% per annum. This excludes emissions from land use, land use changes, forestry and bunker fuels because time series data are not available.

Among the tropical regions South East Asia reported the greatest increase in CO_2 emissions between 1950 and 2008, followed by South Asia and South America (see Figure 2.1). Over this period South East Asia increased its annual CO_2 emissions from 30 Mt to 2,026 Mt (7.5% per annum), South Asia from 43 Mt to 901 Mt (5.4% per annum) and South America from 41 Mt to 659 Mt (4.9% per annum).

In contrast, Oceania and the Caribbean had the lowest increase in CO_2 emissions, with Oceania's increasing from 13 Mt in 1950 to 54 Mt in 2008 (2.5% per annum) and the Caribbean from 9 Mt to 111 Mt (4.5% per annum).

Globally, annual CO_2-equivalent per capita emissions of all GHG's increased slightly between 1990 and 2005, from 5.6 tonnes per person (tpp) to 5.7 tpp (see Figure 2.2). Emissions in the Rest of the World were much higher overall and increased slightly from 7.7 tpp in 1990 to 7.8 tpp in 2005, while in the Tropics it increased from 2.4 to 2.9 tpp.

In contrast to total CO_2 emissions, the highest per capita CO_2-equivalent emissions of GHG's in the Tropics are in Oceania, primarily due to tropical Australia and Hawaii. If these two nations are excluded from the Oceania dataset, per capita emissions fall from 7.8 to 2.7 tpp in 1990 and from 7.0 to 2.1 tpp in 2005. South America and Central America are the second and third highest per capita emitters of GHG's, while South Asia is the lowest at 1.6 tpp.

Central & Southern Africa and Oceania emissions fell between 1990 and 2005 while increasing in all other regions. Oceania had the greatest reduction, with emissions falling by 0.9 tpp, followed by Central & Southern Africa with a 0.4 tpp reduction.

South East Asia reported the greatest increase in per capita CO_2-equivalent GHG emissions in the 15 years to 2005, up by 1.3 tpp to 3.6 tpp, followed by Central America and South America with 0.6 tpp. Overall, South East Asia is increasing both its total and per capita emissions more rapidly than other tropical regions, in part reflecting the relatively high levels of economic growth.

Box 2.1 The Kyoto Protocol – and beyond

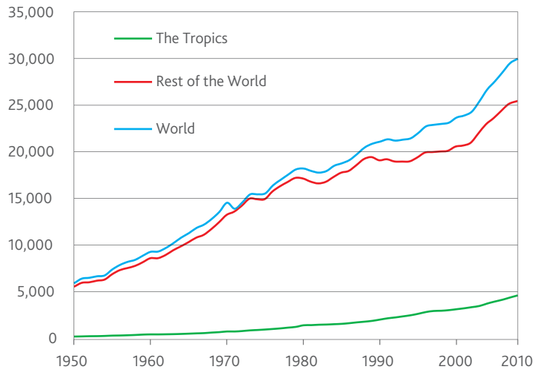
The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC). It was adopted in 1997 and entered into force in 2005. The primary difference between the UNFCCC and Kyoto Protocol is that the convention is non-binding, while the Kyoto Protocol is a binding commitment by 37 industrialised nations and the European community to reduce greenhouse gas (GHG) emissions (UNFCCC 1997). These nations committed to an average decrease in GHG emissions of 5% between 2008 and 2012 (UNFCCC 1998).

Subsequent efforts by the global community to further reduce GHG emissions have had limited success. While the 2010 Cancún Conference gained voluntary agreements from 76 nations to control emissions (which at the time were responsible for 85% of anthropogenic CO_2 emissions), the targets are not binding. At the 2012 Doha Conference, Kyoto Protocol nations agreed to extend the Protocol to 2020, with additional pledges to reduce greenhouse gas emissions (UNFCCC 2012a). However, many of the largest greenhouse gas emitters (e.g. the U.S. and China) are yet to ratify the protocol.

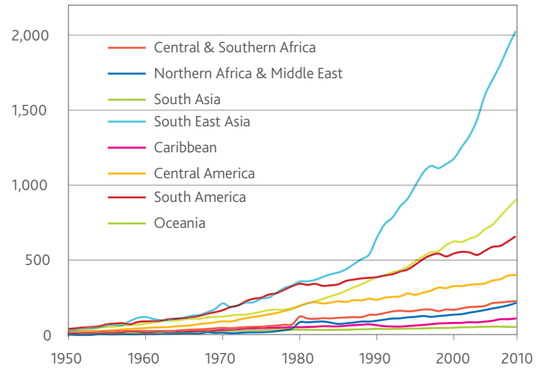
Wanakbori thermal power station, India. Image: Dhruv Patel.

Figure 2.1 CO_2 emissions

Million tonnes



Million tonnes



Source: WRI (2012), EC-JRC/PBL (2011), State of the Tropics project.
*Excludes contributions from land use, land-use change, forestry and bunker fuels.
Percentages are the proportion of global emissions from the Tropics and Rest of the World.

Carbon dioxide and other greenhouse gas sources

The carbon cycle is complex, with carbon cycling between living organisms, soil, water and the atmosphere (see Figure 2.4). The cycle varies naturally with CO_2 levels ranging from 180 to 300 ppm in the atmosphere over the last 420,000 years (Petit et al. 1999). Other gases, including methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) are also greenhouse gases and, like CO_2, have both natural and anthropogenic sources.

The main sources of anthropogenic CO_2 include burning of fossil fuels (oil, coal, and gas), land use change, deforestation and industry (IPCC 2007a). For methane and nitrous oxide, the main anthropogenic source is agricultural activity (Bousquet et al. 2006), with landfill and mining also important contributors. Methane also originates from a variety of natural sources including vegetation decomposition, termite activity, bushfires and oceanic microbial activity (Bousquet et al. 2006). The contribution of GHG's like methane and nitrous oxide to total emissions is much lower than for CO_2, but many of these gases are much more potent. For example, methane is 21 times and nitrous oxide 310 times more potent as a GHG than CO_2 (Forster et al. 2007).

In 2004, the highest sectoral contributors to anthropogenic GHG emissions were power generation (26% of total emissions), industrial activities (19%) and forestry/ deforestation (17%) (see Figure 2.3). Certain industries have particularly large carbon footprints. For example, cement production is a key industrial contributor, accounting for 4% of annual CO_2 emissions (Canadell et al. 2007). Cement production emits CO_2 as both a waste product from the heating of calcium carbonate to produce lime, and from the fossil fuels used in the heating process.

Effects and consequences

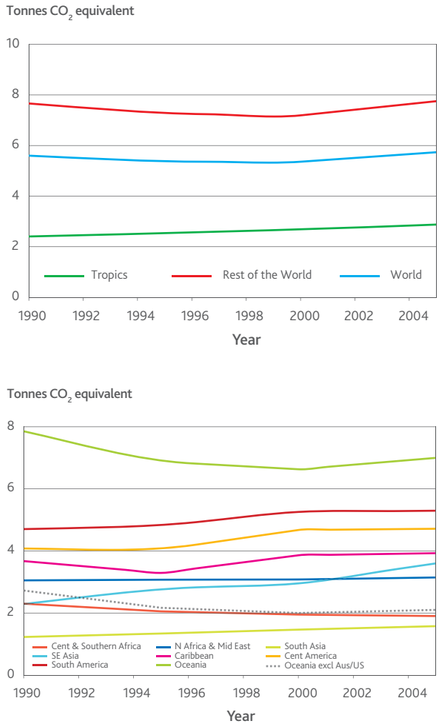
There is increasing consensus amongst the majority of scientists that rapidly increasing concentrations of anthropogenic emissions of GHG's into the atmosphere are already having notable impacts on the world's climate (IPCC 2007b). Direct effects of climate change include sea level rise, increased land and ocean temperatures (10 of the warmest years recorded since 1880 have been since 1998), receding snow and glacier cover and changes in rainfall rates, distribution and intensity (Forster 2007; IPCC 2007a).

All communities will be affected by the impacts of climate change, but these effects will vary from place to place. For example, coastal communities will need to contend with rising sea-levels and associated storm surge events and even these effects are likely to vary between regions. Globally, between 1950 and 2000 the highest annual sea level rises were in South Asia and South East Asia, with higher than average rises also recorded along the east coast of North America (Church et al. 2004) (see Table 2.1).

The consequences of a changing climate on human health are projected to be wide ranging, and to include increases in weather-related mortality, infectious disease rates and respiratory illnesses. Many of these consequences will vary between regions (see Table 2.1). Temperature increases associated with climate change are also expected to increase the range of many vector-borne diseases including malaria and dengue, due primarily to increased or changed vector distributions and decreased incubation periods for vectors and parasites (Githeko et al. 2000).

Changing rainfall patterns and intensity associated with climate change will also impact water supply and security for many nations. Beyond the need for drinking water, this can have direct impacts on power generation (from hydroelectric supply) and food security (see Table 2.1). Aquaculture production in South East Asia is considered to be particularly vulnerable to climate change due to a combination of increased sea levels, severe weather events and changing rainfall patterns (IPCC 2007c).

Figure 2.2 **Greenhouse gas emissions per capita (CO_2-equivalent)***



Source: WRI (2012), EC-JRC/PBL (2011), State of the Tropics project
* Excludes contributions from land use, land-use change, forestry and bunker fuels.

Mitigation

Fossil fuel power generation is the major source of anthropogenic CO_2 emissions. Efforts to reduce emissions have so far focused on developing low carbon technologies for power supply and increasing renewable power generation. Globally, between 1980 and 2010 renewable electricity generation (from hydropower, solar, wind and geothermal sources) increased from 1,750 billion to 4,150 billion kilowatts (an increase of 2.9% per annum) (EIA 2013b). However, the proportion of electricity generated from renewable sources dropped slightly over this period from 22% to 21% (see Electricity Supply Indicator).

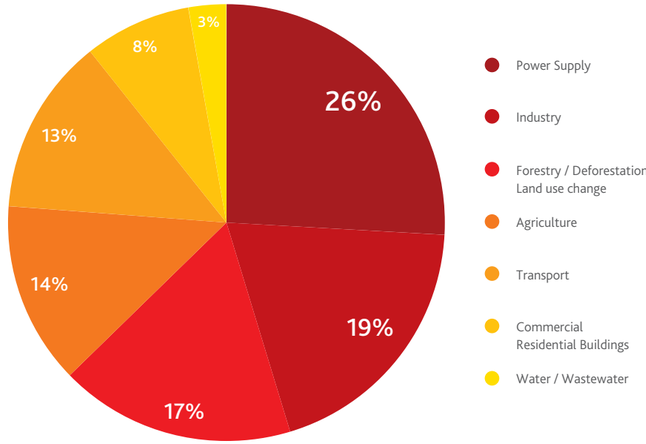
The increased focus on the role of renewable energies in reducing CO_2 emissions has led to considerable research and investment in new technologies. In 2008, hydroelectricity was the largest source of renewable power with 3,100 billion kilowatt hours (kWh) generated, followed by wind with 210 billion kWh (EIA 2011) (see Electricity Supply Indicator). Nonetheless, hydroelectric power still contributes to GHG emissions, primarily in the form of methane (Canadell & Rupach 2008), and has other environmental effects associated with water quality, biodiversity and sedimentation (IEA 2012a) (see Box 2.2). Mitigation efforts also include developing a variety of carbon capture technologies (see Box 2.3).

Land use change and deforestation is the third greatest anthropogenic contributor to annual CO_2 emissions (see Figure 2.3). Among terrestrial systems, tropical forests are the greatest carbon sinks, locking up large quantities of carbon in both biomass and soil (Sabine et al. 2004). Sustainable forestry in the Tropics has the potential to be a major contributor to global carbon sequestration. However, the loss of natural forests remains one of the world's greatest conservation challenges (Canadell & Raupach 2008). Initiatives such as the United Nations' Reduce Emissions from Deforestation and Forest Degradation (REDD) are helping. REDD aims to encourage carbon retention in forests by allowing nations to purchase CO_2 credits, through agreements with developing nations, to retain carbon stocks in forests that would otherwise be logged (UN REDD 2009). "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

The Kyoto Protocol also allows signatories with emissions targets to implement sustainable development projects (Clean Development Mechanisms) to reduce CO_2 emissions in developing nations as a means of meeting their Protocol obligations (UNFCCC 2013). These Clean Development Mechanisms promote sustainable development in poorer nations, reduce global emissions and provide flexibility in meeting emissions targets. Large-scale examples include technology transfers for renewable energy projects (Gillenwater & Seres 2011). Other projects are much smaller in scale, and are directed at improving household efficiencies. For example, in Nigeria the introduction of efficient wood fuel stoves to around 12,500 poor households reduced firewood consumption by 80% compared with traditional wood fireplaces (UNFCCC 2012b).

There are also a number of natural feedback mechanisms in the carbon cycle that can help mitigate climate change, including the

Figure 2.3 **Proportion of anthropogenic greenhouse gas emissions (CO_2 equivalent) by sector, 2004**



Source: Adapted from data in Intergovernmental Panel on Climate Change (IPCC 2007b).

concentration of aerosols in the atmosphere – such as dust – which reflect infrared radiation back into space. Interestingly, while ozone acts as a GHG in the lower part of the atmosphere (troposphere), in the upper atmosphere or stratosphere it reflects infrared radiation (Forster et al. 2007).

Natural sinks are also important in the mitigation of anthropogenic greenhouse gas emissions. One of the largest sinks for CO_2 is the ocean, though the increase in the concentration of oceanic CO_2 is causing acidification. Acidification has a direct impact on many marine organisms; corals, calcareous phytoplankton, bivalves and crustaceans require calcium carbonate for their shells and skeletal structures. (see Corals Indicator) (Kurihara 2008). Ocean acidification has the potential for major losses of marine biodiversity, with cascade effects up food chains. Natural feedback mechanisms and sinks have contributed to the mitigation of anthropogenic emissions to date, but their capacity is finite, and more sustainable solutions are required.

Looking forward

Attempts under the Kyoto Protocol and other agreements to limit GHG emissions are encouraging, but current trends have global emissions increasing rather than stabilising or decreasing. While anthropogenic emissions may have a local source, the impacts of not reducing emissions will be felt globally, and the consequences of climate change are likely to be felt disproportionately in many tropical regions. Even if emissions are reduced, communities, nations and regions will need to build resilience and adaptive capacity to cope with the unavoidable impacts of climate change.

Nonetheless, addressing anthropogenic GHG emissions and climate change is a global challenge that will require global solutions that balance the need to improve the quality of life and living standards of many people in the world while minimising the carbon footprint.

Box 2.2 Hydroelectricity – past, present and future

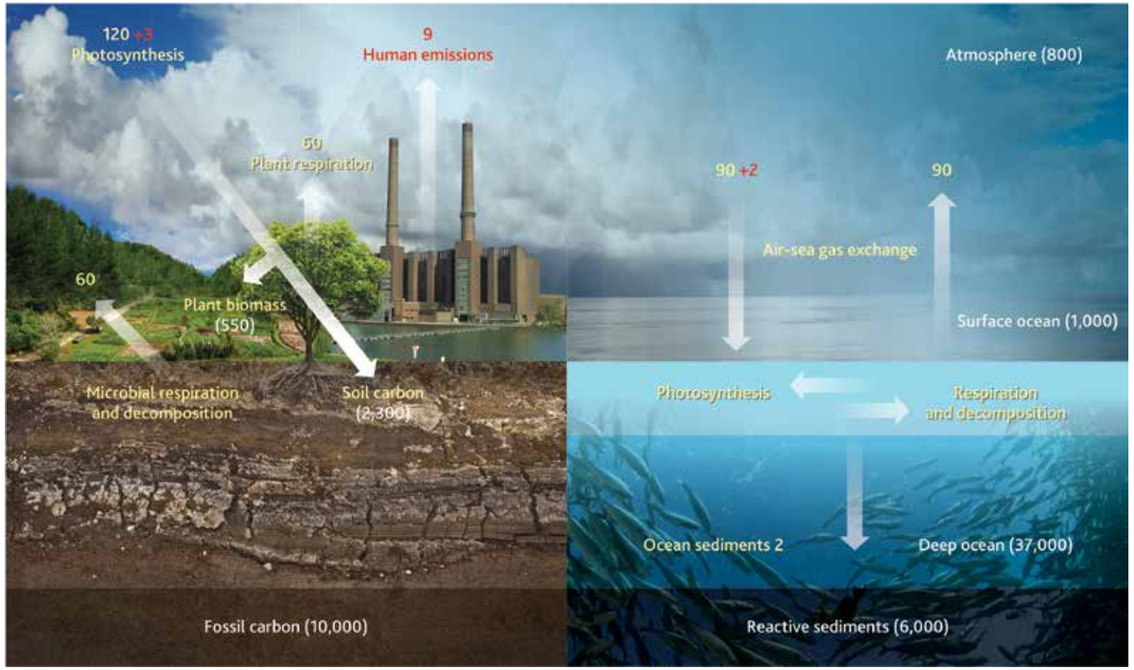
The first hydroelectric system was developed in 1881 to provide electricity for street lighting. Today, hydroelectricity is the world's largest source of renewable energy. However, as a proportion of total renewable power generation its contribution has been falling since 2004 as new technologies have developed (REN21 2012).

Although renewable, hydroelectricity's green credentials have recently been questioned, as the dams typically needed for generation have been identified as a significant source of methane - a greenhouse gas (GHG) 21 times more potent than CO_2. Dam construction results in the submersion of large areas of land, with the vegetation rotting and generating methane gas that is released to the atmosphere. Some research suggests that tropical hydroelectric dams in particular generate more GHG than conventional thermal plants (Giles 2006). Other research indicates the extent of GHG emissions from hydroelectric dams is dependent on the age, size and location of the project, with overall GHG emissions lower per unit of energy generated than previously estimated (Barros et al. 2011). Construction of dams also results in habitat loss in flooded areas and can have significant effects on downstream ecosystems due to changes in flow regimes, water temperatures, sedimentation and dissolved oxygen levels. These effects can have wider impacts on the local ecology, especially river reliant species like migratory fish. Compulsory community displacement from large hydroelectric dam projects has had significant social and economic impacts on affected communities. Recent examples include the large-scale environmental and social issues associated with the Three Gorges Dam in China and the Bel Monte Dam in Brazil (AIDA 2011, International Rivers 2012).

Hydroelectricity is also vulnerable to supply interruptions caused by droughts and upstream water over extraction. Although typically located on rivers with reliable flows or fed by large dams, many hydroelectric systems have been subject to reduced flows as a consequence of changing rainfall patterns (Aichinger 2011, Bekoe & Logah 2013). Modelled climate impact scenarios also suggest that hydroelectric systems reliant on glacier feeds may be increasingly vulnerable to interrupted or reduced water flows (dé Lúcena et al. 2009).

Hydroelectricity, Ghana. Image : World Bank Photo Collection.

Figure 2.4 The carbon cycle*



Source: Diagram adapted from USDOE, Biological and Environmental Research Information System (NASA 2011).
* Movement of carbon between land, atmosphere, and oceans in billions of tons of carbon per year.
Yellow numbers are natural fluxes, red are human contributions. White numbers indicate stored carbon.

Box 2.3 Carbon capture technologies

Carbon capture technologies aim to either prevent CO_2 being released into the atmosphere or to stimulate greater CO_2 consumption by plants or inorganic materials. This may be through biological carbon capture whereby, for example, power station flue gases are passed through algal cultures to capture CO_2 and generate feedstock for biofuels (Saunders et al. 2012).

Other carbon capture technologies involve storing GHGs underground in depleted oil and gas fields. However, the longer term reliability of this technique remains unproven (IEA 2009).

Another proposal for capturing (or sequestering) carbon is to seed oceanic waters with elements like iron to stimulate phytoplankton blooms. The theory is that iron stimulation will fertilise large phytoplankton blooms that will take up large quantities of carbon which, when they die, will settle out to the ocean floor. However, the validity of this approach is subject to considerable scientific debate (Tollefson 2012).

Table 2.1 **Potential consequences of climate change in tropical regions**

Region	Agriculture	Water	Ecosystems	Coasts	Health
Central & Southern Africa	Agricultural production & food security severely compromised.	Increased pressure on water resources leading to increased water stress & decreased water security.	Impacts on grassland & marine ecosystems. Increased risk of desertification. Coral & mangrove systems impacted.	Increased flood risks for Eastern Africa with impacts on fisheries, tourism & coastal communities. Intrusion of salt water into freshwater resources.	Risk of increased transmission of diseases including malaria.
Northern Africa & Middle East	Loss of agricultural area & reduced productivity.	Severe water stress likely.	Increased desertification.	Low-lying, densely populated coastal areas at high risk of flooding and inundation.	Increased frequency & occurrence of climate-induced disease & heat stress.
South Asia	Decreases in crop yield. Shifts & loss of agricultural area.	Increased water stress & changing water regimes from accelerated glacier loss.	Significant loss of mangrove ecosystems. Impacts on coral ecosystems.	Significant loss of coastal ecosystems through flooding & sea water intrusion. Increased flood risk in urban coastal areas.	Increased frequency & occurrence of climate-induced disease & heat stress. Expansion of habitat for disease vectors.
South East Asia	Decreases in crop yield. Shifts & loss of agricultural area. Potential reductions in fisheries /aquaculture.	Increased water stress & flood risk from changed rainfall patterns & intensity.	Glacier retreat. Changes in both terrestrial & marine ecosystems. Increased extinction risk for flora & fauna.	Significant loss of coastal ecosystems through flooding & sea water intrusion.	Increased frequency & occurrence of climate-induced disease & heat stress.
Caribbean	At risk of desertification & salinisation leading to reduced productivity.	Water security & supply variability impacts.	Increased risk to terrestrial, coastal & marine communities from increased hurricane activity.	Sea level rise and storm surge to affect coastal communities, mangroves & fisheries.	Increased frequency & occurrence of climate-induced disease & heat stress. Expansion of habitat for disease vectors.
Central America	At risk of desertification & salinisation leading to reduced productivity.	Water security & supply variability impacts.	Increased risk of desertification in semi-arid areas.	Many coastal areas & mangrove systems very vulnerable to sea level rise & storm surge.	Increased frequency & occurrence of climate-induced disease & heat stress. Expansion of habitat for disease vectors.
South America	At risk of desertification & salinisation leading to reduced productivity.	Water security & supply variability impacts.	Significant risk of increased extinction rates. Changes in habitat from forests to grasslands. Increased risk of forest fires.	Sea level rise to affect coastal communities, mangroves, fisheries & water supply	Increased frequency & occurrence of climate-induced disease & heat stress. Expansion of habitat for disease vectors.
Oceania	Shifts & loss in both agricultural area & productivity.	Water resources particularly on small islands severely compromised. Overall water stress to increase.	Increased droughts & fires (Australia). Coral & mangrove ecosystems under threat. Increased extinction risk for flora & fauna.	Significant risk to coastal infrastructure from sea level rise. Increased risks from storm surge etc.	Increased occurrence of climate-induced heat stress.
Rest of the World	Shifts in agricultural areas & impacts on agricultural productivity.	Increased flood & drought risk. Potential increase in water stress.	Glacier retreat, loss of snow & ice cover. Shifts in dispersal of some species & loss of others.	Significant loss of coastal wetlands & threats to coastal communities.	Reappearance of historic diseases (e.g. malaria). Greater exposure to water & insect-borne disease & increased heat stress

Sources: IPCC (2007c), IFAD (2011 a,b,c), BOM/ CSIRO (2011)

Electricity generation

Since the invention of the battery in 1800 electricity has become an integral part of human society, and how it is created, distributed and managed will help shape the future of communities and ecosystems. Electricity's first wide-scale application was as street lighting in a number of European and North American cities in the late 1870s. Since then electricity generation has increased and access to it has had major impacts on how businesses and households operate, providing opportunities to introduce time saving equipment and technologies.

Although the first wide-scale application of electricity for domestic use occurred more than 140 years ago, as recently as 2010 almost 1.4 billion people (or 20% of the global population) still had no access to electricity, with an additional one billion people having only limited access (IEA 2011a). Despite projections of continued increases in electricity production it is expected that many people, particularly in rural areas that are typically supplied before urban regions, will continue to have limited access into the foreseeable future (IEA 2010). This appears to especially be the case for sub-Saharan Africa and southern Asia.

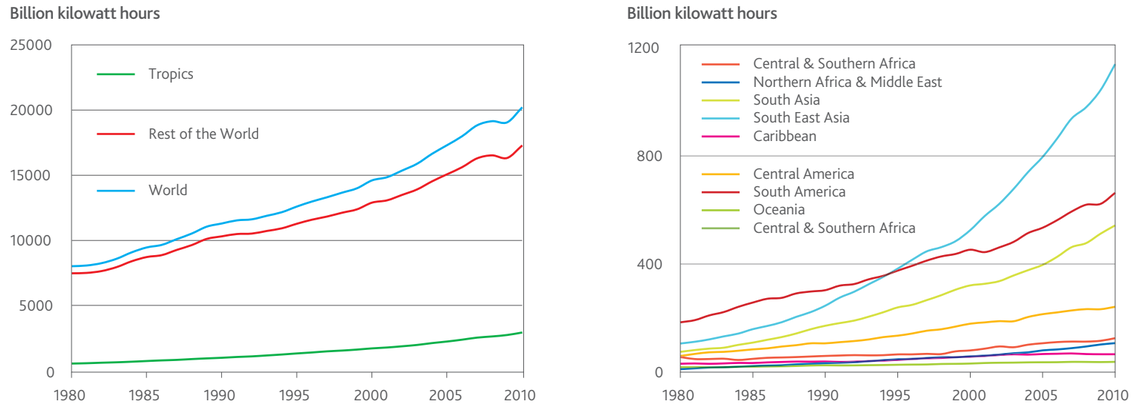
Electricity can be generated from several fuel sources, and how each country chooses to develop their electricity supply sector is based on a range of criteria including supply risks and price, and numerous social and environmental considerations. At present the main fuels used to generate electricity are coal, gas, water (hydroelectric) and nuclear (IEA 2012b). Most electricity is produced from fossil fuels which generates carbon dioxide (CO_2) emissions in the combustion process that contribute to increased atmospheric greenhouse gas concentrations and climate change (see Greenhouse Gas Indicator). Projecting ahead, concerns about climate change and national concerns regarding fuel security suggest that the types of fuel sources used to produce electricity will need to change, with renewable and low-carbon technologies necessarily providing a greater share of generation capacity.

Trends

Global electricity generation[1] increased from 8,000 billion kilowatt hours in 1980 to more than 20,000 billion kilowatt hours in 2010, a 150% increase, or 3% increase per annum on average (although the energy intensity of economic activity is declining). Most of this electricity is generated in the Rest of the World, with the Tropics accounting for only 7% of global

[1] For simplicity the term 'electricity generation' is used, though it refers to 'net electricity generation'. Net electricity generation is gross electricity generation less the electricity used in station operations.

Figure 2.5 **Electricity generation***



Source: EIA (2013), State of the Tropics project.
*Net electricity generation is gross electricity generation less the electricity used in station operations.

generation in 1980, increasing to 15% in 2010 (see Figure 2.5).

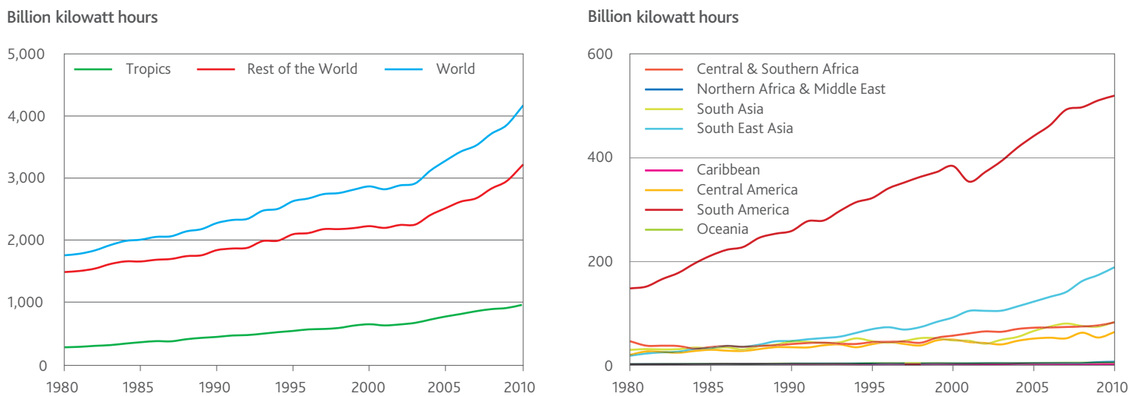
In the Tropics, South America was the largest electricity producer in 1980, but was overtaken by South East Asia in 1994. Between 1980 and 2010 South East Asia increased electricity generation by almost 1,000% from 106 billion kilowatt hours to 1,140 billion kilowatt hours. Most of this increase occurred in tropical China. After South East Asia the largest generators in the Tropics in 2010 were South America and South Asia respectively, with Oceania and the Caribbean the smallest generators. Lower production in Oceania and the Caribbean regions reflects their relatively small populations, at around 12 and 40 million respectively. In the period 1980 to 2010, Northern Africa & the Middle East increased electricity production by more than 800%, while in Oceania and the Caribbean, production doubled.

Globally around 20% of electricity comes from renewable sources such as hydroelectric, solar, wind and biomass. Although renewable generation has increased by almost 240% since 1980 (increasing from 1,800 billion kilowatt hours to 4,200 billion kilowatt hours in 2010), its proportion of global production has fallen slightly, from 22% in 1980 to 21% by 2010 (see Figure 2.6, Table 2.2). The proportion of global renewable electricity generation in the Tropics has increased from 15% to 23% over that time.

Renewable energy represents a significantly greater proportion of electricity production in the Tropics compared with the Rest of the World (see Table 2.2), although the proportion has declined significantly, from 50% in 1980 to 33% in 2010 driven largely by a large decrease in South Asia. In the Rest of the World the proportion of electricity generated from renewable sources fell from 20% in 1980 to 17% in 2005, before increasing to 19% in 2010.

South America generates the largest amount of renewable electricity among the tropical regions, with 520 billion kilowatt hours in 2010, followed by South East Asia (190 billion kilowatt hours), with Northern Africa & Middle East, Oceania and the Caribbean producing the least (see Figure 2.6). Since 1980 renewable electricity generation in South East Asia has increased by almost 900%, though it began from a low base. Central & Southern Africa and South America have the highest proportions of electricity generated from renewable sources. In 1980 these regions generated more than 80% of their electricity from renewable sources (see Table 2.2), primarily through hydroelectricity. This fell to 66% and 78% respectively by 2010, as the supply from renewables has not kept pace with the overall increases in generation capacity. In contrast, the Caribbean and Northern Africa & Middle East have the lowest proportion of renewable electricity generation, representing less than 5% of overall electricity production in 2010. Except for Oceania, the proportion of electricity generation from renewable sources fell in all tropical regions between 1980 and 2010. In South Asia, despite the energy supply from renewable sources almost trebling, its proportion of the electricity mix fell from 40% to 15% as total generation increased more than seven-fold.

Figure 2.6 **Renewable electricity generation***



Source: EIA (2013), State of the Tropics project.
*Net renewable electricity generation is gross electricity generation less the electricity used in station operations.

Table 2.2 **Proportion of total electricity generated by renewable sources (%)***

Region	1980	1985	1990	1995	2000	2005	2010
Tropics	**50**	**48**	**44**	**40**	**38**	**34**	**33**
Central & Southern Africa	83	72	69	68	71	68	66
Northern Africa & Middle East	5	5	5	4	3	3	5
South Asia	40	30	27	20	15	17	15
South East Asia	18	21	19	18	18	15	17
Caribbean	7	8	7	5	4	5	4
Central America	34	36	33	30	28	24	27
South America	81	82	85	86	85	83	78
Oceania	14	16	15	16	14	13	14
Rest of the World	**20**	**19**	**18**	**19**	**17**	**17**	**19**
World	**22**	**21**	**20**	**21**	**20**	**19**	**21**

Source: EIA (2013), State of the Tropics project.
*Net electricity generation is gross electricity generation less the electricity used in station operations.

Energy sources

Both fossil fuels and renewable resources are used for electricity generation. The main fossil fuels used are coal and gas, which accounted for 41% and 22% of global generation respectively in 2010. Hydroelectricity is the major source of renewable energy, accounting for 16% of global electricity generation in 2010 (see Table 2.3). Looking forward, the dominance of coal in the generation mix may change as the impacts of anthropogenic CO_2 emissions on climate change translate into policies to mitigate emissions growth (IEA 2010). This will include a greater emphasis on developing commercially viable low carbon technologies, as well as increasing operational efficiencies to lower fossil fuel consumption. Increased generation from low carbon sources is expected to be from both existing (e.g. wind, solar) and emerging technologies (e.g. hydrogen fuel cells, wave energy).

For each nation the choice of fuels used for electricity generation is influenced by supply, cost and accessibility factors, as well as social and political sensitivities. For example, Saudi Arabia, a major oil producer, uses oil as the primary fuel for electricity generation (Table 2.3). Similarly, in Australia coal is abundant and cheap, and accounted for 77% of electricity generation in 2008-09 (EIA 2012a). However, despite also having significant uranium supplies, no nuclear power capacity exists in Australia due to social sensitivities.

Although not large on a global scale, biomass is still an important part of the overall energy mix in many nations, and especially in developing nations. Biomass sources for electricity generation vary markedly, and include industrial by-products like sugarcane bagasse (which is increasingly used in sugar producing nations such as Ecuador and Brazil) and methane from landfill sites. For both these sources there is scope to increase generation, with estimates that only 10% of landfill methane emissions are captured (Themeilis & Ulloa 2007). For many communities in parts of Africa and Asia though, the lack of access to reliable electricity requires ongoing dependence on biomass such as firewood for domestic cooking, lighting and heating. However, such sources can have considerable environmental and health impacts (IEA 2010).

Nuclear fuel generates 13% of global electricity. From a greenhouse gas perspective it is a low carbon technology, and has the potential to help nations meet emission reduction targets. However, nuclear generation tends to face significant opposition due to public concerns about radiation, waste management and the threat of weapons proliferation (IAEA 2009). Hydroelectricity provided about 16% of global electricity generation in 2010 and 82% of renewable generation, although on both these measures its significance has decreased since 1980 (EIA 2013). Rapid development of renewable technologies such as solar and wind, especially in the past 10 to 15 years, has been a factor in this. For example, generation from non-hydro renewable sources increased at 33% per annum between 2000 and 2010, compared with 3.8% per annum for hydro. Although this is off a low base, it is significantly faster than the increase in total electricity generation (3.3% per annum), and has outstripped projected growth rates (IEA 2011b).

Although still in its developmental phase, wave power is emerging as a potentially cost-effective, low carbon electricity source. It does, however

come with some environmental issues most notably its potential to cause changes to coastal dynamics, sediment transport and marine habitats. These issues will need to be addressed, though they are considered manageable, with scope for development in temperate and tropical regions (Barstow & Falnes 1996, Boehlert 2007).

Another renewable energy source in demonstration phase is hydrogen generators and fuel cells (Niez 2010). Hydrogen provides a heat source for steam production that drives turbines for electricity generation. A key benefit of using hydrogen is that generation can readily occur in remote locations and can provide a combined heat and power source.

In the short to medium term, improved efficiency in the production and consumption of energy is considered the most economic and available means of reducing greenhouse gas emissions and improving energy security (Beér 2006). Increased efficiencies result in lower CO_2 emissions and improved economics.

These goals are also critical for many emerging nations, particularly India and China, due to their increasing demand for fossil fuels.

Infrastructure

Along with water, telecommunications and transport, infrastructure for the generation, transmission and distribution of electricity provides a foundation for social and economic development (Stevens et al. 2006). Expanding and maintaining complex, stable and cost-effective national and international infrastructure networks requires long term planning, and has geo-political, security, economic, environmental, demographic and technological implications for nations (Stevens et al. 2006).

Between 2000 and 2010 global investment in transmission and distribution infrastructure was around US$127 billion per year, or 0.22% of global GDP. By 2030, this is expected to increase to US$241 billion, or 0.24% of global GDP (Stevens et al. 2006). For developed nations with extensive and integrated transmission and distribution networks already in place, most investment will be for the maintenance and upgrading of infrastructure (Stevens et al. 2006). In developing regions though, expansion of the electricity network will consume the bulk of investment. Historically, social and economic considerations have been the major factors influencing electricity network development. However, there is now an increasing emphasis on developing environmentally sustainable infrastructure that mitigates wider environmental impacts on biodiversity, air and water quality and environmental health (IEA 2011a).

In nations where electricity infrastructure is unreliable, demand tends to exceed supply, with the reasons for constrained supply varying depending on national histories and political stability. In 2007-08 in Nigeria, a nation with major oil and gas reserves, power outages averaged 46 days per year due to limited generation and transmission capacity, poor maintenance and insufficient feedstock (EIA 2012c). Without increased investment in electricity infrastructure this situation is unlikely to improve, as ongoing demand will continue to outstrip supply. Similarly, in Angola the ad hoc nature of the distribution network means that only 30% of the overall population and 10% of the rural population has physical access to electricity (EIA 2012d). As a consequence in both nations, particularly in rural areas, the majority of households rely on biomass for cooking, lighting and heating (EIA 2012c).

In other parts of the Tropics rapid economic growth has created challenges in meeting increased demand for electricity. In India the electricity deficit is estimated at around 8.5% of demand (KPMG 2012). Increases in generation capacity to meet this shortfall are focused on coal, with plans for up to 455 new coal fired power stations and up to 519,000 megawatt generation capacity (Yang & Cui 2012). As well as environmental issues, the focus on coal-based electricity generation is impacting energy security, with India moving from being a net exporter of coal to the fourth largest importer in 2010 (Yang & Cui 2012).

In some nations and regions, part of the increased demand for electricity is being met through national and international grid networks (see Box 2.4). These networks help spread generation and transmission risks and potentially create a more reliable supply. However, distributed electricity networks also come with risks that need to be managed, including distribution bottlenecks, impacts of natural disasters and industrial or political sabotage (OTA 1990, Aichinger 2011). The gridded nature of electricity networks also increases the risk of cascade effects through the systems, with equipment failure affecting electricity supply in areas outside the immediate region of damage (Bernstein et al. 2011, The Economic Times 2012). Complicated electricity networks, especially those that cross national boundaries or are managed through distributed computing networks, can also be vulnerable to cyber-attack (SANS Institute 2001, ICS CERT 2012). In fact, the reliance of distributed networks on electronic information and communication technologies is seen as a key vulnerability in the power supply industry (Aichinger 2011).

In addition to existing threats, climate change modelling suggests that electricity networks will be at greater risk of extreme weather events, resulting in more service interruptions and higher costs to develop and maintain infrastructure (Shaeffer et al. 2012). For example, energy infrastructure in the Gulf of Mexico is considered vulnerable to the effects of more severe weather events and to longer-term changes such as rising sea levels. Recognising this, Mexico's Climate Adaptation Strategy has a focus on establishing decentralised, small-scale and robust energy supply systems to meet these challenges (Ebinger & Vergara 2011, Hurd 2012). As energy security is increasingly recognised as a critical issue for many nations, developing sufficiently robust electricity networks to cope with changing conditions is essential.

The future for renewable energy

Power generation research is recognised as entering a transitional phase, with an increasing proportion of research and development expenditure and capital investment shifting to lower carbon technologies (IEA 2010). Between 2004 and 2009 investment in renewable energy increased almost 600%, from US$17 billion to US$115 billion. This was not only due to global recognition of the need to reduce CO_2 emissions, but also as the result of increased concerns about energy security (IEA 2010).

The cost effectiveness of renewable energy has improved rapidly in recent years as technology has improved and as larger scale projects have become feasible. A better understanding of the environmental costs of electricity production from fossil fuels is also making renewable technologies more socially appealing in many nations. Unfortunately though, pricing in most electricity markets does not reflect the true costs of production as there is no account for costs related to environmental damage (IEA 2011b).

In addition to reduced CO_2 emissions, the modular nature and supply diversity that comes with many renewable technologies can also improve energy security. The use of renewable power at a community level is gaining momentum in a number of developing nations, where reliable access to distributed power generation is limited. Renewable, stand-alone energy systems can be an effective means of providing electricity to isolated or remote communities (IEA 2011b). For example, in Timor-Leste, a nation where energy poverty is chronic, the Australian Alternative Technology Association's International Project Group provides stand-alone solar electricity systems to communities, contributing to improved educational, health and communication opportunities (ATA 2013).

Renewable power sources are not without challenges. A major limitation is the lack of a cost-effective base load supply in many systems. Without sunlight or wind, and an effective backup storage capacity to meet demand when supply is low, these renewables cease to generate electricity. To date a lack of cost-effective storage capacity has constrained the expansion of many renewables. Even hydroelectricity, which has been a reliable form of base load renewable energy, is beginning to suffer supply issues in some regions (see Box 2.2). Development of hybrid systems which combine multiple renewables or renewable and conventional energy sources helps address supply interruptions and fluctuations, making them especially viable for modular community supply (Niez 2010).

A number of emerging renewable energy technologies are also being met with community resistance on the basis of aesthetic and health concerns. Wind power in particular is often criticised as unsightly and noisy, with the noise affecting human wellbeing and local biodiversity, particularly birds. Research has found that

Table 2.3 **Top five nations for electricity production by fuel type - 2010**

Rank	Fuel type (% of world generation)				
	Coal/Peat	Natural Gas	Hydro	Nuclear	Oil
Rank 1	China (38)	USA (21)	China (21)	USA (30)	Saudi Arabia (13)
Rank 2	USA (23)	Russia (11)	Brazil (12)	France (16)	Japan (10)
Rank 3	India (8)	Japan (6)	Canada (10)	Japan (10)	USA (5)
Rank 4	Japan (4)	Iran (4)	USA (8)	Russia (6)	Iran (5)
Rank 5	Germany (3)	UK (4)	Russia (5)	Rep. Korea (5)	Mexico (4)
World production (TWh)*	8,698	4,768	3,516	2,756	989
Proportion of world generation (%)	41	22	16	13	5

Source: IEA (2012b), State of the Tropics project.
*Terawatt hours.

impacts on local biodiversity and visual amenity are possible (Macintosh & Downie 2006), but there is no substantiated evidence for human health impacts (NHMRC 2010).

Looking forward

Access to reliable power is recognised as critical to poverty reduction and to improving living standards. Looking forward, as electricity demand increases, an ever greater share of this demand will need to be achieved in a sustainable manner to minimise environmental effects. In many cases, economic growth in developing nations will be major drivers of increased energy demand. Many of these nations are in the Tropics, where an expanding middle class is expected to have a major impact on consumer demand for a wide range of goods and services, including energy (IEA 2010). Fortunately though, many of these nations will have the opportunity to exploit renewable technologies that are being developed and commercialised, rather than relying on fossil fuel technologies. As well as slowing growth in anthropogenic CO_2 emissions, these alternative and sustainable electricity options can also act to address energy security issues currently facing many nations.

Box 2.4 International power sharing

The electricity supply industry has supported national and international network connectivity since these systems were first established over a century ago. The major benefits of interconnection are larger and generally more efficient and reliable networks, although a range of legal, political, technical and economic issues need to be addressed and managed if they are to be effective.

Greater independence and transparency in the global electricity supply industry in recent years has led to increased cooperation and cross-border trade in electricity (APEC 2002). For example, a number of significant international agreements are in place in Southern and Western Africa, Central and North America, the European Union and the Greater Mekong region (Castalia Strategic Advisors 2009).

In West Africa the 15 nations comprising the Economic Community of West African States (ECOWAS) established a regional electricity supply agreement (WAPP) which aims to improve the reliability, security and cost of supply. A similar cross-border trade initiative has also been established by 12 Southern African nations (SAPP) with similar goals (EIA 2012d). The outcome of these programs has been variable and is largely dependent on compliance with the legal framework regarding the reliability of supply. The WAPP has proven to be successful, in part due to strong government commitments to the Treaties and Protocols, while the SAPP has suffered a number of supply and reliability issues resulting from national failures to meet their commitments (Castalia Strategic Advisors 2009).

Electricity lines, Vietnam. Image: United Nations.

Wind farm, Africa.
Image: Warrenski.

Air pollution

Air pollution arises from a range of processes including burning fossil fuels for energy and other industrial activities, vegetation fires and volcanoes. Burning fossil fuels creates greenhouse gases (GHG) and air pollutants. While they have the same source their impacts are different, with air pollution impacts tending to be more localised, immediate and obvious. Nonetheless, GHG and pollutants may interact in the atmosphere and separately or jointly cause a variety of environmental impacts on local, regional and global scales. They may also have significant health impacts.

The six main air pollutants are particulates, carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3) and heavy metals (see Box 2.5). Air pollution can include primary or secondary pollutants, gases and particulates, and may be local or non-local in origin. Larger particles and materials like coarse sand tend to be suspended for a short time due to their size and weight while smaller particles, aerosols and gases can remain in the atmosphere for long periods.

Air pollution has been a human health issue ever since fire has been used for heating and cooking. Demographic transition from rural to urban settings has been a factor in declining urban air quality, especially since the industrial revolution (Bruce et al. 2000, Mosley 2013). Today air pollution is a problem that primarily affects urban environments although pollutants may spread over regional and even global scales (Lawrence et al. 2007, Liu & Mauzerall 2007). For example, in recent years smog haze of aerosol pollutants from Europe and Asia has occasionally reached the Artic, demonstrating the pervasive effect and global 'reach' of air pollution (Law & Parrish 2010).

Air pollution can also have negative impacts on biodiversity and ecosystems. Freshwater and estuarine systems may be affected by acidification and excess nutrient loads resulting in algal blooms and low oxygen levels (Lovett & Tear 2008). Air pollution also acidifies and depletes important nutrients in soil which can impact productivity. Certain airborne pollutants also affect the photosynthetic ability of plants.

From a human health perspective an important measure of air quality is the concentration of particulate matter less than 10 micrometres (μm) in diameter. These particles are readily breathed in and can cause lung damage or breathing difficulties, with smaller particles generally posing greater risks to human health. The World Health Organization (WHO) has identified an annual mean PM_{10} threshold of 20 μg/m^3 to minimise health effects, though nations are free to set their own ambient air quality standards.

Policies that reduce GHG emissions targets can significantly reduce the costs of meeting air quality targets and vice versa.

Trends

Annual mean PM_{10} concentrations

Particulate air pollutants are measured as the mass of particles that are less than 10 μm in diameter divided by the volume of air sampled in cubic metres (m^3). Globally the annual mean PM_{10} concentration almost halved in the twenty years to 2010, from 75.8 μg/m^3 to 35.9 (see Figure 2.7), with the downward trend observed in both the Tropics and the Rest of the World (see Figure 2.7). In 2010 PM_{10} concentrations were slightly higher in the Tropics (39.4 μg/m^3) than in the Rest of the World (34.4 μg/m^3). Both these figures are considerably higher than the WHO guideline of 20 μg/m^3 for minimising health impacts (WHO 2006).

In the Tropics, Northern Africa & Middle East consistently averaged the highest PM_{10} concentrations, and Oceania the lowest, at 78 μg/m^3 and 22.1 μg/m^3 respectively in 2010. In Northern Africa & Middle East, many particulates are likely to be natural in origin as the region has naturally high dust and aerosol sea salt levels (Pozzer et al. 2012). Oceania, South America (28.1 μg/m^3) and the Caribbean (28.2 μg/m^3) are the only tropical regions to have PM_{10} concentrations below 30 μg/m^3 although, again, none of these are within the WHO threshold.

Box 2.5 Major air pollutants

Particulate matter: Particulate matter is a mix of extremely small particles and liquid droplets including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. The size of particles is directly linked to their potential health impacts. Particles less than 10μm in diameter (PM_{10}) pose the greatest threat because they can penetrate deep into the lungs and bloodstream. Exposure to small particles can affect both the lungs and the heart.

Carbon monoxide (CO): CO is a colourless, odourless gas that originates from the burning of fossil fuels, mostly in cars. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (such as the heart and brain) and tissues. At extremely high levels CO can cause death. CO can affect concentrations of GHG in the atmosphere, including methane, tropospheric ozone and carbon dioxide.

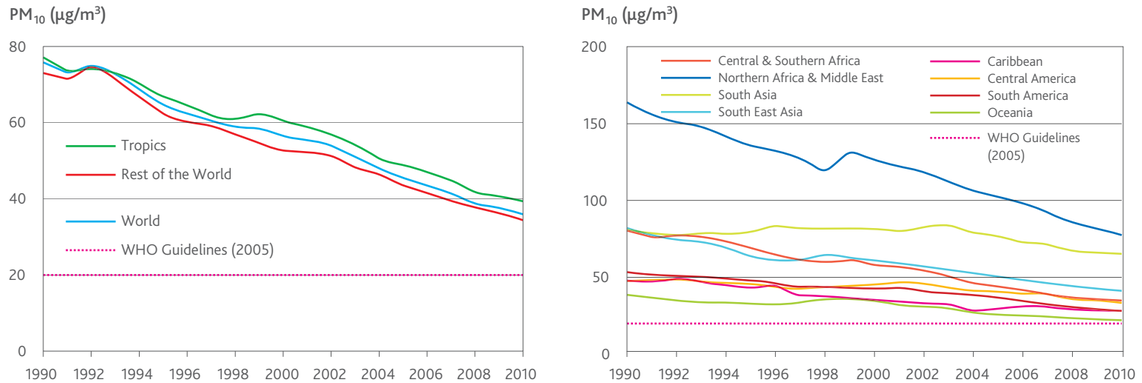
Sulphur dioxide (SO_2): SO_2 is primarily formed during the combustion of fossil fuels. SO_2 air pollution has significant impacts on human (respiratory) health and can influence habitat suitability for plants and animals. SO_2 emissions are also a precursor to acid rain and atmospheric particulates.

Nitrogen oxides (NO_x): NO_x are highly reactive gases produced from the reaction of nitrogen and oxygen in the air during combustion, and include nitrogen dioxide (NO_2), nitrous acid and nitric acid. NO_x gases react to form smog and acid rain, and are central to the formation of tropospheric ozone. NO_2 has adverse respiratory effects for healthy people and those with existing respiratory conditions.

Ozone (O_3): Ground-level ozone pollution (tropospheric ozone) is created when UV rays react with ozone precursors and oxygen to form ozone. Anthropogenic ozone precursors include NO_x and volatile organic compounds formed during the combustion of fossil fuels. Ozone pollution is mainly generated in urban settings, but can be transported to other areas by prevailing winds. Exposure to ozone can inflame lung tissues, cause respiratory infections and aggravate existing respiratory conditions.

Heavy metals: Anthropogenic heavy metal air comes from sources such as combustion of fossil fuel, metallurgical processes such as the purification of metal and garbage incineration. Heavy metals are toxic even at low concentrations in air, and their presence is correlated with cancer, neurotoxicity, immunotoxicity and cardiotoxicity.

Figure 2.7 PM_{10} air quality



Source: World Bank (2013), State of the Tropics project.

South Asia has had the smallest proportional decrease in PM_{10} concentrations since 1990 (19%), and Central & Southern Africa the largest (57%).

Air pollution effects

Air pollution generated through human activities is widely recognised as having both acute and chronic impacts on human health. These impacts are most common and severe in urban environments. However, rural populations are also affected, particularly by indoor air pollution. The WHO estimates that approximately 3 billion people cook and heat their homes using open fires and stoves that burn biomass (wood, animal dung and crop waste) and coal, and that nearly 2 million people die prematurely from illness attributable to indoor air pollution. Drought induced dust storms and wildfires, often caused or exacerbated by human activities, also affect health in rural populations.

The effects of PM_{10} on human health have been widely researched. A review in the United States found that mortality increases by around 0.5% for every 10 μg/m^3 increase in PM_{10} (Samet et al. 2000). Air pollution also tends to be associated with economic development and industrialisation. In China for example, a nation that is experiencing sustained and rapid economic growth, almost 75% of the urban population is exposed to air quality that does not meet national standards (Shao et al. 2006). Urban air pollution also affects the integrity of buildings and structural metals and can contribute to increased maintenance costs (Kucera & Fitz 1995).

The long-term environmental impacts of air pollution are increasingly recognised for their global impact, especially with respect to climate. These impacts vary dependent on the type of pollutant. For example, acid forming aerosols (SO_2) and nitrogen deposition pose the greatest environmental risks to the ozone layer and forest ecosystems, and cause numerous problems for global ecosystems (Percy 2003, Percy & Ferretti 2004, Paoletti et al. 2009).

Although ozone is a natural compound in air it may also act as a pollutant in increased concentrations. Formed by the reaction of nitrogen oxides, high concentrations in the lower atmosphere cause atmospheric haze and irritation to airways and eyes. Within the ecosystem, increased ozone concentrations can reduce the photosynthetic capacity of plants, reduce agricultural yields and contribute to fish kills (EPA 1997).

Sulphur dioxide reacts with other compounds in the atmosphere to produce sulphuric acid and acid rain, which was a leading cause of deforestation in parts of Europe in the twentieth century (Bussotti & Ferretti 1998). It can also increase the acidity in freshwater lakes with impacts on aquatic ecosystems.

Nitrogen is an essential nutrient for plants, but increased levels in the atmosphere can lead

to higher than normal deposits in plants, with impacts on plant community composition and biodiversity (Lovett & Tear 2008). Increased levels of nitrogen can also change the microbial ecology of soils, potentially reducing biodiversity and impacting soil fertility. Nitrogen is readily leached from soil during rain, and the runoff can lead to eutrophication of freshwater lakes and rivers (see also the Renewable Water indicator).

Managing air pollution

Air pollution remains a major concern in many urban environments, even where there have been considerable efforts to reduce anthropogenic emissions (see Box 2.6). Recognition of links between atmospheric sulphur emissions in Europe and acidification of lakes in Scandinavia was the impetus for the 1979 Geneva Convention of Long-range Transboundary Air Pollution. Since then most nations have adopted air quality guidelines. For many industries there are also national emission standards to manage air quality, though the effectiveness varies depending on the level of governance. Many of these policies also include standards for the management of greenhouse gases and carbon dioxide emissions.

In many nations' stricter vehicle emission standards have encouraged manufacturers to increase fuel efficiency and decrease emissions for a range of pollutants, with tangible improvements to air quality. Lead is a prime example. Once commonly used as a fuel additive, lead was a major and dangerous air pollutant that has now essentially been phased out globally (O'Brien 2011). The value of environmental and health benefits from eliminating lead emissions from fuel is estimated to exceed costs by more than 10-fold (Tsai & Hatfield 2011). The move towards stricter vehicle emissions standards is expected to continue.

In recent decades there has been a change in the origin of many air pollutants. Tighter emission regulations in Europe and North America have resulted in a decrease in the contribution from these areas. While there have been improvements in air quality in many cities in the north, recent research suggests that in regions of rapid economic and population growth, without the implementation of adequate air quality standards, global anthropogenic air pollutants will increase (Pozzer et al. 2012). This is the case in many parts of Asia (Shao et al. 2006; Streets & van Aardenne 2010) and other nations with rapidly developing megacities (Lawrence et al. 2007). Emissions of NO_x, which are mainly sourced from the energy, transport and industrial sectors illustrate the general change in primary origin of global air pollutants. In 2000, East Asia overtook Europe and North America as the major source of NO_x emissions. Nonetheless, global emissions are expected to begin falling by 2030 as efficiencies and regulations improve worldwide (Streets & van Aardenne 2010).

Looking forward

Widespread recognition of the detrimental impacts of air pollution on human health and ecosystem function has led to the implementation of policies to improve air quality. Although there have been major improvements in urban air quality in many parts of the world, some pollutant categories remain problematic and, from a human health perspective, most nations fail to meet WHO health-related air pollution guidelines.

While emissions and environmental impacts of SO_2 have been reduced markedly, the management of other pollutants such as NO_x and ozone has been less effective. There is clearly significant scope to improve human and environmental health by improving air quality. Nonetheless, economic and population growth in the Tropics will, at least in the short term, increase demand for goods and services that contribute to air pollution. These pressures will require an increased and ongoing commitment to improving standards and mitigation measures in order to improve air quality.

Box 2.6 Hong Kong's air quality improvements

As in many other urban environments air quality in Hong Kong is largely determined by emissions from motor vehicles and power plants. Efforts to improve air quality have therefore focussed on reducing emissions from these two sources.

To reduce local-sourced particulate pollutants from power stations, in 1997 Hong Kong banned the construction for new coal fired plants and encouraged the use of natural gas. More stringent emission caps for power companies have also been applied since 2005. As a result, power plant emissions have been substantially reduced even though demand for power has increased. At a regional level Hong Kong is working with neighbouring, Guangdong Province, to develop co-operative programs to address smog problems in the Pearl Harbour Delta region.

Efforts to reduce vehicle emissions have been multifaceted, and include tighter sulphur content regulations for fuels (especially diesel) to reduce SO_2 emissions. Other programs include retrofitting of emission reduction devices to motor vehicles, grants to upgrade public transport vehicles from diesel to liquid natural gas and penalties for excessive vehicle emissions (HK EPD 2013).

These changes have had a significant impact on Hong Kong's air quality, even though there have not been improvements in all air pollutant classes (HK EPD 2010). Furthermore, economic losses associated with air pollution (estimated at approximately US$5 billion per annum) have not decreased , and in 2010 there were over 3,100 premature deaths and 155,000 hospital bed days linked directly to the effects of polluted air (HEI 2013).

Pollution in Hong Kong. Image: Danielle Viera.

References

Aichinger M. (2011). *Power blackout risks: Risk management options position paper.* CRO Forum, Amsterdam.

AIDA (2011) *Belo Monte Hydroelectric Dam.* Interamerican Association for Environmental Defense http://www.aida-americas.org/en/project/belomonte (accessed on 31 January 2013).

APEC (2002). *Cross-border power.* A report to the Asia-Pacific Economic cooperation Energy Working Group. Resources Law International, Australia.

ATA (2013). *The gift of light.* Alternative Technology Association http://www.ata.org.au/international-projects-group (accessed on 30 January 2013).

Baede APM, Ahlonsou E, Ding Y, Schimel D. (2001). The climate system: an overview, in Houghton JT, Ding Y, Griggs DJ, Noguer, van der Linden PJ, Dai X, Maskell K, Johnson CA. (Eds) Climate Change: The Scientific Basis - *Contribution of Working Group One to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, New York.

Barros N, Cole JJ, Tranvik LJ, Prairie YT, Bastviken D, Huszar VLM, del Giorgio P, Roland F. (2011). Carbon emissions from hydroelectric reservoirs linked to reservoir age and latitude, in *Nature Geoscience* **4**(9).

Barstow SF, Falnes J. (1996). *Ocean wave energy in the South Pacific: the resource and its utilisation.* South Pacific Applied Geoscience Commission (SOPAC)/ Government of Norway, Norway.

Beér J. (2006). High efficiency electric power generation: The environmental role, in *Progress in Energy and Combustion Science* **33**(2).

Bekoe EO, Logah FW. (2013). The impacts of droughts and climate change on electricity generation in Ghana, in *Environmental Sciences* **1**(1).

Bernstein A, Bienstock D, Hay D, Uzunoglu M, Zussman G. (2011). *Power grid vulnerability to geographically correlated failures – analysis and control implications.* Columbia University Electrical Engineering Technical Report #2011-05-06. Columbia University, New York.

Boehlert GW, McMurray GR, Tortorici (Eds) (2007). *Ecological effects of wave energy development in the Pacific Northwest.* NOAA Technical Memorandum NMFS-F/SPO-92.

BOM/ CSIRO (2011). *Climate Change in the Pacific: Scientific Assessment and New Research.* Volume 1: Regional Overview. Volume 2: Country Reports. Australia.

Bousquet P, Ciais P, Miller JB, Dlugokencky EJ, Hauglustaine DA, Prigent C, van der Werf GR, Peylin P, Brunke E-G, Carouge C et al (2006). Contribution of anthropogenic and natural sources to atmospheric methane variability, in *Nature* **443**(7710).

Bruce N, Perez-Padilla R, Albalak R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge, in *Bulletin of the World Health Organization* **78**(9).

Bussotti F, Ferretti M. (1998). Air pollution, forest condition and forest decline in Southern Europe: an overview, in *Environmental Pollution* **101**(1).

Canadell JG & Raupach MR (2008). Managing forests for climate change mitigation, in *Science* **320**(1456).

Canadell JG, Le Quere C, Raupach MR, Field CB, Buitenhuis ET, Ciais P, Conway TJ, Gillett NP, Houghton RA, Marland G. (2007). Contributions to accelerating CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks, in *Proceedings of National Academy of Sciences* **104**(47).

Castalia Strategic Advisors (2009). *International experience with cross-border power trading. Report to the Regional Electricity Regulators' Association & World Bank.* Castalia Strategic Advisors, Washington DC.

Church JA, White NJ, Coleman R, Lambeck K, Mitrovica JX. (2004). Estimates of regional distribution of sea level rise over the 1950-2000 period, in *Journal of Climate* **17**(13).

de Lucena AFP, Szklo AS, Schaeffer R, Dutra RM. (2010). The vulnerability of wind power to climate change in Brazil, in *Renewable Energy* 35(5).

de Lucena AFP, Szklo AS, Schaeffer R, Souza RR, Borba BSMC, Costa IVL, Pereira Jnr AO, da Cunha SHF (2009). The vulnerability of renewable energy to climate change in Brazil, in *Energy Policy* **37**(3).

Ebinger J, Vergara W. (2011). *Climate impacts on energy systems: Key issues for energy sector adaptation.* The International Bank for Reconstruction and Development/ The World Bank, Washington.

EC-JRC/PBL (2011). *Emission Database for Global Atmospheric Research (EDGAR), release version 4.2.* European Commission, Joint Research Centre (JRC)/ Netherlands Environmental Assessment Agency (PBL) http://edgar.jrc.ec.europa.eu/index.php.

EIA (2011). *International energy outlook 2011.* U.S. Energy Information Administration, Washington DC.

EIA (2012a). *Australia energy analysis brief.* U.S. Energy Information Administration, Washington DC.

EIA (2012b). *Ecuador energy analysis brief.* U.S. Energy Information Administration, Washington DC.

EIA (2012c). *Nigeria energy analysis brief.* U.S. Energy Information Administration, Washington DC.

EIA (2012d). *Angola energy analysis brief.* U.S. Energy Information Administration, Washington DC.

EIA (2013). *International Energy Statistics.* U.S. Energy Information Administration http://www.eia.gov/countries/data.cfm (accessed on 21-22 January 2013).

EPA (1997). *Health effects of Ozone.* United States Environmental Protection http://www.epa.gov/region07/air/quality/o3health.htm (accessed on 5 July 2013).

Field CB, Raupach MR, Victoria R. (2004). Introduction. The global carbon cycle: Integrating humans, climate and the natural world, in Field C, Raupach MR. (Eds), *Global Carbon Cycle: Integrating Humans, Climate and the Natural World.* Island Press. Washington DC.

References | Continued

Forster P, Ramaswamy V, Artaxo P, Berntsen T, Betts B, Fahey DW, Haywood J, Lean J, Lowe DC, Myhre G et al (2007). Changes in atmospheric constituents and in radiative forcing, in Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. (Eds), *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group One to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Giles J (2006). Methane quashes green credentials of hydropower, in *Nature* **444**(7119).

Gillenwater M, Seres S. (2011). The Clean Development Mechanism: a review of the first international offset programme, in *Greenhouse Gas Measurement and Management* **1**(3-4).

Githeko AK, Lindsay SW, Confalonieri UE, Patz JA (2000). Climate change and vector-borne diseases: a regional analysis, in *Bulletin of the World Health Organization* **78**(9).

HEI (2013). Hedley Environmental Index. School of Public Health at The University of Hong Kong http://hedleyindex.sph.hku.hk/home.php (accessed on 24 July 2013).

HK EPD (2010). *Air Quality in Hong Kong 2010.* Hong Kong Environmental Protection Department, Hong Kong.

HK EPD (2013). *Hong Kong's Environment:* air. Hong Kong Environmental Protection Department http://www.epd.gov.hk/epd/english/environmentinhk/air/air_maincontent.html (accessed on 3 July 2013).

Hurd B. (2012). Climate vulnerability and adaptive strategies along the Rio Grande/Rio Bravo border of Mexico and the United States, in *Journal of Contemporary Water Research and Education* **149**(1).

IAEA (2009). *Climate change and nuclear power.* International Atomic Energy Agency, Vienna.

ICS-CERT (2012). *ICS CERT Monitor. October-December 2012.* Industrial Control Systems Cyber Emergency Response Team, US Department of Homeland Security, Washington DC.

IEA (2007). *World energy outlook:* China and India insights. OECD/ International Energy Agency, Paris.

IEA (2009). *Carbon capture and storage.* OECD/ International Energy Agency, Paris.

IEA (2010). *World energy outlook.* OECD/ International Energy Agency, Paris.

IEA (2011a). *Advantage energy: Emerging economies, developing countries and the private-public sector interface.* OECD/ International Energy Agency Information paper, September 2011, Paris.

IEA (2011b). *Deploying renewables 2011 – Best and future policy practice.* OECD/ International Energy Agency, Paris.

IEA (2012a). *Technology roadmap: High-efficiency, low-emissions coal-fired power generation.* OECD/ International Energy Agency, Paris.

IEA (2012b). *Key world energy statistics.* OECD/ International Energy Agency, Paris.

IEA (2012c). *Technology roadmap: Hydropower.* International Energy Agency OECD/ International Energy Agency, Paris.

IFAD (2011a). *Addressing climate change in the Near East & North Africa.* International Fund for Agricultural Development, Rome.

IFAD (2011b). *Addressing climate change in Asia & the Pacific.* International Fund for Agricultural Development, Rome.

IFAD (2011c). *Addressing climate change in West & Central Africa.* International Fund for Agricultural Development, Rome.

International Rivers (2012) *Three gorges dam – a model of the past.* International Rivers, Berkeley.

IPCC (2007a). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Intergovernmental Panel on Climate Change, Geneva.

IPCC (2007b) *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson, CE (eds.) Cambridge University Press, Cambridge.

Kampa M, Castanas E. (2008). Human health effects of air pollution, in *Environmental Pollution* **151**(2).

KPMG (2012). *KBuzz Sector Insights.* Issue 19, KPMG India.

Kucera V, Fitz S. (1995). Direct and indirect pollution effects on materials including cultural monuments, in Water, *Air and Soil Pollution* **85**(1).

Kurihara H. (2008). Effects of CO_2-driven ocean acidification on the early developmental stages of invertebrates, in *Marine Ecology Progress Series* **373**.

Law K, Parrish D. (2010). Observational evidence and capabilities related to intercontinental transport of ozone and particulate matter, in Dentener F, Keating T, Akimoto H (Eds), *Hemispheric transport of air pollution 2010. Part A: Ozone and particulate matter.* Air Pollution Studies No: 17, United Nations, Geneva.

Lawence MG, Butler TM, Steinkamp J, Gurjar BR, Lelieveld J. (2007). Regional pollution potentials of megacities and other major population centers, in *Atmospheric Chemistry and Physics* **7**(14).

Liu J, Mauzerall DL. (2007). Potential influence of inter-continental transport of sulphate aerosols on air quality, in *Environmental Research Letters* **2**(4).

Lovett GM, Tear TH. (2008) *Threats from above: air pollution impacts on ecosystems and biological diversity in the Eastern United States.* The Nature Conservancy and the Cary Institute of Ecosystem Studies, Maryland.

Macintosh A, Downie C. (2006). *Wind farms: the facts and fallacies.* The Australia Institute, Discussion Paper 91, Canberra.

Mosley S. (2013). Environmental history of air pollution and protection, in *Encyclopedia of Life Support Systems.* United Nations Educational, Scientific and Cultural Organization.

NASA (2011) *The Carbon Cycle.* National Aeronautics and Space Administration http://earthobservatory.nasa.gov/Features/CarbonCycle/ (accessed on 16 January 2013).

NHMRC (2010). *Wind turbines and health: A rapid review of the evidence.* National Health and Medical Research Council, Canberra.

Niez A. (2010). *Comparative study on rural electrification policies in emerging economies: Keys to successful policies.* OECD/ IEA Information paper, March 2010, Paris.

NOAA (2013) *Trends in atmospheric carbon dioxide.* National Oceanic and Atmospheric Administration http://www.esrl.noaa.gov/gmd/ccgg/trends/ (accessed 14 January 2013).

O'Brien E. (2011). Chronology of leaded gasoline/ leaded petrol history, in *Lead Action News* **12**(3).

OTA (1990). *Physical vulnerability of electric system to natural disasters and sabotage.* Office of Technology Assessment, United States Congress, Washington.

Paoletti E, Grulke NE, Bytnerowicz A. (2009). *More harmful climate change impacts in polluted forests – a review.* XIII World Forestry Congress, Buenos Aires, 18 – 23 October 2009.

Percy KE. (2003). *Air pollution and forest health: Status and trends in northern forests.* XII World Forestry Congress, Québec City.

Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis J, Delaygue G et al (1999). Climate and atmospheric history of the past 420,000 years from the Vostok Ice Core, Antarctica, in *Nature* **399**(6735).

Pozzer A, Zimmerman P, Doering UM, van Aardenne J, Tost H, Dentener F, Janssens-Maenhout G, Lelieveld J. (2012). Effects of business-as-usual anthropogenic emissions on air quality, in *Atmospheric Chemistry and Physics* **12**(15).

REN21 (2012) Renewables 2012 *Global Status Report.* Renewable Energy Policy Network, Paris.

Sabine CL, Heimann M, Artaxo P, Bakker DCE, Chen C-TA, Field CB, Gruber N, Le Quéré C, Prinn RG, Richey JE et al (2004). Current status and past trends of the global carbon cycle, in Field C, Raupach MR. (Eds), *Global Carbon Cycle: Integrating Humans, Climate and the Natural World.* Island Press, Washington DC.

Samet JM, Zeger SL, Dominici F, Curriero F, Coursac I, Dockery DW, Schwatrz J, Zanobetti A. (2000). *The national morbidity, mortality, and air pollution study. Part II: Morbidity and mortality from air pollution in the United States.* Health Effects Institute Research Report No 94, Cambridge MA.

SANS Institute (2001). *Can hackers turn your lights off? The vulnerability of the US power grid to electronic attack.* SANS Institute InfoSec Reading Room.

Saunders RJ, Paul NA, Hu Y, de Nys R. (2012). Sustainable sources of biomass for bioremediation of heavy metals in waste water derived from coal-fired power generation, in *PLoS ONE* **7**(5).

Schaeffer R, Szklo AS, de Lucena AFP, Borba BSMC, Nogueira LPP, Fleming FP, Troccoli A, Harrison M, Boulahya MS (2012). Energy sector vulnerability to climate change: A review, in *Energy* **38**(1).

Shao M, Tang X, Zhang Y, Li W. (2006). City clusters in China: air and surface water pollution, in *Frontiers in Ecology & the Environment* **4**(7).

Siegenthaler U, Stocker TF, Monnin E, Luthi D, Schwander J, Stauffer B, Raynaud D, Barnola J-M, Fische H, Masson-Delmotte V, Jouzel J. (2005). Stable carbon cycle-climate relationship during the late Pleistocene, in *Science* **310**(5752).

Stevens B, Schieb P-A, Andrieu M. (2006). A cross-perspective on the development of global infrastructures to 2030, in *Infrastructure to 2030: Telecom, land transport, water and electricity.* OECD Publishing, Paris.

Streets D, van Aardenne J. (2010). Emissions inventories and projections, in Dentener F, Keating T, Akimoto H (Eds), *Hemispheric transport of air pollution 2010. Part A: Ozone and particulate matter.* Air Pollution Studies No: 17, United Nations, Geneva.

The Economic Times (2012). Northern & Eastern grids collapse: Biggest power failure in India. http://articles.economictimes.indiatimes.com/2012-07-31/news/32961774_1_power-grid-corporation-northern-grid-southern-grid (accessed 26 March 2013).

Themelis NJ, Ulloa PA. (2007). Methane generation in landfills, in *Renewable Energy* **32**(7).

Tollefson J (2012). Ocean-fertilization project off Canada sparks furore, in *Nature* **490**(7421).

Tsai PL, Hatfield TH. (2011). Global benefits from the phaseout of leaded fuel, in *Journal of Environmental Health* **74**(5).

UNFCCC (1997). *Status of ratification of the Kyoto Protocol.* United Nations Framework Convention on Climate Change http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php (accessed on 14 January 2013).

UNFCCC (2012a). *Outcome of the work of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol.* United Nations Framework Convention on Climate Change http://unfccc.int/resource/docs/2012/cmp8/eng/l09.pdf (accessed on 17 January 2013).

UNFCCC (2012b). *Efficient wood stoves for Nigeria.* United Nations Framework Convention on Climate Change http://cdm.unfccc.int/Projects/DB/RWTUV1245685309.5 (accessed on 12 February 2013).

UNFCCC (2013). *Clean Development Mechanisms.* United Nations Framework Convention on Climate Change http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php (accessed on 21 January 2013).

References | Continued

UN-REDD Programme (2009). *About REDD+.* United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries http://www.un-redd.org/AboutREDD/tabid/582/Default.aspx (accessed on 21 January 2013).

WHO (2006). *Air quality guidelines: Global update 2005.* World Health Organization, Copenhagen.

World Bank (2013). PM_{10} country level data. http://data.worldbank.org/indicator/EN.ATM.PM10.MC.M3 (accessed on 25 June 2013).

WRI (2012) *Climate Analysis Indicators Tool 2012, version 9.0.* World Resources Institute, Washington DC.

Yang A, Cui Y. (2012). *Global Coal Risk Assessment: Data Analysis and Market Research.* World Resources Institute Working Paper.

Aquaculture in Malawi.
Image: Stevie Mann, Worldfish.

Storm over Darwin Harbour, Australia.
Image: Charles Rantz Strebor.

'Kapag may usok, may apoy'
There is no effect without some cause.

Filipino proverb

Essay 1

The climates of the Tropics, and how they are changing

Blair Trewin
Bureau of Meterology

Blair Trewin has been a climate scientist with the Australian Bureau of Meteorology since 1998. He is a member of the World Meteorological Organisation's (WMO) Expert Team on Climate Change Detection and Indices, and was the scientific co-ordinator of WMO's annual Statement on the Status of the Global Climate in 2010 and 2011. He was the 2012-13 President of the Australian Meteorological and Oceanographic Society and is the editor of the Australian Meteorological and Oceanographic Journal.

The climates of the Tropics, and how they are changing

Blair Trewin

Many features combine to make up the diverse climates of the Tropics. It is a warm region; mean annual temperatures exceed 20°C almost throughout the Tropics, except at high elevations, and exceed 25°C in many parts of the tropical zone. The tropical zone encompasses some of the wettest locations on Earth, as well as some of the world's driest deserts. It also includes some of the world's communities most vulnerable to natural disasters; population pressures drive settlement of flood- or drought-prone areas, and less developed countries lack the resources to create resilience to extremes of climate. Limitations in physical and human infrastructure also contribute to limited capacity to warn of, or respond to, major disasters, although this is an area where great strides have been made in many countries in recent decades.

What makes up a tropical climate?

The classical definition of a tropical climate is one in which the mean temperature of the coolest month exceeds 18°C (see Figure E1.1), although this is a relatively narrow definition; on most continents, the poleward boundary of the zone thus defined is some distance within the Tropics of Cancer and Capricorn, even at sea level. Such a definition also excludes high-altitude areas within the Tropics, as mean temperatures typically decrease at a rate of about 6°C per 1000 metres.

A small annual range of temperature is characteristic of the Tropics. Near the Equator, the difference in mean temperature between the warmest and coldest months is rarely more than 4°C, and at some locations (such as Quito, Ecuador) it is less than 1°C. Annual ranges of temperature become larger as one moves further from the Equator, but even at the limits of the tropical zone, few locations have an annual range of more than 15°C.

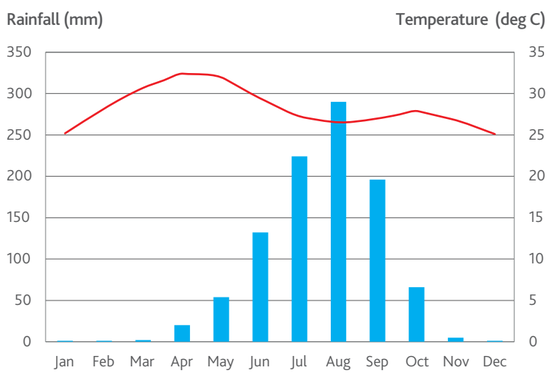
This low annual range of temperature makes traditional mid-latitude definitions of seasons of limited value; while it is possible to define "winter" and "summer" in any location that is not actually on the Equator, in many tropical locations, it is more common to speak of seasons in terms of the monsoon, "warm" and "cool" or "wet" and "dry" seasons. Outside the immediate proximity of the Equator, the coolest month is usually in "winter" (most often January in the Northern Hemisphere and July in the Southern Hemisphere), but the hottest month is not necessarily in "summer". In continental regions where there is a sharp, well-defined wet season – the African Sahel, much of the Indian subcontinent, and to a lesser extent northern Australia – the hottest weather occurs in the weeks prior to the onset of the wet season, sometimes with a smaller secondary peak at the end of the wet season (see Figure E1.2).

The equatorial zone is also characterised by consistent warmth and very small day-to-day temperature fluctuations; for example, at Singapore, the highest temperature on record is 36°C, and the lowest 18.9°C. Many locations within 15° latitude of the Equator, especially on islands or near the coast, have never reached 40°C and have highest recorded temperatures less than 5°C above the average daytime maximum temperature of the warmest month. This is in part due to island and coastal temperatures being largely controlled by ocean temperature, although in equatorial regions, even continental interiors (such as the Amazon basin) rarely, if ever, reach 40°C. Extreme temperatures are higher further from the Equator, although they still fall short of the world's highest extremes, most of which have occurred slightly outside the Tropics (including most of the instances of temperatures measured under standard conditions of 50°C or above).

While tropical climates are characterised by small variations in temperature, they include an immense variety of rainfall regimes. The Tropics include the driest parts of the world, the Atacama Desert on the west coast of South America where mean annual rainfall is less than 1 millimetre, as well as some of the wettest, locations in western Colombia and in Hawaii which receive more than 10,000 millimetres a year.

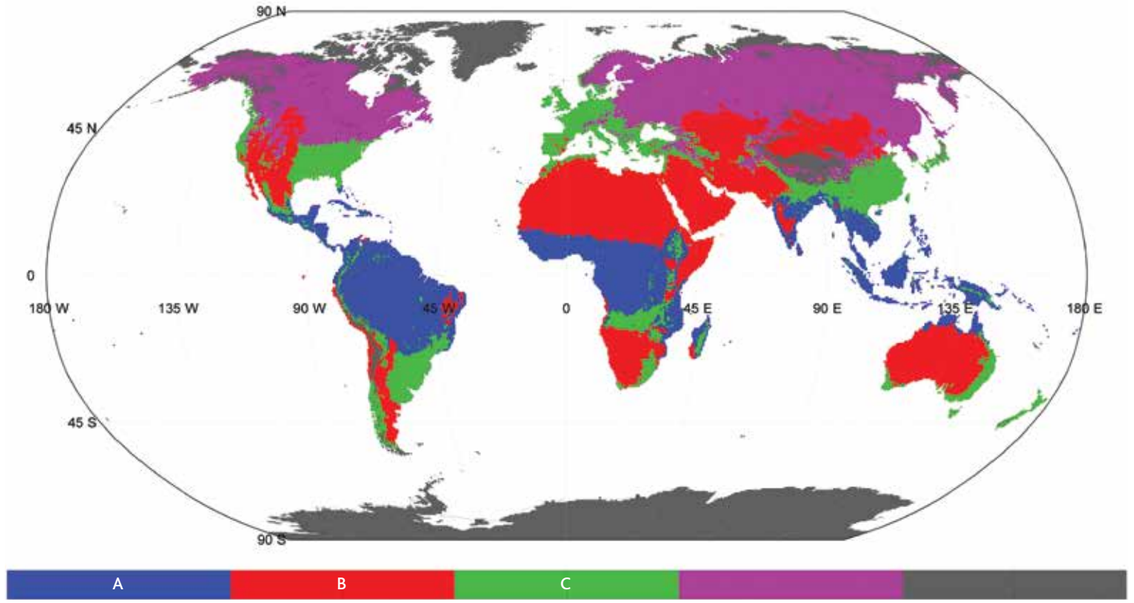
The classical model of tropical rainfall is one of an equatorial zone where rain occurs all year, transitioning to a "monsoon" or "savanna"

Figure E1.2 **Mean monthly rainfall and temperature at Bamako, Mali.**



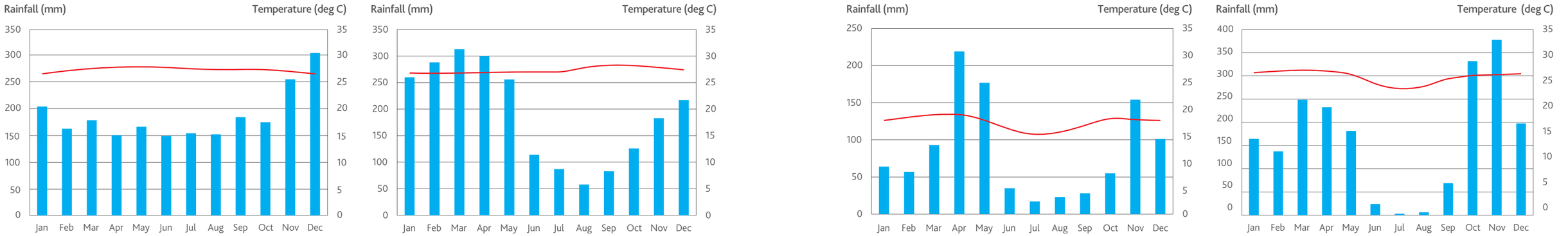
Source: WMO (2012)
Note: Blue bars are montly rainfall averages and the red line is mean temperature.

Figure E 1.1 **Map of the major global climatic zones**



Source: Chen & Chen 2013
Note: Major global climatic zones include tropical zones (blue, type A), according to the Köppen climatic classification. In this classification tropical zones are defined by the mean temperature of the coolest month, and by rainfall (A: Tropical, B: Dry, C Mild temperate, D: Snow, E: Polar).
WHO/ UNICEF (2012).

Figure E1.3 **Mean monthly rainfall and temperature at four near-equatorial locations:**
(A) Singapore, Singapore; (B) Manaus, Brazil; (C) Nairobi, Kenya and (D) Lambarene, Gabon.



Source: WMO (2012)
Note: Blue bars are montly rainfall averages and the red line is mean temperature.

climate with a well-defined wet and dry season (in summer and winter respectively), with the wet season becoming shorter with increasing latitude before it disappears altogether as one moves into the arid zone near the Tropics. This structure exists most clearly in west and central Africa north of the Equator, and in the Indonesian/Australian region.

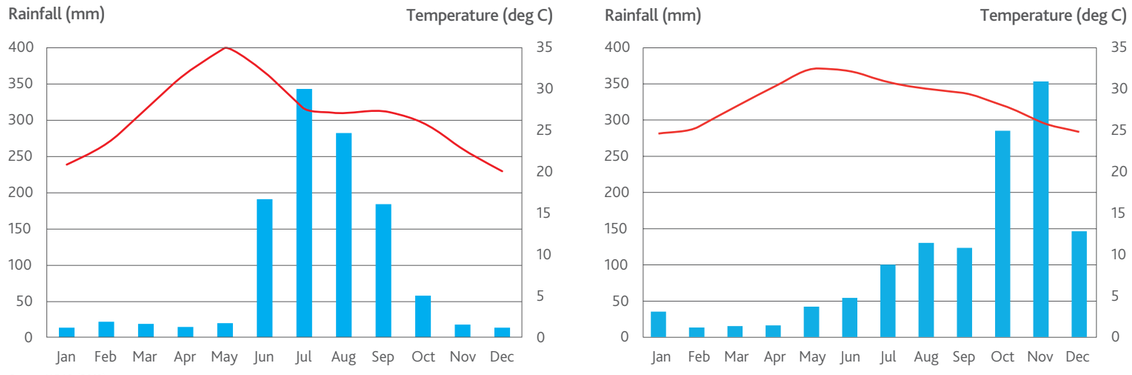
Reality is a good deal more complex than that, but strong seasonal variations of rainfall are a common feature of tropical climates. Even near the Equator, a wide range of rainfall regimes exist. Regions such as the equatorial parts of the Indonesian archipelago, parts of equatorial Africa, and western Colombia are wet all year, but some other equatorial regions have a distinct drier season – sometimes relatively but not totally dry (as with the mid-year period over much of the Amazon), but in some regions, the near-total seasonal dryness of the savanna zone extends all the way to the Equator, as in western Africa. Highland East Africa has a more complex pattern still, with two rainy seasons (March-May and October-November), and dry conditions in between, especially on the north side of the Equator. Some examples of rainfall regimes in near-equatorial locations are shown in Figure E1.3.

Moving away from the Equator and into the 10-20° latitude range, climates where there is a single, clear-cut wet season, most commonly in that hemisphere's summer, become the norm. In some parts of the world, such as west and central Africa (both north and south) and much of northern Australia, almost all the year's rain falls within four or five months with the remainder of the year being almost completely dry (e.g. Figure E1.2). Elsewhere, especially within reasonable proximity of east coasts (e.g. southern coastal China, the east coasts of Africa and South America south of the Equator, large parts of India, and much of the Queensland coast in Australia), rain can occur in all months of the year but there is still a clear distinction between the wetter and drier months. A variation on this theme comes in some parts of the world where coasts are at right angles to the trade winds; many of these locations are relatively rainshadowed during the summer monsoon and receive their heaviest rain when the monsoon retreats in autumn and the trade winds become re-established. Examples include the central coast of Vietnam and the east coasts of southern India and Sri Lanka (all of which have their peak rainfall in October and November), and parts of coastal Brazil whose rainfall peaks between April and June. Figure E1.4 illustrates some climates of this type.

Island climates can be more complex still, with substantial changes in the seasonal regime over short distances depending on aspect. In the southwest Pacific, windward southeast sides of islands receive significantly more rainfall than leeward sides during the "dry" season, and thus have a more even spread of rainfall than leeward sides or island interiors. On the larger islands the heating of land and convergence of sea breezes during the warmest months of the year causes the development of convective cloud and showers in the late afternoon.

At the outer limits of the Tropics, in areas sufficiently far from east coasts, the wet

Figure E1.4 **Examples of monsoonal climates in India:**
(A) Nagpur, in central India (B) Chennai, on the southern east coast.



Source: WMO (2012)
Note: Blue bars are montly rainfall averages and the red line is mean temperature.

Box E1.1 Climatic definitions of the Tropics

The traditional definition of the Tropics is the area between the Tropics of Cancer and Capricorn (approximately latitude 23°N and 23°S respectively).

The most widely used system of climatic classification, the Köppen classification (Chen and Chen, 2013), has two major classifications within the Tropics, humid tropical climates and arid/semiarid climates. The main temperature criterion for humid tropical climates is that the mean temperature of the coolest month is above 18°C, with various rainfall-based criteria distinguishing humid tropical climates from arid/semiarid climates. In regions where humid tropical climates transition to moist temperate climates rather than arid/semiarid ones, the boundary of humid tropical climates is generally fairly close, in low-altitude areas, to the Tropic of Cancer/Capricorn, although it is a little closer to the equator in east Asia.

A wide variety of definitions are in use for various applications; for example, the UK Meteorological Office report on temperatures in the region between 30°N and 30°S, while NASA report on a zone bounded by 24°N and 24°S. The IPCC Fifth Assessment Report also reports various results for the region between 30°N and 30°S.

Some characteristic features of tropical climates can extend well beyond the Tropics. The Indian monsoon's influence extends throughout the subcontinent, including those areas north of the Tropic of Cancer, and monsoon-type features can also extend well beyond the Tropics in other regions, particularly east Asia. Most tropical cyclones form within the Tropics, but many of them move well outside the Tropics during their lifetime, particularly in the North Atlantic where destructive tropical cyclones have occurred as far north as Newfoundland.

Papua New Guinea. Image: Mark Ziembicki.

season peters out altogether and the climate becomes consistently arid under the fringes of the subtropical high pressure belt. Many of the world's major deserts have their equatorward limit between latitude 15° and 20°, including the Saharan and Arabian deserts, the Australian deserts, and Africa's Kalahari. South America is too narrow in this latitude range to support a major continental desert, but does have the world's most extreme example of a coastal desert dominated by the stabilising influence of cool ocean currents offshore; the narrow Atacama Desert along the west coast of Peru and northern Chile. A similar mechanism governs the Namib Desert on the west coast of southern Africa.

Major features of the tropical circulation

The most fundamental feature of the tropical atmospheric circulation is a zone where warm air rises from the surface to the upper atmosphere (a process known as convection), creating a zone of low pressure at the surface. Once in the upper atmosphere, this air moves towards the poles before descending in the subtropics, the descending air creating a zone of high surface pressure (the subtropical high or ridge). To complete the process, air then flows at surface level from the high-pressure area in the subtropics towards the low-pressure zone near the Equator. The whole structure is known as the Hadley Cell (see Figure E1.5).

The zone of near-equatorial low surface pressure is variously known as the Intertropical Convergence Zone (ITCZ), or the monsoon trough; the former term is derived from the fact that it is where surface winds flowing in from the subtropical ridges of the Northern and Southern Hemispheres converge. The ITCZ moves with the seasons, being centred (on a global-mean basis) north of the Equator during the Northern Hemisphere summer, and south of the Equator during the Southern Hemisphere summer (although it generally stays closer to the Equator when in the Southern Hemisphere due to the lesser influence of the continents, and in the central and eastern Pacific remains north of the Equator all year). As an active area of convection it also tends to be the most favoured zone for the formation of storms.

The winds between the subtropical ridge and the ITCZ are referred to as the "trade winds". Due to the effect of the Earth's rotation, these winds are deflected to the left in the Southern Hemisphere and to the right in the Northern Hemisphere, and hence generally blow from the southeast and northeast respectively. If the ITCZ is some distance from the Equator, the trade winds from the opposite hemisphere will cross the Equator and thus shift direction – so, for example, during the Northern Hemisphere summer, winds originating in the Southern Hemisphere turn from southeast to southwest as they cross the Equator. In some parts of the world, the trade winds interact with circulations around subtropical high-pressure systems and troughs to generate additional convergence zones. The South Pacific Convergence Zone (SPCZ), which typically runs southeast from the tropical western Pacific to French Polynesia (and is a very strong influence on the climate of many South Pacific island countries), is the best-known example.

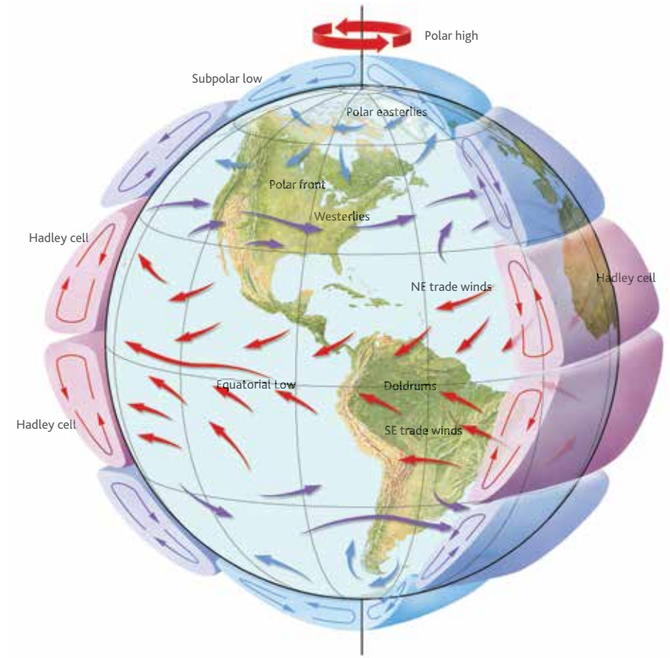
In those areas which are crossed by the ITCZ during the course of the year, the result of this is seasonally reversing winds (the original definition of the monsoon); for example, over the Indian subcontinent, winds are generally southwesterly when the ITCZ is to the north (normally between June and September) and northeasterly when the ITCZ is to the south. Similarly when the SPCZ is to the north of Fiji (Southwest Pacific) the winds are generally southeasterly and cool due to their high latitude origin. When the SPCZ is to the south of Fiji the winds are northerly and warm with more moisture content.

Cold and warm fronts, which are regular features of the circulation at higher latitudes, are generally absent from the Tropics. Mid-latitude systems can, however, have an indirect influence on the Tropics, particularly through driving surges of cool, dry air into the Tropics as a result of high pressure building behind cold fronts passing at higher latitudes. South America, where the Andes act as a barrier to westward diffusion of cold air at low levels, is particularly noted for this, with such surges occasionally reaching the Equator, but it is also a feature of regions such as northern Australia, eastern parts of central America, and east Asia. In the latter two cases, the relative proximity of very cold continental air masses to the north means that such surges can bring low temperatures into the Tropics; for example, locations such as Hong Kong and Hanoi occasionally have mid-winter daytime maximum temperatures below 10°C.

Strong mid-latitude systems can also interact with tropical systems such as the SPCZ on occasions to amplify rainfall in those regions.

As many of the weather features which formed the basis of the development of weather forecasting at higher latitudes are absent in the Tropics, the science of forecasting took longer to develop in the Tropics; in particular, surface pressure gradients are not as reliable a guide to surface wind speed and direction as they are at mid-latitudes.

Figure E1.5 **The global circulation, including an illustration of the Hadley Cell**



Source: Gary Hicks, Science Photo Library

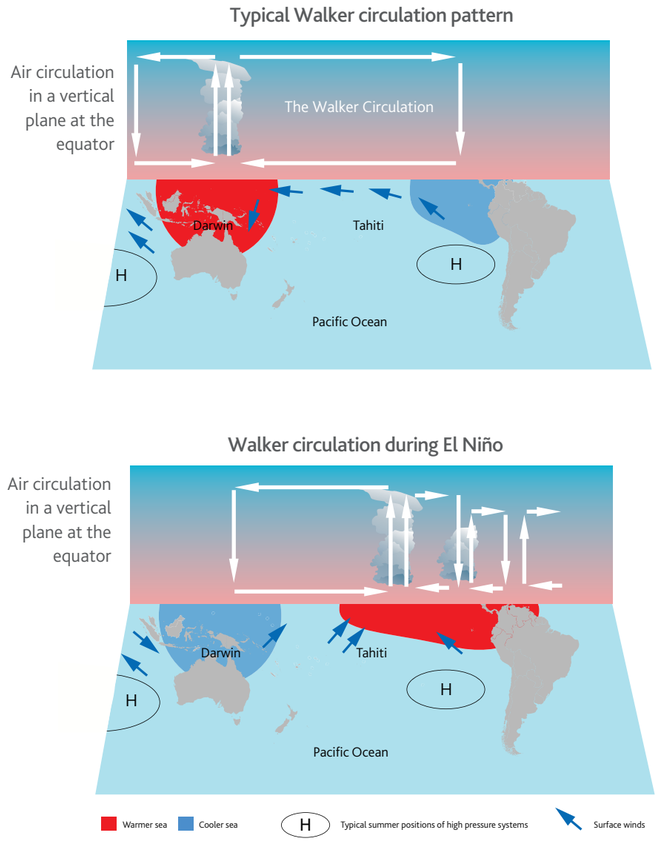
Key drivers of climate change and variability in the Tropics

There are many factors which influence variations of climate in the Tropics on a variety of timescales, from those which operate on a timescale of weeks, to long-term changes over a period of decades or centuries. These interact to create complex patterns of variability overlying longer-term trends.

The most significant long-term driver of climate change in the Tropics over the last century, as elsewhere on the globe, has been the increased concentration over time of greenhouse gases such as carbon dioxide (CO_2) in the atmosphere. Successive assessments have given an increasing level of confidence that observed increases in temperature over the last 50 to 100 years are primarily attributable to increased concentrations of greenhouse gases driven by human activity. Regional attribution of temperature trends cannot be done with quite the same level of confidence in the Tropics that it can in some other regions because of more limited observations, but nevertheless, the IPCC AR5 (IPCC, 2013) concluded that it is likely that human influence has made a substantial contribution to the observed warming since 1950 in each of the inhabited continents, including those located primarily or partly in the Tropics.

Other changes in radiative forcing can affect climate globally or regionally. In contrast with the influence of greenhouse gases, aerosols can have a measurable cooling effect (especially in heavily polluted areas) and may also be linked to changes in atmospheric circulation – for example, some studies have linked increased aerosols in east Asia to changes in the north Australian monsoon which have led to increased rainfall in north-western Australia. Natural forcings, such as variations in solar activity or major volcanic eruptions, can also have an influence on global climate. The 1991 eruption of Mount Pinatubo in the Philippines suppressed mean global temperatures by up to 0.4°C over a period of several years, while 19th century eruptions such as those of Tambora (1815) and Krakatoa (1883) are believed, from the available data, to have had even larger impacts.

Figure E1.6 **The typical atmospheric circulation pattern in the tropical Pacific Ocean and how it changes during an El Niño year.**



Source: Australian Bureau of Meteorology (2008)

The climate also has numerous internal modes of variability. The most prominent of these is the El Niño-Southern Oscillation (ENSO). This phenomenon is characterised by changes in ocean temperatures in the eastern and central equatorial Pacific but has impacts on climate over many parts of the world. During an El Niño event, the waters in this region (which are normally substantially cooler than other equatorial waters, due to the influence upwelling from below the ocean surface off the west coast of South America) are warmer than normal (by 1 to 2°C in a typical event, although in the strongest events, such as 1982-83 and 1997-98, anomalies have reached 4°C) (see Figure E1.6). This results in a weakening of the easterly (equatorial) trade winds in the Pacific (the surface part of what is known as the Walker Circulation) on both sides of the Equator, with flow-on consequences for the atmospheric circulation over a large part of the world. El Niño events are associated with a high risk of dry conditions over areas such as the western Pacific including eastern Australia, southern Africa, much of the Indian subcontinent, and northeast Brazil, while they are associated with high rainfall in east Africa and on the west coast of South America. Through their influence on the location of the ITCZ and SPCZ (Australian Bureau of Meteorology and CSIRO, 2011), El Niño events also have a strong influence on the rainfall on many Pacific Islands (positive or negative, depending on island location). La Niña events are the near reverse of El Niño – that is, waters are cooler than normal in the eastern and central equatorial Pacific – and have broadly opposite climatic impacts.

The typical lifecycle of El Niño and La Niña events is 9-12 months; they tend to form between March and May, when the temperature gradient across the equatorial Pacific is at its weakest, and break down early in the following years. It is rare for an event to continue into a second year (although more common for La Niña to do so than El Niño). On average 2-3 events of each type occur each decade, but there is no consistent cycle; in some periods, such as the 1950s and 1970s, La Niña predominated and El Niño events were rare, whereas for much of the 1980s and 1990s El Niño events occurred regularly and La Niña events were few and far between. This interdecadal variation in the relative frequency of El Niño and La Niña events contributes to a pattern referred to as the Interdecadal Pacific Oscillation (IPO), although the extent to which the IPO functions independently of ENSO is a matter of some debate.

Conditions in the equatorial Indian Ocean also vary on seasonal timescales in a way which has broader influences on the tropical climate. There is a tendency for below-normal temperatures in the eastern Indian Ocean, off the south coast of Java and Sumatra, to be associated with above-normal temperatures off the African coast, and vice versa. This is referred to as the Indian Ocean Dipole (IOD), with its positive phase denoting warm conditions in the western Indian Ocean and cool conditions in the east. The positive phase of the IOD, which is more likely to occur during El Niño years but can also occur during other ENSO phases, tends to be associated with wet conditions in east Africa, and below-normal rainfall over large parts of Australia, especially in the Southern Hemisphere winter and spring. The dynamics of the IOD are less well-understood than those of ENSO and seasonal prediction of its behaviour is still in its infancy.

On longer timeframes, the tendency of temperatures in the North Atlantic to persist above (or below) the long-term trend over periods of 20-30 years has been referred to as the Atlantic Multidecadal Oscillation (AMO). During warm phases of the AMO, one of which has been in progress since the mid-1990s, there are a number of impacts on tropical climate, including a tendency towards increased tropical cyclone activity in the North Atlantic, and increased rainfall in the Sahel and the Indian subcontinent. Climate models suggest that AMO phases are linked with small shifts in the broader ocean circulation but the mechanisms of this are still poorly understood, and no demonstrated predictability currently exists.

An influence which operates on shorter timeframes is the Madden-Julian Oscillation (MJO) (Wheeler and Hendon 2004). This can be characterised as an eastward-moving "pulse" of cloud and rainfall near the Equator which typically recurs every 30 to 60 days, and is most visible over the Indian Ocean and the western Pacific. Active phases of the Indian and Australian monsoons are most likely to occur when the MJO pulse passes local longitudes, something which is also associated with a higher risk of tropical cyclone formation. The MJO is predictable with useful skill over periods up to about three weeks, supporting forecasting of wet and dry periods on timescales longer than those feasible with conventional weather-forecasting methods.

Long-term temperature trends and variability in the Tropics

Like the rest of the world, the Tropics have warmed over the last century (see Figure E1.7), with steady warming from the early 20th century to about 1940, then a levelling off until the mid-1970s, then a rapid rise to the end of the century. Depending on the data set used, the total warming over the 1910-2012 period in the Tropics and near-Tropics has been 0.7-0.8°C, about 0.1°C less than that over the globe as a whole. Warming over the Tropics has been slower than over higher latitudes of the Northern Hemisphere, but faster than over mid- to high latitudes of the Southern Hemisphere.

Finer geographic patterns of warming over the century are challenging to assess, due to very limited pre-1950 data over continental Africa, the Amazon and much of the tropical Pacific. In the last 30 years, the Sahara, Sahel and Arabian Peninsula have been amongst the most rapidly-warming parts of the world, whilst large parts of the eastern and central tropical Pacific have seen weak cooling, associated with decadal variability in the El Niño-Southern Oscillation (ENSO).

Temperatures averaged over the Tropics show more interannual variability than those averaged over the globe as a whole. This partly reflects the smaller area over which averaging is being done, but also reflects the fact that the bulk of ENSO's influence on temperature is felt in the Tropics. A strong El Niño year will typically be about 0.2°C warmer in the Tropics than the years around it, and

a strong La Niña year about 0.2°C cooler, whereas for the globe as a whole the signal is about half that size (WMO, 2012). The most recent strong El Nino year, 1998, is clearly the warmest year on record in the Tropics to date, whereas globally it is closely matched with 2005 and 2010. Recent years have seen La Niña predominate over El Niño, with particularly strong events in 2008 and 2011, and hence tropical temperatures in the last few years have been relatively low compared with global means.

How has tropical rainfall changed over time?

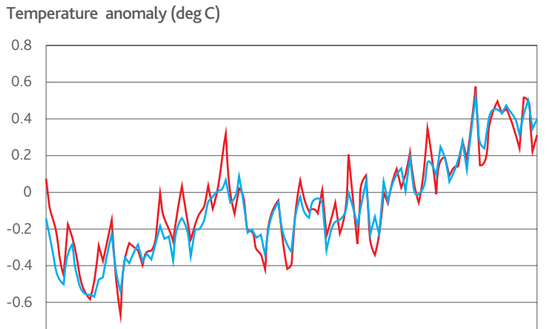
Rainfall in many tropical regions of the world has shown marked fluctuations from year to year, and from decade to decade. Many of these fluctuations are associated with ENSO, which has a marked influence on rainfall in many parts of the Tropics. Over land, there are more tropical regions where El Niño has a drying influence than there are regions where it is associated with increased rainfall (the reverse is true over the oceans), and hence total tropical rainfall on land is generally substantially higher in La Niña years, and lower in El Niño years.

The IPCC 5th Assessment Report (AR5) (IPCC, 2013) reported that downward trends in total tropical rainfall which had prevailed from the 1970s to the 1990s had reversed in the last decade, and that there was now no significant trend over either the 1901-2008 or 1951-2008 periods. This reversal is largely associated with decadal fluctuations in ENSO, with the dominance of El Niño through the 1980s and 1990s replaced by a number of major La Niña events in the years from 1999 onwards. The IPCC also cautions that confidence in reported rainfall trends in the Tropics is low in the first half of the 20th century, and medium from 1950 onwards, due to limitations in the available data.

Focusing on the most recent 30 years, rainfall has increased significantly since 1979 in a number of tropical regions, including the Sahel (which was affected by chronic drought from the mid-1970s to the 1990s but has been quite wet in recent years), southern Africa from Zambia southwards, the western tropical Pacific and much of northern Australia, especially the Northern Territory and northern Western Australia. The only large areas showing significant decreases over that timeframe are Brazil south of about 10°S and the central equatorial Pacific. Few tropical areas show significant trends over the 20th century as a whole, partly because few areas have consistent data over that length of time.

There are also few coherent signals of changes in rainfall extremes, at either end of the scale. The IPCC reports indications of an increase in the frequency of high precipitation extremes in parts of South America, but mixed or inconclusive changes in other tropical land areas. There is low confidence in assessment of changes in flooding, and also for drought in many areas. (In part, this is because of a wide range of indicators used for drought – some are purely rainfall-based, others attempt to incorporate other variables such as temperature and soil moisture). The strong increases in rainfall since 1960 in north western Australia have been accompanied by a decrease in drought, while west Africa shows a likely increase of drought since 1950 (although this signal is dominated by the protracted late 20th century drought in the Sahel).

Figure E1.7 **Mean annual temperatures (anomalies from 1961-90 mean) for the globe (blue line) and for areas between latitudes 30°N and 30°S (red line)**



Source: HadCRUT data set, Brohan et al. 2006

Tropical cyclones – their occurrence and long-term changes

Tropical cyclones (generally referred to as hurricanes in the Atlantic and Northeast Pacific, and typhoons in the Northwest Pacific) are amongst the most significant atmospheric phenomena in the Tropics. They can be exceptionally destructive, through a combination of extreme winds, very heavy rain leading to freshwater flooding and landslides, and storm surges causing dangerously elevated sea levels in coastal areas near landfall. In the most extreme cases (Figure E1.8), maximum wind gusts have exceeded 300 km/h, daily rainfalls have occurred in excess of 1000 millimetres in 24 hours, and storm surges have driven coastal waters 10 metres or more above their normal levels. In particular, cyclone-related storm surges have caused catastrophic loss of life on a number of occasions along heavily-populated, low-lying coastlines, especially around the coast of the Bay of Bengal.

To obtain sufficient energy to form or maintain intensity, tropical cyclones normally need to be over water with a sea surface temperature of at least 26°C. They also require sufficient Coriolis force to generate initial rotation, so do not normally occur within about 4° latitude of the equator. Once formed, their intensity and longevity is governed by numerous factors, including sea temperatures, the available moisture in the surrounding environment, and the presence or absence of wind shear (differential wind speed/direction at different elevations), which if present to an excessive degree can rapidly weaken a cyclone. Tropical cyclones will normally weaken quickly once they move over land (although the moisture associated with cyclones can penetrate inland for very long distances, especially over continents with few topographic barriers such as western and central Australia). They will also normally lose intensity as they move over cooler waters, although under certain conditions they can transition into intense extratropical cyclones (which are distinguished from tropical cyclones by having a cold rather than warm core in the upper levels, and by their typically larger size) as they move to higher latitudes – something especially common in the North Atlantic and Northwest Pacific. Tropical cyclones are typically smaller than mid-latitude systems, especially at low latitudes; some highly destructive systems, such as Tracy (which largely destroyed Darwin in 1974), have had fields of gale-force winds only a few tens of kilometres across.

The majority of tropical oceans are able to support tropical cyclone formation for at least some of the year. The world's most active tropical cyclone region is the Northwest Pacific, which on average has about 30% of the global total (which is normally 85-90 cyclones per year), with the Philippines being the world's most frequently hit country. The Northwest Pacific also has the highest

Box E1.2 How do we monitor climate in the Tropics?

One of the major challenges in monitoring climate change and variability is that of obtaining appropriate long-term observations to do so.

On land, much of our information comes from "conventional" meteorological observing stations, set up under the auspices of meteorological authorities in the countries where they are located. These stations measure a range of variables, most often temperature and rainfall. Few of these were set up with the primary intention of assessing climate change; more commonly, they were established to support weather forecasting, or for purposes such as tracking seasonal rainfall for agriculture.

In the ocean, observations such as those of winds, pressure and sea surface temperature have been made from ships since the 19th century. These have been supplemented over time by a range of moored and drifting buoys, which are particularly valuable in ocean regions away from shipping lanes. More recently, subsurface information has become available through tools such as the Argo floats, which spend most of their lives drifting about 1500 metres below the surface but rise to the surface, taking measurements on the way, every few days; this information is especially important in monitoring and predicting El Niño and La Niña events, as changes in the subsurface of the equatorial Pacific are often a precursor to changes at the surface.

Remotely sensed data sets, mostly from satellites, are becoming increasingly important in climate monitoring. Satellites and, for systems near land, radar are especially critical in monitoring tropical cyclones, as cyclones spend the bulk of their lives over oceans with few or no conventional observations (only in the North Atlantic are aircraft routinely used for tropical cyclone monitoring), and even when they make landfall, instruments often fail to capture the cyclone's full intensity (either because there are no instruments in the right place, or because those which are there fail to survive the cyclone). Prior to the satellite era, some tropical cyclones which stayed out to sea throughout their lives are likely to have been missed altogether, especially in the Southern Hemisphere and the central North Pacific. Satellites are also used to track elements such as cloud cover, rainfall – an especially valuable tool has been the Tropical Rainfall Measurement Mission (TRMM), a joint US/Japan satellite launched in 1997 – and sea surface temperature.

All of these data sets have their challenges, and these challenges are particularly acute in many tropical areas. In many less developed countries – which are disproportionately located in the Tropics - maintaining conventional land-based observation networks over time has been difficult, due to factors such as a lack of funds, a lack of personnel with suitable technical expertise, and armed conflict or civil unrest, and while the situation is improving in some countries, it is deteriorating in others. Even where observations are being made, they are often not accessible in a timely manner because of poor communications, while many historical observations are available only in hard-copy documents (often held by former colonial powers) and are thus effectively unavailable for analysis. Some countries also limit the sharing of their data for commercial or military reasons. Work is ongoing amongst many national and international institutions (e.g. Thorne et al 2011) to address these issues, but progress is slow. Elsewhere, regions such as northern Australia and the Amazon basin in Brazil are in countries with well-developed national meteorological services, but have very sparse populations and hence sparse observation networks. The consequence of all of this is that stations with 100 years or more of continuous reliable observations, relatively common in Europe and North America, are few and far between in the Tropics, especially in Africa and parts of South America.

Satellite observations have been very useful for ongoing climate monitoring, and are now routinely used for tracking seasonal rainfall, especially in Africa where they have been critical in providing real-time information from regions such as the Sahel and the Horn of Africa where such information is difficult to obtain from more traditional sources. The main disadvantage of satellite-based data sets is their relatively short length, normally insufficient for assessments of long-term climate change. Few satellite-based data sets go back further than the late 1970s, although with careful analysis, satellite data suitable for tropical cyclone analysis extends into the late 1960s.

Figure E1.8 **Satellite image of Typhoon Haiyan approaching the Philippines, 7 November 2013**

Source: NASA Images.

frequency of intense tropical cyclones, and has had the majority of the world's most intense systems, and most intense landfalls. Northwest Pacific cyclones can occur at any time of year, although they are most common from July to October, and least common from January to April. The North Atlantic, Northeast Pacific, Southwest Pacific and North and South Indian Oceans also experience regular tropical cyclones, and regular landfalls on most of the surrounding coasts and islands (except for the African coast, where landfalls are rare on the east coast and almost unknown on the west). The Southeast Pacific is too cool to support tropical cyclones, and they are also exceptionally rare in the South Atlantic.

Whilst most tropical cyclones form within the Tropics, some go on to have significant impacts outside the Tropics, especially in the North Atlantic and Northwest Pacific, where sea surface temperatures near or above 26°C extend well north of the Tropics during summer and early autumn. Tropical cyclones regularly make landfall on the Japanese island of Honshu and on the Korean Peninsula, between latitudes 35 and 40°N, and have also done so at similar or higher latitudes in the northeast United States and the Atlantic provinces of Canada, causing major destruction as far north as 48°N in Newfoundland.

The total number of tropical cyclones globally remains remarkably stable from year to year; years with fewer than 75, or more than 100, cyclones are rare. However, the geographic distribution of cyclones shows more interannual variability, with ENSO acting as a strong influence. In general, El Niño years see an eastward displacement of cyclones in the Northwest and Southwest Pacific; fewer cyclones make or approach landfall on the coasts of Australia and China, and more occur in the central South Pacific and in longitudes near and east of Japan. El Niño years also tend to see fewer tropical cyclones in the North Atlantic, and more in the Northeast Pacific. La Niña years generally display the opposite pattern.

The IPCC Fifth Assessment Report (IPCC 2013) reported little evidence of significant trends in global tropical cyclone activity, with low confidence in observed changes of most indicators, both in terms of total numbers and of intensity, although more confidence exists in a few regions for limited time periods (e.g. for an increase in the frequency and intensity of the most intense tropical cyclones in the North Atlantic since the 1970s, something to which the current warm phase of the AMO is at least partly contributing). To some extent, this reflects the large uncertainties which arise from changes in observing technologies over time; outside the North Atlantic, most tropical cyclone intensity assessment (Velden et al. 2006) depends on satellite data (see Box E1.2) which have only been consistently available since the late 1970s. The IPCC assessment of projections of future tropical cyclone activity is that it is likely that the total number of tropical cyclones will either decrease or remain essentially unchanged, while the number of intense cyclones is likely to increase, but at a rate which is sufficiently slow that it is unlikely to be statistically distinguishable from interannual variability for many years to come.

What lies ahead for the tropical climate?

Like the rest of the world, the Tropics are projected to warm substantially over the coming 50 to 100 years. The actual amount of warming, particularly in the second half of the century, depends largely on the trajectory of greenhouse gas emissions; the lowest-emission scenarios considered by IPCC (IPCC 2013) indicate warming of global mean temperature (from a 1986-2005 baseline) of around 1°C by mid-century and 1-2°C by 2100, whereas under high-emission scenarios projected global temperature changes are 1-2°C by mid-century and 3-4°C by 2100.

Most model projections indicate that warming trends over the Tropics will be marginally smaller than those for the globe as a whole, continuing the 20th century pattern of the strongest warming being at high latitudes of the Northern Hemisphere and the weakest warming at mid- to high latitudes of the Southern Hemisphere. There is no clear indication of significant differences in temperature trends within different parts of the Tropics, apart from a weak tendency towards stronger warming in continental regions than over the oceans. Because of the low day-to-day variability of tropical temperatures, however, the change in the frequency of extreme temperatures is expected to be larger over most of the Tropics than in other parts of the world; in many parts of the Tropics now, an individual day 3°C above the 20th century average is an unusually warm day and something only experienced a few times per year, but under the higher-range warming scenarios such conditions would become the norm in the later part of the 21st century.

There is low confidence in projected changes in annual rainfall over most of the Tropics. The majority of models simulate increased rainfall over the equatorial oceans, especially the Pacific, but there are few consistent signals over the tropical continents. There are indications of an intensification of the seasonal rainfall cycle and a lengthening of the monsoon season in many regions (particularly the Indian subcontinent), with the wet season becoming wetter and the dry season drier, as well as of an increase in extreme rainfall events at various timescales, but uncertainties are large.

More confidence can be attached to various changes in the atmospheric circulation – for example, it is considered likely that there will be a broadening of the Hadley cell which will lead to a poleward displacement of the tropical dry zones – but the most clear-cut rainfall impacts of this will be outside the Tropics. It is also considered likely that the eastern tropical Indian Ocean will warm more slowly than the west, indicative of a shift towards more positive modes of the Indian Ocean Dipole, but there is low confidence in changes in the intensity and spatial pattern of ENSO in a warmer climate.

A major area of uncertainty is the potential for feedbacks arising from changes in land cover. The best-known tropical scenario in this respect is the possibility of a major change in the vegetation over large parts of the Amazon basin – as a result of a more pronounced dry season, land use changes, other changes such as altered fire regimes, or a combination of all of these – and a consequent reduction in moisture availability (and hence rainfall) through reduced transpiration. Whilst the possibility that such a (potentially irreversible) "step change" could occur is known, the critical thresholds which might result in such a change are largely unknown, and hence IPCC currently assigns low confidence to any assessment of possible changes of this type.

Future climate change is an issue of concern worldwide. Many tropical countries are particularly vulnerable to its impacts, because of the generally lower resilience of less developed countries to extreme events of any kind. In marginal areas, even minor changes in rainfall regimes can have a major impact on agricultural productivity. Some tropical countries also have heavily-populated areas on low-lying coasts which are highly vulnerable to sea level rise; in extremis, some low-lying coral atolls (such as those which make up the Maldives, Tuvalu and Kiribati) may be rendered uninhabitable should sea levels rise sufficiently far.

References

Australian Bureau of Meteorology (2008) The Walker Circulation. http://www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml?bookmark=walkercirculation (accessed December 2013).

Australian Bureau of Meteorology and CSIRO. (2011). *Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1. Regional Overview* www.pacificclimatechangescience.org.

Brohan P, Kennedy JJ, Harris I, Tett SFB, Jones PD. (2006). Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850 in: *Journal Geophysical Research*, 111.

Chen D, Chen HW. (2013). Using the Köppen classification to quantify climate variation and change: an example for 1901-2010 in: *Environmental Development*, **6.**

IPCC (2013). *Climate Change 2013: The Physical Science Basis.* Working Group I contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Thorne PW, Willett KM, Allan RJ, Bojinski S, Christy JR, Fox N, Gilbert S, Joliffe I, Kennedy JJ, Kent E, Klein Tank A, Lawrimore J, Parker DE, Rayner N, Simmons A, Song L, Stott PA, Trewin B. (2011). Guiding the creation of a comprehensive surface temperature resource for twenty-first century climate science in: *Bulletin of the American Meteorological Society* **92.**

Velden C, Harper B, Wells F, Beven JL, Zehr R, Olander T, Mayfield M, Guard C, Lander M, Edson R, Avila L, Burton A, Turk M, Kikuchi A, Christian A, Caroff P, McCrone P. (2006). The Dvorak tropical cyclone intensity estimation technique: a satellite-based method that has endured for over 30 years in: *Bulletin of American Meteorological Society* **87.**

Wheeler MC, Hendon HH. (2004). An all-season real-time multivariate MJO index: development of an index for monitoring and prediction in: *Monthly Weather Review* **132.**

WMO (2012). *WMO Statement on the status of the global climate in 2011,* WMO-No. 1085, World Meteorological Organization, Geneva.

'Where water is boss, the land must obey'

African proverb

Malaysian Borneo.
Image: Mark Ziembicki.

Chapter 3

Land and Water

Summary of land and water indicators

Indicator		The Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Land Degradation (% Land Area Degraded 1981-2003)		**28**	38	5	21	53	31	39	20	34	**16**	**20**
Agricultural Land* % (1980-2009)		**37-39**	39-41	41-47	58.8-59.1	24-31	54-56	47-50	26-29	55-45	**35 – 37**	**36-38**
Renewable Water**	Internal 10^9 m^3/year	**29,334**	5,084	146	1,012	5,128	93	877	9,994	1,104	**20,326**	**42,369**
	External 10^9 m^3/year	**22,043**	3,687	169	779	1,403	1	42	3,500	0	**4,127**	**11,418**

Red: Situation is deteriorating
Green: Situation is improving

* The sum of area that is temporary and permanent pasture, temporary and permanent crops, mark and kitchen gardens and temporarily fallow land (FAOStat 2013)

** The maximum theoretical yearly amount of water actually available (for human and environmental use). Internal renewable water resources are based on surface water run-off from rainfall and snow, as well as long term average groundwater that is recharged from rainfall and snow that falls within a nation's borders. External renewable water is water that flows in from outside a nation's borders (including the proportion of transboundary lakes) in rivers and underground aquifers.

Tropical ecosystems and human communities need productive, healthy land and clean water to achieve environmental and development goals. Land degradation and misuse of water resources are common issues across the globe. Most of the world's renewable water resources are found in the Tropics, where pressures on the resource are increasing at a rapid rate. The impacts of climate change along with rapid population growth, and industrial and agricultural development will increasingly threaten finite land and water resources into the future.

There is a balance between preserving natural ecosystems and having enough land and water to provide food, shelter and industry for human communities. Humans are often in direct competition with natural ecosystems for land and water resources, most of which are used for large scale production of food and other consumable products. Given the vast area of land now used for agriculture and other human activities, land use and management must be included in any discussion of tropical ecosystems.

Headline indicator

Land degradation

Land degradation affects the integrity and functioning of ecosystems and, along with climate change and biodiversity loss, is a major threat to the environment, economies and society. It is caused by a number of factors including poor agricultural practices, deforestation, overgrazing and industrial activity.

Supplementary indicators

Agricultural land

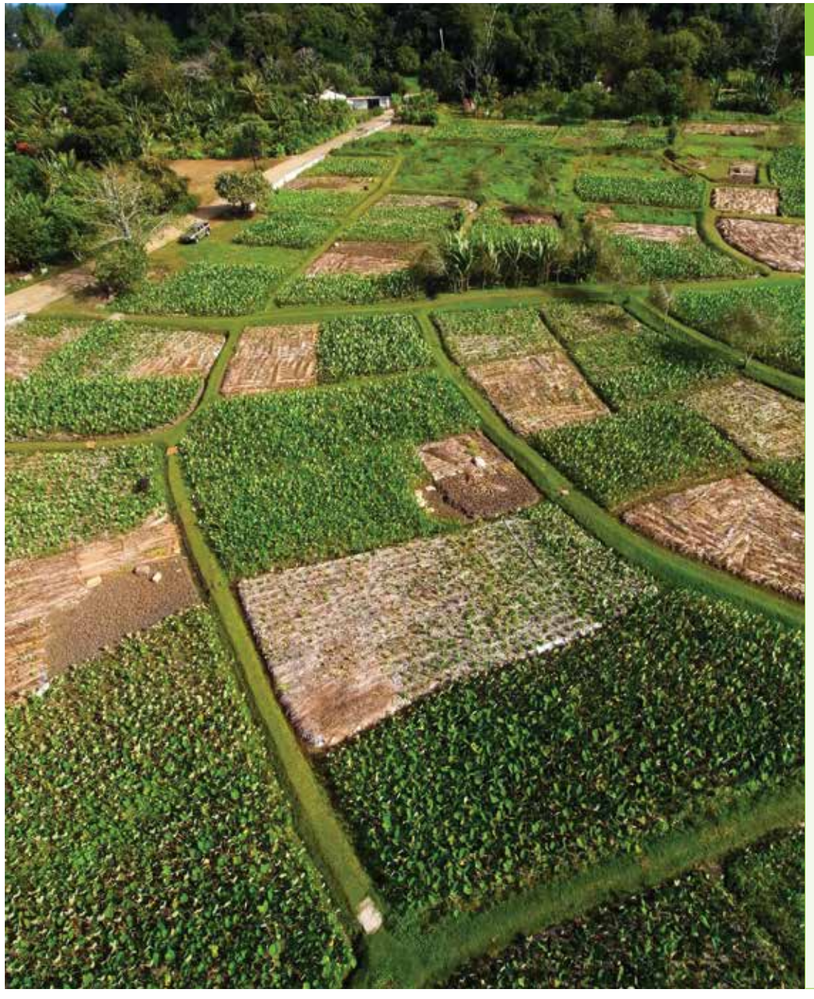
All nations rely on agriculture for the majority of their food production and, increasingly, as a source of energy. Agricultural land is capable of producing food and other plant and animal products for local human populations and trade. As populations increase, demand for more agricultural land, and more productivity from existing agricultural land will rise.

Renewable water resources

The state of the hydrological cycle and water quality are major factors contributing to ecosystem health and human wellbeing. The amount of water available for ecosystems and human society is limited to only 0.3% of total water on Earth. Renewable water refers to the proportion of this available water that is regularly replenished. Efficient and sustainable use of this resource is critical for the maintenance of ecosystem services and sustainable development.

Links to other dimensions

Protected areas, aquaculture, mangroves, health, economic output, biodiversity.



Taro fields, French Polynesia. Image: Pierre Lesange.

Is it getting better?

Land degradation

Nearly a third of all land in the Tropics became degraded between 1981 and 2003 compared to the global average of 20%. South East Asia had the greatest area of land degradation at 53%. Deforestation followed by poor agricultural practices were the major causes of land degradation in the Tropics. Water erosion is considered the main type of damage to land in the Tropics and in the Rest of the World.

Agricultural area

Although the amount of land used for agriculture increased by only 2% in the Tropics between 1980 and 2009, productivity of that land has increased dramatically. For example, livestock production increased by 89% for cattle/buffalo and 44% for sheep and goats compared with much more modest growth in the Rest of the World (3% and 4% respectively). Total cereal production in the Tropics has more than doubled in that time but still lags the Rest of the World in terms of both tonnage and yield.

Renewable water resources

The Tropics has just over half of the world's renewable water resources (54%) of which a quarter is generated outside national borders. Despite this, almost half of the tropical population was considered vulnerable to water stress in 2010.

Current water use patterns are considered unsustainable in many regions. Agriculture accounts for 81% of water withdrawals in the Tropics compared with 69% globally. Although tropical rivers are on average less polluted than those in the Rest of the World, there is large regional variation with South East Asia having the highest pollution discharge in the world.

Land degradation

The United Nations defines land degradation as "the long-term loss of ecosystem function and services, caused by disturbance from which the system is unable to recover unaided" (UNEP 2007). It may be caused by a number of factors, often acting in combination, including deforestation, poor agricultural practices, overgrazing and industrial activities (Van Lynden & Oldeman 1997, Lambin et al. 2003, Zika & Erb 2009).

Land degradation ranks with climate change and biodiversity loss as a major threat to the environment, economy and society. (UNEP 2007). It can interrupt biological cycles with ecological, economic and social impacts which may in turn further reinforce poor land use practices (UNEP-GEF 2006). Indeed, unsustainable land use is a key driver of degradation (Maitima et al. 2009). Land degradation affects a large proportion of the world's land mass, affecting as much as a third of the world's population, with a disproportionate impact on poor nations.

The primary types of land degradation include wind and water erosion, soil acidification, loss of soil fertility, compaction, salinisation and loss of soil carbon (WMO 2005). However, the wide and complex range of physical and chemical processes associated with land degradation can make it difficult to accurately measure and identify the source of land degradation, especially at regional and global scales. Inherent difficulties in isolating the effects of spatial and temporal variability in climate and rainfall also complicate measurement (see Box 3.1).

Trends

The extent of land degradation that occurred between 1981 and 2003 is assessed here using remote sensing techniques to estimate changes in the net primary productivity of soil after controlling for a range of key factors such as changes in rainfall and urbanisation. The data do not take into account soil degradation that occurred prior to 1981. Box 3.1 provides details on the methodology.

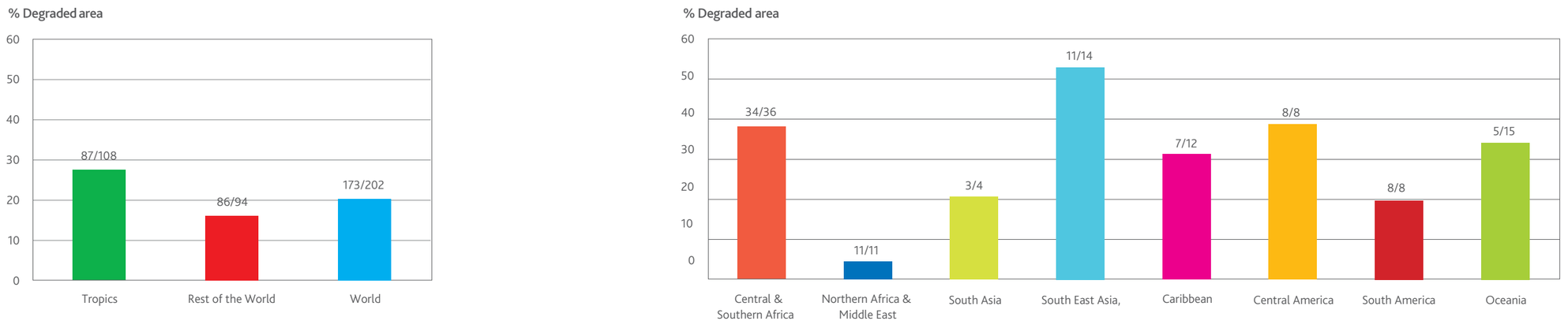
Globally an additional 35 million square kilometres of land was degraded between 1981 and 2003, or around 20% of the global land mass, although not all nations experienced measurable degradation (Bai et al 2008a). Relative to 1981, by 2003 an additional 28% of the Tropics' land mass was experiencing land degradation, compared with 16% for the Rest of the World (see Figure 3.1).

Of the tropical regions South East Asia had the greatest proportion of its land area degraded over this period (53%) with 11 of its 14 nations registering increases in area of degraded land. Central & Southern Africa recorded degradation across an additional 38% of its land area, with all but two of its nations experiencing notable degradation (see Figure 3.1). In Central America an additional 39% of land was degraded, with all nations reporting some degree of degradation. Northern Africa & Middle East had the lowest proportion of land degraded between 1981 and 2003, reflecting the large expanse of desert area across this region which has naturally low measurable NDVI and NPP, and limited change over time.

Globally, deforestation and poor agricultural practices are the two primary human-induced causes of land degradation. These practices result in water erosion and chemical contamination, the two main types of human induced land degradation. In the Tropics deforestation was identified as the major cause of land degradation, being a key factor in land degradation in 57 of 80 nations. Poor agricultural practices were a major factor in 31 nations (see Table 3.1). In contrast, agriculture is the leading cause of land degradation in the Rest of the World (59 out of 85 nations) compared with deforestation in 46 nations (see Table 3.1).

Figure 3.1

Change in area of degraded land (% of land mass), 1981 to 2003*



Source: Bai et al (2008b), State of the Tropics project.

* Land degradation is assessed using RUE-adjusted NDVI. Numbers above bars represent number of nations for which the area of degraded land increased/ total number of nations in each region. Urban areas and inland waterways are excluded from the analysis.

Across the Tropics deforestation was the primary cause of human induced degradation in all regions except Northern Africa & the Middle East, where it was overgrazing. In South America and Oceania overgrazing was the second most frequent cause of land degradation, while for all other tropical regions poor agricultural practices were the second most frequent cause.

Globally, water erosion is the main type of land degradation followed by chemical contamination (e.g. soil acidification, increased sodicity, salinisation and other chemical alterations to soil quality (WMO 2005)). In Northern Africa & the Middle East wind rather than water erosion was the most common type of land degradation.

Causes and effects

Land degradation has a significant impact on the global and human environment through climate change and biodiversity impacts (see Box 3.2), damage to fresh and marine water systems and increases in persistent organic pollutants (UNEP–GEF 2006). Although erosion and other soil changes can be natural processes, accelerated losses are often due to poor land management practices. The footprint of these impacts frequently extends well beyond the immediate area of degradation with downstream (or downwind) effects including eutrophication, sedimentation and infrastructure damage (WMO 2005). Since 1960, eutrophication associated with land degradation and deforestation has resulted in more than 245,000km^2 of coastal harbours and waters becoming hypoxic, or biological dead zones (Diaz & Rosenberg 2008).

Land degradation can be both a cause and a consequence of poverty, with flow on effects to social structures. The lack of economic resilience in many communities on marginal agricultural lands contributes to the complicated issue of resource and land use sustainability (see Box 3.3); with much of the land degradation in these regions driven by short-term needs for food and shelter (Kates & Haarmann 1992). A series of case studies across Asia, Africa, Central and South America revealed that land degradation reduced agricultural output by 3 to 7% of GDP, with strong links between poverty and land degradation across all regions (Berry et al. 2003).

Variability in factors like soil cover and type, population density and rainfall mean that some land areas are more vulnerable to degradation than others. Drylands cover 40% of the global land area and are particularly vulnerable to degradation due to low and variable rainfall, high transpiration rates and high temperatures (Safriel & Adeel 2005, Zika & Erb 2009). This is reflected in highly variable spatial and temporal vegetation cover which makes monitoring dryland degradation particularly complex (Lepers et al. 2005, Middleton & Thomas 1992). Despite this vulnerability drylands support

one-third of global agriculture (Zika & Erb 2009), though for many regions and particularly in Asia, desertification and top soil loss are major issues (Lepers et al. 2005).

Many community-based programs in sub-Saharan Africa use soil and water conservation techniques that integrate local technologies and adaptive management (UNDP 2012). For example, in Namibia community-based solutions include rotational grazing and herd culls at the start of dry seasons to reduced pressures on pastures (WRI et al. 2011). Likewise, many developed nations recognise the importance of community-based natural resource management programs, and integrate them as key aspects in national land care policy (see Box 3.4).

Looking forward

Land degradation is a major global issue with environmental, social and economic impacts. As with many environmental indicators, increasing pressures from population growth, climate variability and poor management practices are increasingly affecting land productivity. Efforts to address land degradation in the Tropics will require integrated approaches that recognise and address poverty, degradation, resource use and climate change.

To this end the United Nations Conference on Sustainable Development (Rio+20) recognised the urgent need to reverse land degradation and to achieve a 'land-degradation-neutral' world (UN 2013). The United Nations Convention to Combat Desertification also has a goal of Zero Net Land Degradation, with a provisional target date of 2030 (UNCCD 2012). Any strategy will need to integrate local and regional land use variability into monitoring programs to ensure accurate and reproducible measures of success.

Box 3.1 Measuring land degradation

A significant challenge associated with monitoring land degradation is the difficulty in accurately assessing regional and global changes over time. However, advances in remote sensing technology offer opportunities to develop reproducible global scale measures of land productivity and degradation (Zika & Erb 2009, Lepers et al. 2005). One technique that has been developed is the Normalised Difference Vegetation Index (NDVI) which is used to estimate net primary productivity (NPP).

NPP is a measure of net change in carbon content in vegetation and can be used as a simple indicator of land degradation. Decreases in NPP indicate reduced plant growth and health, and can be interpreted to imply reduced soil quality, while increases in NPP represent an improvement (Bai et al. 2008a).

Changes in NPP can arise from both natural and human induced activities. Seasonal climatic variations produce natural changes in productivity across landscapes, and droughts are an extreme climatic event which will lower NPP. Consequently, methods have been developed to discriminate between natural change in NPP and change associated with human induced land degradation. One such technique is the Rain Use Efficiency (RUE)-adjusted NDVI which compensates for changes in rainfall on NPP and allows a better estimate of human induced change (Bai et al 2008a, Prince et al. 1998). With this technique a negative trend in RUE-adjusted NDVI is interpreted as degradation.

Whilst these approaches provide a useful method for assessing land degradation, they have their limitations (Bai et al 2008a, Wessels et al. 2007, Wessels et al. 2012). RUE-adjusted NDVI is a useful proxy measure of land degradation but it does not accurately discriminate between true land degradation and land use change (e.g. forest to agriculture). The coarseness of resolution (>1km) for many remote sensing data sets means that fine scale change is often difficult to identify and for many applications the utility lies in national or global change patterns rather than absolute measures at local scales (Nielsen & Adriansen 2005). Notwithstanding these limitations remote sensing is currently the most effective and reproducible method for monitoring land degradation at regional, continental and global scales.

Zorro villiage, Burkina Faso. Image: Ollivier Girard CIFOR.

Image: Sam Beebe.

Box 3.2 Land degradation and climate effects

Land degradation has a direct influence on people's lives through productivity losses and desertification. Although the local processes directly linking land degradation and human impacts are well known, many of the global connections are less well understood. Research has demonstrated that land degradation can significantly affect local and regional nutrient and water cycles, biodiversity, global carbon sequestration and, as a result, climate (Lambin et al. 2003, UNEP-GEF 2006).

Land degradation is a result of multiple drivers, both human and biophysical. In Africa it is estimated that more than 60% of land degradation risks are a result of climatic stresses such as variable soil moisture, moisture stress, and high soil temperatures (WMO 2005).

The combination of these stresses and poor land management practices can result in increased degradation, and exacerbate the impacts of droughts and large-scale meteorological phenomena like the El Niño Southern Oscillation and North Atlantic Oscillation (WMO 2005).

Vegetation loss can be both a cause and a consequence of land degradation. For example, loss of vegetation can drive a feedback process through decreased evaporation and increased albedo (radiation reflection to the atmosphere) which reduces cloud formation (WMO 2005).

This in turn can lead to reduced rainfall, further compounding vegetation loss and lower evaporation. These effects can be felt well beyond the immediate area of impact, as has been the case with deforestation in the Amazon Basin (WMO 2005).

Looking forward, modelling suggests that a doubling of global carbon dioxide concentrations could increase the area of global desert by 17% (WMO 2005). This is in addition to increased risk of degradation due to changes in rainfall patterns and intensity.

Box 3.3 Land degradation, poverty and environmental refugees

Land degradation is a key factor in economic and social poverty, affecting up to 1.5 billion people worldwide. For many subsistence farming communities agriculture is undertaken on poor quality soils that are particularly vulnerable to degradation.

When drought occurs or crops fail, those families that do not have the economic resilience to remain within the community are displaced as environmental refugees (Lonergan 1998, Myers 2002). Such displacements may have national or international destabilising effects due to sudden changes in population densities, numbers and the need for humanitarian aid (Lonergan 1998).

In 2000 and 2011, the combination of drought and conflict in the Horn of Africa caused the displacement of more than two million people as environmental refugees (Myers & Kent 2001, OCHA 2011). A further 10 million people were severely affected by the drought without being displaced (OCHA 2011). Multiple factors influenced these crises, though long term land degradation is recognised as affecting both the environment and human capacity to respond to these events (Myers 2002, Raleigh 2011).

International aid efforts may alleviate the worst effects of drought and famine, but can only ever address the immediate crisis (Myers & Kent 2001). More effective, longer term national and regional land management solutions are required to mitigate the compounding effects of extreme climatic events and land degradation on human populations.

Kenya. Image: USAID.

Box 3.4 Innovation in addressing land degradation

Increasing recognition that land degradation is a key issue for economic and environmental well-being is leading to some innovative approaches to address the problem (Alexander & Nelson 2003, ALI 2012, Fernendez-Gimenez et al. 2008). In 1986 both the Australian 'Landcare', and German 'Landschaftspflegeverbände' were established as bottom-up collaborative programs for sustainable land use management. Since then, the Landcare initiative has been exported to more than 20 nations as a community-based model for improved land management and remediation of land degradation (Catacutan et al. 2009). It has become one of the most successful sustainable land management programs in the world, with a locally-driven but globally-supported framework.

Growing concerns over increases in greenhouse gas emissions are also prompting a rethink on alternative uses of marginal agricultural lands. The 'Carbon Farming Initiative' is an Australian program that promotes revegetation of these lands to bind carbon (Barbier 2012). The program is considered a model for other nations to manage land degradation and store carbon while generating an income for communities on marginal agricultural land.

Revegetation nursery. Image: Mark Ziembicki.

Table 3.1 **Dominant causes and types of human induced land degradation**

		Primary causes of Degradation		Primary degradation types	
Region	**Number of nations reporting**	**Cause**	**Number of nations**	**Type**	**Number of nations**
Tropics	**80**	**Deforestation** **Agriculture**	**57** **31**	**Water erosion** **Chemical contamination**	**68** **29**
Central & Southern Africa	31	Deforestation Agriculture	22 12	Water erosion Chemical contamination	26 8
Northern Africa & Middle East	11	Overgrazing Agriculture/ Deforestation	11 2	Wind erosion Water erosion	9 7
South Asia	3	Deforestation Agriculture	3 3	Water erosion Chemical contamination	3 3
South East Asia	10	Deforestation Agriculture	10 7	Water erosion Chemical contamination	10 6
Caribbean	6	Deforestation Agriculture	6 2	Water erosion Chemical Contamination/ Physical Deterioration	6 1
Central America	8	Deforestation Agriculture	6 5	Water erosion Chemical contamination	7 5
South America	8	Deforestation Overgrazing	6 4	Water erosion/Chemical Contamination Physical deterioration	6 2
Oceania	3	Deforestation Overgrazing	2 1	Water erosion	3
Rest of the World	**85**	**Agriculture** **Deforestation**	**59** **46**	**Water erosion** **Chemical contamination**	**70** **37**

Source: Bot et al 2000 (based on GLASOD survey), State of the Tropics project.
Note: Cause and type of land degradation is assessed at the national level. As nations may report more than one primary cause and/ or type of degradation, the regional aggregation of primary causes and types may be greater than the number of nations.

Agricultural land area

All nations rely on agriculture for a large proportion of food production and, increasingly, as a source of energy. In the late 1800s the economist Thomas Malthus suggested that agricultural production was a major constraint on population growth. However, the increase of land available to agriculture, coupled with improvements in productivity, have seen agricultural output outpace population growth, especially since the 'Green Revolution'[2] that commenced in the mid-20th century. The Green Revolution has contributed to a significant reduction in the proportion of the global population that is undernourished. Its impacts, however, have not been universal. In Africa, for example, the benefits of improved agricultural technology and techniques have often lagged behind other parts of the world.

Historically increased agricultural output was linked to increased cultivated area, but since 1960 cultivated area has increased by only 10% while production has almost doubled. This increase in intensity of land use has come at the cost of greater use of other resources. For example, the use of exploitable, renewable freshwater for agriculture increased from around 10% in 1950 to 30% by the late 1990s (Shiklomanov 2000). Since the start of the Green Revolution there has also been rapid growth in the use of fertilisers and pesticides.

Although the increase in agricultural land since 1960 has been relatively modest, most of this additional land has come at the expense of intact tropical forests (Gibbs et al. 2010). That is, agricultural expansion has, and continues to be, a major driver of tropical deforestation. Deforestation has significant impacts on natural ecosystems that provide locally and globally important services such as carbon storage, hydrological cycles and biodiversity. While some biodiversity may be maintained on land used for food production, most biodiversity, especially in the Tropics, requires relatively undisturbed habitats (GO-Science 2011).

The global population is expected to increase by almost 30% by 2050 and consumption patterns are changing. Meeting the food, fodder and energy requirements of an increasingly affluent global population without further undermining environmental systems is a crucial challenge (Mueller et al. 2012). More integrated approaches to conservation and food security will be required if the objectives of sustainable development and a healthy environment are to be achieved.

Trends

Agricultural land includes temporary and permanent pasture, temporary and permanent crops, market and kitchen gardens and temporarily fallow land[3]. Globally, the area of agricultural land increased at a rate of 0.3% per annum between 1961 and 1994, whereupon it was relatively stable until 2001 before declining modestly to 2010. It is estimated that from 1980 to 2010 the area of agricultural land increased by 1,150,000km^2 (6.5%) in the Tropics, and by 1,170,000km^2 (4.0%) in the Rest of the World (see Table 3.2). In 2010 there was an estimated 18.9 million square kilometres of agricultural land in the Tropics, representing 38.9% of its land area (up from 36.5% in 1980), while in the Rest of the World there was 30.1 million square kilometres of agricultural land, representing 36.9% of its land area (up from 35.3% in 1980).

Of the tropical regions, South Asia has the highest proportion of land area classified as agricultural (61% in 2010) (see Figure 3.2). At the other end of the spectrum, 27% of land in South America is classified as agricultural, and in South East Asia the proportion is 32%. Northern Africa & the Middle East reports the largest increase in total agricultural land area between 1980 and 2010, with an additional 510,000km^2 under agricultural production (a 14% increase), with particularly large increases in Mali, Niger and Sudan. Other regions with large increases were South East Asia (370,000km^2 a 32% increase), South America (360,000km^2 or 12%) and Central & Southern Africa (320,000km^2 or 6%). Oceania was the only region to experience a decline in agricultural land area with a fall of 460,000km^2 (-21%) to 1.8 million square kilometres. The majority of this decline occurred in the pastoral lands of tropical Australia.

Increases in the area of agricultural land have been relatively modest in most regions over the past 30 years, but there have been significant increases in agricultural output in terms of both livestock holdings and cereal production, including in the Tropics (see Figure 3.3).

Although weather and drought conditions will affect year-to-year production, there is a clear shift to more agricultural production occurring in the Tropics. Between 1980 and 2010 cattle/buffalo holdings in the Tropics increased by 46%, and sheep/goat holdings by 99%. In comparison, over the same period, cattle/buffalo holdings in the Rest of the World increased by 2%, and sheep/goat holdings by 10% (see Figure 3.3). In 1980, there were 770 million head of cattle/buffalo in the Rest of the World, compared with 565 million in the Tropics. By 2010, cattle/buffalo numbers in the Tropics exceeded those in the Rest of the World (830 million and 790 million respectively). Globally, almost 95% of the increase in cattle/buffalo holdings occurred in the Tropics.

In the Tropics, South America has had the greatest increase in cattle/buffalo production since 1980, with the number increasing by 104 million to 245 million head in 2010 – an increase of 74% and accounting for 37% of the total global increase in holdings. Other tropical regions to report large increases in cattle/buffalo holdings are Central & Southern Africa (an additional 66 million head, or a 61% increase), Northern Africa & Middle East (39 million, 90%), South Asia (26 million, 15%) and South East Asia (22 million, 45%). Increases were more modest in Central America and Oceania, while in the Caribbean there was a slight decrease in cattle/buffalo numbers.

For sheep/goats the greatest increase in holdings in the Tropics since 1980 was in Central & Southern Africa, with an additional 190 million head to 315 million (154% increase). Other regions with major increases were Northern Africa & Middle East (an additional 116 million, or 99%), South Asia (75 million, 83%) and South East Asia (24 million, 132%). Oceania recorded a drop in sheep/goat numbers of almost four million, or a reduction of 60% on 1980 levels, driven by changes in Australia.

The vast majority of the world's cereal production is in the Rest of the World, although there has been a shift to greater production in the Tropics from 17% in 1980 to 24% in 2010. Between 1980 and 2010 cereal production in the Tropics increased by 340 million tonnes (131%) to almost 600 million tonnes. Over the same period cereal production in the Rest of the World increased by almost 600 million tonnes, to 1,880 million tonnes in 2010, an increase of 46%. With the exception of the Caribbean and Central America, each of the tropical regions more than doubled cereal production in the 30 years to 2010. The biggest increases were in Central & Southern Africa with an increase of 173% to 96 million tonnes, Northern Africa & Middle East with an increase of 159% to 21 million tonnes, and South East Asia with an increase of 153% to 243 million tonnes.

Compared with the Tropics, increases in cereal yield (harvested production per unit of harvested area) in the Rest of the World were slightly higher between 1980 and 2010, at 73% versus 67%, although yields in the Tropics are significantly below that of the Rest of the World (see Figure 3.3). In 2010 the cereal yield in the Rest of the World was almost 60% higher than in the Tropics, up from around 50% higher in 1980. That is, the benefits of improved technology and production methods is having a greater impact in the Rest of the World, with more land under cereal crops being the major factor driving increased production in the Tropics. The harvested cereal area in the Rest of the World decreased by 16% from 550 million to 460 million hectares in the 30 years to 2010, while in the Tropics it increased by almost 40% to 230 million hectares. In the

Table 3.2 **Agricultural land***

	1980	1985	1990	1995	2000	2005	2010	Change (1980 to 2010)	
								Area	%
Tropics	**17.7**	**18.0**	**18.3**	**18.5**	**18.6**	**18.8**	**18.9**	**1.15**	**6**
Central & Southern Africa	5.6	5.6	5.7	5.5	5.6	5.8	5.9	0.32	6
Northern Africa & Middle East	3.7	3.7	3.9	4.0	4.1	4.2	4.2	0.51	14
South Asia	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.01	1
South East Asia	1.1	1.2	1.3	1.3	1.4	1.4	1.5	0.37	32
Caribbean	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.00	2
Central America	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.05	7
South America	3.1	3.2	3.3	3.5	3.4	3.5	3.5	0.36	12
Oceania	2.3	2.3	2.1	2.2	2.1	2.0	1.8	-0.46	-21
Rest of the World	**28.9**	**29.4**	**30.0**	**30.7**	**30.8**	**30.4**	**30.1**	**1.17**	**4**
World	**46.6**	**47.4**	**48.3**	**49.2**	**49.3**	**49.2**	**48.9**	**2.32**	**5**

Source: FAOStat (2013), State of the Tropics project.
*million km^2

[2] The "Green Revolution" refers to the rapid increase in agricultural outputs in the 20th century, driven by advances in the sciences, substantial public investments and policy support for agriculture.

[3] FAO defines agricultural area as the sum of areas under (a) arable land - land under temporary agricultural crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow. Abandoned land resulting from shifting cultivation is not included in this category; (b) permanent crops - land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee); land under trees and shrubs producing flowers, such as roses and jasmine; and nurseries (except those for forest trees, which should be classified under "forest"); and (c) permanent meadows and pastures - land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

Tropics the greatest improvements in cereal yields have been in South America (by 125% to 3.8 tonnes per hectare), South Asia (by 99% to 2.8 tonnes per hectare) and South East Asia (by 83% to 4.0 tonnes per hectare). The Caribbean was the only tropical region to report a fall in the cereal yield over this period, falling by 15% to 1.6 tonnes per hectare. Nonetheless, relatively low yield growth in Central & Southern Africa and Northern Africa & Middle East – which account for 40% of the harvested area in the Tropics – has acted to constrain yield growth for the Tropics as a whole.

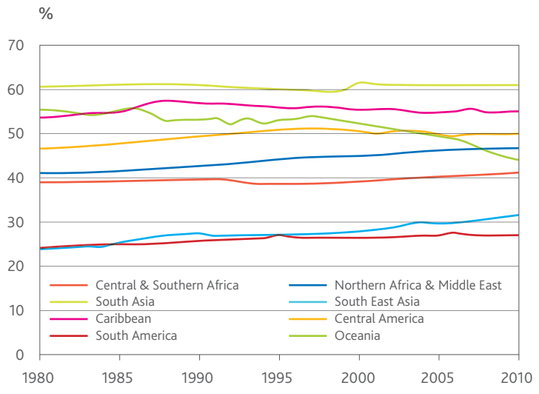
Issues

While improvements in agricultural productivity over the past 60 years may have limited the expansion of agricultural land into forests and other habitats to an extent, improvements in productivity have also had other significant environmental consequences. These impacts include changes in land use and increased land degradation, increased allocation of finite resources to agriculture (with diminishing returns), and climate change impacts. For human society, increased competition between the food and non-food agricultural sectors is contributing to food security and affordability issues in many societies.

Globally, most of the increase in agricultural area since 1980 has been due to the conversion of forests to agricultural land for either cropping or livestock (Gibbs et al. 2010). The net change in forest area to agricultural cropping is estimated at 45,000km^2 per year, and there are further losses associated with the conversion of forests to woodland/ grassland for livestock (Holmgren 2006). It is also estimated that 16,000km^2 of agricultural land is converted to urban uses each year. Much of this land is often prime agricultural land on the urban fringe.

Unsustainable agriculture is also a leading cause of land degradation (see Land Degradation) and, along with deforestation, poor agricultural practices are a major cause of land degradation globally, contributing to the loss of around 20,000km^2 of agricultural land each year.

Figure 3.2 **Agricultural land area in the Tropics***



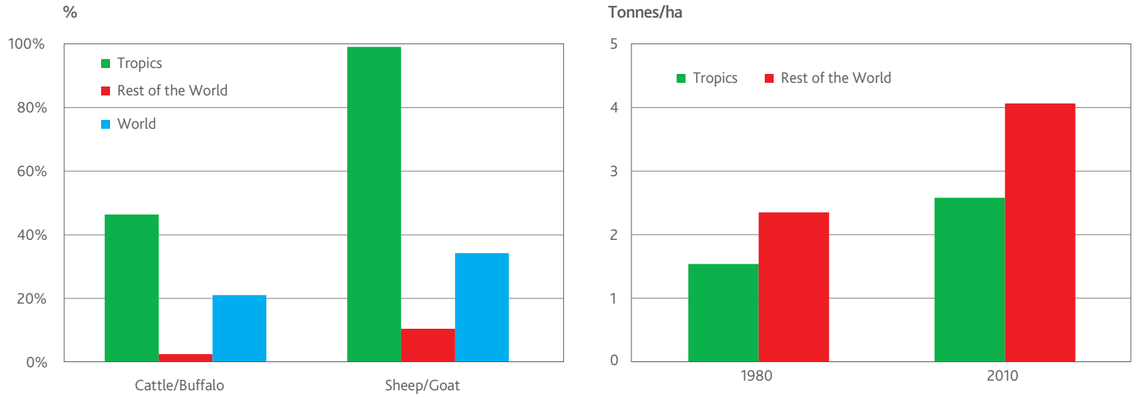
Source: FAOStat (2013), State of the Tropics project.
*Percentage (%) of total available land

With respect to resource allocation, much of the improvement in agricultural productivity has been associated with increased irrigation and greater use of inorganic fertilisers (Nellemann et al. 2009).

Despite our dependency on irrigation for agriculture, the relative share of global water supplies for the agricultural sector has been decreasing over time as demand for municipal and industrial uses has increased more rapidly (Shiklomanov 2000). Nevertheless, agriculture still accounts for around 70% of water use, and total withdrawals across all sectors have been increasing rapidly. Even before considering changing food consumption patterns, more water will be needed to produce food for a growing human population. Less than 30% of global cultivated land is irrigated, but already around 15-35% of global irrigation withdrawals are estimated to be unsustainable (MEA 2005), with impacts on ecosystem health in affected areas.

Increased fertiliser use has also been important in improving agricultural productivity, especially in high-income and rapidly developing nations. Since the 1960s fertiliser consumption has increased by a factor of four, but inappropriate and excessive use is having many environmental impacts. Aquatic ecosystems are particularly affected where nutrient enrichment creates eutrophic and biological dead zones (Nellemann et al. 2009). Recent research suggests there is significant scope to reduce the environmental impacts of agriculture by eliminating nutrient overuse while still allowing for considerable increases in production (Mueller et al. 2012). The supply of many inorganic fertilisers is also finite, and costs have increased significantly recently, and are expected to remain high in the longer term. In the absence of improved farm management practices, higher fertiliser prices combined with the impacts of water scarcity and land availability could constrain future opportunities to increase agricultural productivity (OECD/FAO 2012).

Figure 3.3 **Change in livestock numbers and cereal yield between 1980 and 2010**



Source: FAOStat (2013), State of the Tropics project.

Despite agricultural production increasing at a faster rate than population over the past 60 years, an estimated 12% of the world's population (870 million) is chronically undernourished (FAO 2012a). Although this proportion is declining, the extent of the problem at any given time is influenced by factors such as economic and weather conditions and, ultimately, food availability and prices.

Except for during the 1973-75 food crisis, in the 40 years to 2003 the FAO Food Price Index (FPI)[4] of real food prices trended downwards (FAO 2011). However, the trend has reversed since 2003 and there was a significant increase in 2007-08. Several factors are contributing to this trend but the increase in production of biofuels – often supported by government subsidies – is recognised as a major cause (Mitchell 2008). Especially in 2007-08, other factors such as higher energy-related input costs, drought, inventory rundowns, export bans and speculative activities have also played a role, but many of these impacts were the result of, or exacerbated by, increased biofuels production.

Looking forward, the FPI is likely to continue to increase which will have flow on effects for global undernourishment. Concerns are now being expressed that the decline in real agricultural commodity prices is over, along with the era of affordable access to food (Pardey et al. 2012). There is no evidence that small-scale agriculture producers are benefitting from this increase in prices.

Despite a significant proportion of the world's population remaining undernourished, competition between agricultural food and non-food production will continue to potentially exacerbate the problem. The main non-food competitors are biofuel production, cotton production and feedstock supplies to meet changing food consumption patterns. With biofuels, concerns regarding greenhouse gas emissions and declining oil reserves are seeing large shifts in agricultural production towards bio-ethanol and bio-diesel production, which has been a major contributor to sharp price increases for some agricultural staples (see Box 3.5).

Meat production is increasing due to changes in diets, particularly in rapidly growing developing economies and future demand is expected to outstrip supply (FAO 2002). This will further increase pressure on agricultural land, though it may be partly offset by the intensification of livestock production (FAO 2002). However, while intensive, industrialised livestock farming requires less land for stock it requires large quantities of feedstock grain which requires more land. In addition, intensive livestock farming produces large quantities of organic wastes and greenhouse gas emissions which can be difficult to manage.

Benefits/utility

Agricultural production and economic development are intrinsically linked. Historically,

[4] The Food Price Index (FPI) is calculated using international prices for cereals, oils, dairy, meats and sugar.

Box 3.5 Biofuels

Demand for biofuels is increasing, reflecting concerns about the future of fossil fuel supplies and their contribution to anthropogenic climate change. Many nations are keen to develop biofuel industries to improve national energy security, as well as take advantage of other economic and environmental benefits (Peskett et al. 2007).

Responses to the development of the biofuels industry have been divided. Supporters of the industry see it as mitigating greenhouse gas emissions and providing alternative economic opportunities and security for poorer regions. Detractors suggest that biofuel production is occurring at the expense of food production (Peskett et al. 2007), which is affecting food supply, prices and security, with disproportionate impacts on the poor.

Like all activities, biofuel production has costs and benefits and tends to have both 'winners' and 'losers'. For crops that have lost traditional markets or are in excess supply, biofuel production can benefit both local and national economies. Similarly, the use of agricultural waste for biofuel production can be beneficial. But shifts in agricultural production to meet international energy demand at the expense of local or national food demand can have significant costs in the form of food shortages and commodity price increases, with associated impacts on human wellbeing.

For example, in the Caribbean, sugar cane that was once destined for overseas markets is now used to produce biofuels following declines in European sugar imports (Peskett et al. 2007). This has supported farm incomes and provided a degree of income and industry diversification.

In contrast, in Brazil and the United States, the switch from food crops such as soya bean and wheat in the 1980s to bio-ethanol crops such as sugar cane and corn resulted in the production of fewer staple food crops and led to price increases (Rathmann et al. 2010). On the positive side though, a number of biofuel programs are targeting marginal or degraded agricultural lands, although the long-term viability of many of these programs remains uncertain (FAO 2008, Koh & Ghazoul 2008).

Increases in land area dedicated to biofuel crops will inevitably entail losses of existing agricultural land used to produce food, or an expansion of the agricultural footprint into forests, woodlands and grasslands. From an environmental perspective, and especially in the Tropics, the conversion of primary and secondary forests to farmland can lead to significant biodiversity loss and community displacement. The increase in palm oil plantations in South East Asia is an informative example. It is estimated that 55-59% of oil palm expansion in Malaysia and Indonesia occurred in forest areas (Koh and Ghazoul 2008). While palm oil exports have contributed to economic growth, there have also been adverse social and environmental effects, particularly at the community level (Tauli-Copuz & Tamang 2007).

Oil palm plantation. Image: CIFOR.

Box 3.6 Sustainable farming

Historically most agriculture was sustainable; food scraps were recycled to feed livestock and livestock waste was used as fertiliser. This was functional because there were small populations to sustain. As populations increased and food production became increasingly modernised the sustainability of large-scale production processes decreased. Widespread availability of inorganic fertilisers and synthetic pesticides since the 19th century has made these products relatively cheap and accessible, contributing to significant improvements in agricultural productivity and food security. However, these practices have come with associated environmental costs.

Increasing recognition of the environmental impacts of many modern farming techniques combined with higher input costs has led to a small but growing movement among primary producers to more sustainable (or 'organic') agricultural methods (OECD/FAO 2012).

The basis of sustainable farming is improved land management practices (see Land Degradation), including reducing reliance on inorganic fertilisers and pesticides. Methods include no-till farming, crop rotation, the use of green manures and other practices that improve the retention of moisture and organic matter in soils and reduce erosion (Derpsch 2004; Huggins & Reganold 2008).

These methods can also increase carbon sequestration and reduce greenhouse gas emissions (Omonode et al. 2011). Compared with conventional farming, organic farming has been demonstrated to retain significantly higher organic content, have thicker topsoil depth and less soil erosion (Reganold et al. 1987). In the long term organic farming is therefore more effective at maintaining soil productivity, but yields are 5-34% lower depending on soil type, crop and farm practises (Seufert et al 2012).

Sustainable, organic farming can also benefit poor communities as it reduces the need for inorganic fertilisers and pesticides. It has been suggested that at a local level, sustainable/organic agriculture may be a realistic alternative to intensive agriculture within 30 years (FAO 2002), although a key trade-off will be improving yields to ensure the environmental benefits of these practices are not negated by a need for increased farmland at the expense of forests and biodiversity.

improvements in agricultural productivity have allowed labour to be released for other economic activities. Productivity improvements since the mid-20th century have also contributed to the significant alleviation of hunger in the world with the proportion of the global human population that is undernourished falling from 37% in 1969-71 to 12% in 2010-12 (FAO 2006, FAO 2012a). Much of the global undernourishment that persists today is due to distribution issues rather than any shortfall in agricultural production (Motes 2010).

An obvious benefit of improved productivity and production is improved food security, especially in developing nations (IFPRI 2002). South America, South East Asia and South Asia in particular have made enormous gains in agricultural productivity over the past 50 years, contributing to substantial reductions in the number of undernourished people in these regions. Modest productivity improvements have been made in sub-Saharan Africa but the number of undernourished people has increased in Central and Southern Africa, Northern Africa and the Middle East. The productivity improvements have been offset by high fertility rates, drought and conflict.

Although most of the international development focus is on rural farming, urban subsistence agriculture is also a key contributor to food security. It is estimated that between 10% and 70% of urban households in developing nations participate in urban agriculture to some extent (Zezza & Tasciotti 2010). Food produced is mostly for personal consumption and provides a degree of food security and dietary diversity for many of the urban poor (Holmer & Drescher 2005, Zezza &Tasciotti 2010). Urban agriculture projects can also assist with local economic development, social inclusion and urban environmental management (Veenhuizen 2006), with much of this production using sustainable farming principles (see Box 3.6).

Looking forward

Substantial progress has been made towards more productive use of agricultural land over the past few decades, though in many instances it has come at a cost to natural ecosystems, particularly in the Tropics. Looking forward, ongoing improvement in agricultural technology and techniques will need to continue if the demands of a larger and increasingly wealthy global population are to be met without significant additions to the stock of agricultural land, against a backdrop of climate change. This will require ongoing and increased investment in crop and animal science to improve productivity and resilience, and to improve our understanding of land and soil dynamics.

More sustainable and productive use of existing agricultural land, water, fertiliser and other inputs will need to be the focus of research and development in this sector. The greatest risks to sustainable use of agricultural land in the future include water availability, climate change and competition with the bio-energy sector. Rather than converting land not already used for agriculture, the rehabilitation of degraded land will be necessary to limit biodiversity and ecosystem services losses. Additionally, creating mechanisms that value natural ecosystems at the same scale as productive agricultural land will assist sustainable development in the Tropics, and will assist in constraining the loss of primary forests to agricultural activities.

Cattle herd, Victoria River, Northern Australia.
Image: Mark Ziembicki.

Coffee grower, YUS Conservation Area, Papua New Guinea.
Image: Mark Ziembicki.

King George Falls, Western Australia.
Image: Mark Ziembicki.

Renewable water resources

Water is essential for all human and ecosystem processes. Unlike many other natural resources, water is highly mobile and crosses geo-political boundaries. Freshwater constitutes only 2.5% of the total water resources on the planet; 69% of this proportion is in polar ice sheets and permanent snow cover and 30% is in underground aquifers. Only 0.3% is available as surface water (Shiklomanov 1993). Due to its mobility and ability to change state (from liquid to gas to solid), water is a difficult resource to catalogue and monitor.

Water availability at a national level can be difficult to define, as there are 263 river basins that either traverse or straddle a total of 145 national borders (Giordano & Wolf 2002). These international river basins hold around 60% of the world's freshwater surface flows and support almost 40% of the global population. Due to its unequal distribution water can be difficult to share equitably among and within nations. Tropical regions with monsoonal climates receive more rainfall than arid or temperate regions, while rainfall patterns determine water volumes and availability. For example, the Amazon River carries around 20% of the global freshwater runoff, while the entire area of continental Europe accounts for only 7% (Gleick 1993). Regardless of the unequal supply among nations, management and governance of water resources has implications for access to safe drinking water and for food production, and also for the provision of underlying ecosystem services such as erosion prevention and flood mitigation that support human wellbeing.

The 1992 Rio Summit recognised water as a finite and vulnerable resource, and developed a framework for the improved and sustainable management of freshwater resources across multiple users and sectors, including the environment (WWAP 2012). Water availability and security remain major issues facing many nations today and, looking forward, the combined impacts of climate change and population growth are expected to exacerbate issues surrounding sustainable management of renewable water resources in the future.

Trends

Data on renewable water resources are limited, and time series data are not available (see Box 3.7). Global renewable water resources[5] are estimated at 53,800 billion cubic metres, with nations in the Tropics accounting for 29,400 billion cubic metres (54%), and the Rest of the World 24,400 billion cubic metres (see Figure 3.4). At a national level the renewable water resource is the sum of internal and external renewable water resources (see Box 3.7). Internal resources primarily consist of rain, snow or groundwater within a nation, while external resources consist of cross-border river flows, trans-boundary lakes and regional underground aquifers. However, only a proportion of renewable water is actually available for human use. This portion is the 'exploitable' or 'potentially utilisable' renewable water resource. Globally it is estimated that only 9,000 billion cubic metres (17%) of renewable water resources are exploitable (WMO 1997, Molden et al. 2001). The unexploited proportion of renewable water resources is primarily accounted for in flood events and minimum long-term river flows (also known as base flows).

In the Tropics, South America has the largest regional renewable water resource at 13,500 billion cubic metres per year, which is almost 50% of all renewable water in the Tropics. South East Asia has the second largest resource at 6,500 billion cubic metres. The Caribbean has the smallest resource at 94 billion cubic metres, followed by Northern Africa & Middle East with 315 billion cubic metres.

Many nations rely on a large proportion of their renewable water supply being sourced from outside their borders. In the Tropics 25% of renewable water comes from outside national borders, while for the Rest of the World it is 17%, with the extent of dependency varying considerably across nations and regions. Of the tropical regions, Northern Africa & Middle East and South Asia have the largest proportion of renewable water coming from external sources at 54% and 44% respectively, with Oceania (0%), the Caribbean (1%) and Central America (5%) having the lowest dependency on external sources. Relying on external water resources does however entail additional supply risks, which are typically managed by the negotiation of formal or informal treaties (see Box 3.8).

From a human perspective, water scarcity is defined as less than 2,000 cubic metres of water available per person per year (FAO 2000). In 1962, 25 nations worldwide suffered water scarcity. By 2010 the number more than doubled to 54 nations (see Figure 3.5). In the Tropics the situation is even worse. The number of nations experiencing water scarcity more than tripled since 1962, from 8 to 26. By 2010, three of the eight tropical regions had at least half their nations experiencing water scarcity.

The statistics relating directly to the number of people affected are equally dire. Whereas less than 3% of the global population was estimated as vulnerable to water scarcity in 1962, by 2010 the number had increased to 39%. Again the proportional change in the Tropics is worse. Rapid population growth has seen a jump from 1% of the population affected in 1962 to almost 50% in 2010. This scarcity is most acute in South Asia, where more than 90% of the population are considered vulnerable, up from less than 1% in 1962. At 62%, Northern Africa & Middle East has the second highest proportion of population vulnerable to water scarcity in the Tropics, up from 18% in 1962.

In contrast, with a large renewable water supply, the nations of South America have no identified water scarcity issues (see Figure 3.4). Although both Central America and Oceania have relatively low renewable water resources, their small populations mean there is no identified water scarcity.

Water use by humans is primarily for agricultural, industrial and municipal purposes. Globally agriculture accounts for 69% of total water withdrawals each year, with industry using 19% and municipal demand 12% (see Table 3.3). Agriculture is the largest sectoral user of renewable water in both the Tropics (81%) and the Rest of the World (64%). In the Rest of the World industrial withdrawals have the second largest demand while in the Tropics municipal withdrawals are greater than industry (see Table 3.3). Global withdrawals from these three sectors are only around 7% of renewable water resources, but 43% of exploitable water.

In the Tropics the proportion of freshwater withdrawals that are for agriculture are particularly high in South Asia and Northern Africa & Middle East (both at 91%). South Asia also uses the greatest proportion of renewable water resources at 28% (see Table 3.3). South America and Oceania have the lowest impact on water resources, extracting less than 1% of renewable water annually. The Tropics uses around 4% of its renewable water compared with 11% for the Rest of the World. However, the unequal distribution of water resources among nations and regions still leaves much of the Tropics suffering chronic water stress.

Box 3.7 Data limitations and renewable water resources allocation

Data for national allocations of external renewable water resources are sourced from the Food and Agriculture Organization AQUASTAT database (FAO 2013), with estimates based on long-term rainfall. Internal renewable water resources are based on surface water run-off from rainfall and snow, as well as long-term average groundwater that is recharged from rainfall and snow that falls within a nation's borders. External renewable water refers to water that flows in from outside a nation's borders (including the proportion of transboundary lakes) in rivers and underground aquifers. Internal and external renewable water resources make up the total renewable water resource[5].

There are inherent difficulties in accurately measuring annual water resources in many nations, including spatial and temporal distribution (FAO 2013). This is likely to be the case until there is improved international cooperation and resourcing (World Water Assessment Programme 2012).

The AQUASTAT dataset does not identify the source of external water. As such, regional external water allocations and total water resources reported here include both intra- and inter-regional distributions. As such, at the regional level the reported data for these variables are likely to be overstated.

Image: World Bank Photo Collection.

Water use, scarcity and international water treaties

In the 20th century water use increased at more than twice the population growth rate and, in some areas, reliable access to water is now limited or non-existent (FAO 2012b). The combination of population growth, economic development and, urbanisation and pollution are placing increased pressure on water resources (FAO 2012b, WWAP 2012).

Some 40% of the world's population live in the 263 major river and lake basins shared by more than one nation, with around two billion people also dependent on more than 300 transboundary groundwater aquifer systems (Giordano & Wolf 2002, UN-Water 2008). Water security is critical to each nation's ongoing viability, and this security can be problematic for nations that rely on external sources. Globally there are around 300 trans-boundary water agreements

[5] Defined by the FAO as the maximum theoretical yearly amount of water actually available (for human and environmental uses).

which secure water supply rights among nations (Jagerskog & Phillips 2006).

As water scarcity (and the risk of water scarcity) increases, greater efforts are being made to improve water-use efficiency. Many of these efficiencies have been in agriculture – the largest sectoral user of water. With the global population set to increase by around 30% by 2050 it is estimated that cereal production will need to increase by around 45% and meat production by 75% to meet demand (Alexandratos & Bruinsma 2012). Significantly more water will be required to meet these increasing demands. Water-related productivity gains have been achieved through developing more water efficient plants, improving agricultural practices and increased investment in water saving infrastructure (Gonzalez-Valero & Chevion 2011, FAO 2012b).

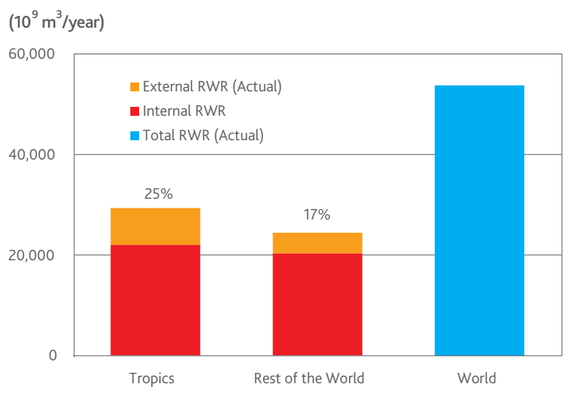
Even where national water resources are considered sufficient, uneven distribution can mean that regional mismatches in supply and demand occur. Although urban centres and agricultural areas tend to develop where water supplies are sufficient, changing rainfall patterns or excessive urban growth can result in demand exceeding supply. Another scenario may be if upstream water resources are increasingly utilised there is less left available for downstream users. Although expensive, desalination is increasingly used to meet supply shortfalls, particularly for the municipal sector. Over 150 nations use desalination to meet some of their freshwater demand (see Box 3.9), and in 2008 there were almost 14,000 facilities worldwide with capacity to supply over 52 million cubic metres of fresh water per day (Henthorne 2009, Fichtner 2011) (see Figure 3.6).

Groundwater is a key component of the hydrological cycle and a major water source. However, as it is not readily visible, the location, quantity and function of groundwater resources is poorly understood (Revenga et al. 2000). Renewable groundwater resources comprise about 22% of renewable water resources, and are used extensively by humans, representing 25% of total water withdrawals, and 50% of potable water (Giordano 2009). This use often has little regard for sustainability and long-term viability. Much of global agricultural production relies on groundwater for irrigation and many major urban centres are dependent on groundwater (WWAP 2009).

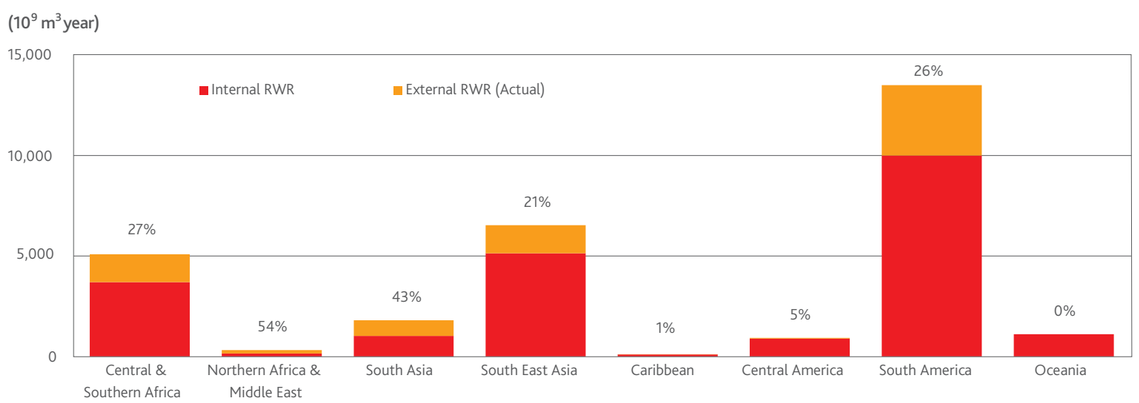
Unlike surface water, groundwater is considered less vulnerable to seasonal rainfall variation due to its large storage volume compared to flow, providing a valuable resource in the absence of surface waters (Giordano 2009). A range of natural processes (which will vary by aquifer), can affect the quality of groundwater for human use. For example, recharge through soil can filter out many impurities but the underlying geology may result in high concentrations of harmful metals and other elements such as arsenic and fluoride, which can affect the health of communities reliant on these resources (Fawell & Nieuwenhuijsen 2003).

Figure 3.4

Renewable water resources (RWR)



Source: Aquastat (FAO 2013), State of the Tropics project.



Note: 'Actual' flows take into account upstream abstraction and water reserved for upstream and downstream nations through formal or informal agreements.
It is a measure of the maximum theoretical amount of water actually available. Numbers above the bars represent regional dependency on external renewable water resources.

Like surface water, groundwater resources are not distributed equitably, and there is greater risk of unsustainable extraction in regions where water is scarce. In Libya and Saudi Arabia extraction is estimated at over 500% of the renewable supply (Giordano 2009). Ironically, the over extraction of groundwater, particularly for irrigation, can lead to waterlogging and salinisation of surface soils (Giordano 2009).

Over extraction of groundwater is also affecting fossil groundwater aquifers. Unlike renewable groundwater sources, fossil aquifers are isolated from recharge potential, with the available water considered to be ancient and largely non-renewable. Although these aquifers are used as a water supply, they are a finite, non-renewable resource (Lopez-Gunn et al. 2011). For example, in Yemen's capital Sana'a, current extraction of water from fossil aquifers is unsustainable. Where the water table was 30 metres below the surface in the 1970s, it is now down to 1,200 metres in some areas, and there is the risk the city could run out of water within five years, creating more than two million water refugees (Waughray 2011).

Less well recognised is the effect invasive species can have on water resources and water use. Invasive plants in particular can have major impacts on both water quality and quantity at local, national and regional levels. In South Africa, for example, it is estimated that the four most invasive plant species use over one billion cubic metres of water per year, equating to 2% of South Africa's renewable water (WRI 2000). Invasive plants can also physically block waterways and channels, affecting the supply and quality of water for downstream users. These impacts can be significant, reducing downstream water availability by up to 80% (WRI 2000).

The impact of changing climate patterns and more intense drought and flood events will also need to be factored into agricultural and water management practices (WWAP 2009). Nonetheless, despite increasing climate change risks, changing demographics are expected to be the primary driver of increased water scarcity into the future (Vorosmarty et al. 2010).

Water quality and quantity

Pollution is an increasing risk to water quality worldwide. Deteriorating water quality has far reaching implications for human and ecosystem health. For humans, changes in water quality can reduce the amount of potentially exploitable water that is available for use, which can increase water scarcity or the cost of obtaining water. Pollutants that affect water quality can be biological, chemical or physical in origin, and the consequences depend on both the natural state of the water resource and its use.

Nutrient overloading, or eutrophication, has become the most widespread water quality issue globally (WWAP 2009). Major causes of eutrophication include agricultural run-off, erosion, and industrial effluent and sewage discharges. The pollutant sources vary among water basins, with many systems in Europe and North America contaminated by fertiliser runoff, while in many Asian and African nations sewage and animal manure contamination is the primary cause of eutrophication (Liu et al. 2012). Increased nutrient loads can stimulate harmful algal blooms and lead to hypoxic or dead zones, particularly in coastal areas which have flow on effects to coastal marine ecosystems and fisheries. By the beginning of the 21st century 776 locations around the world had seasonal and persistent hypoxic or eutrophic coastal systems, of which 80 are in the Tropics. Records for these occurrences date back to 1700 though all but one tropical occurrence has been reported since 1980 (Diaz et al. 2011).

Between 1970 and 2000 the number of rivers polluted with dissolved inorganic nitrogen or phosphorus is estimated to have increased by

Box 3.8 Cross border waters and water treaties

International water sharing obligations were recognised as far back as 1911 with the non-binding Madrid Declaration on the 'International Regulation Regarding the Use of International Water Courses for Purposes Other than Navigation'. Other non-binding treaties subsequently established a range of other 'customary international water laws' (Salman 2007) which have been useful in managing international waters and minimising harmful unilateral decision-making (Giordano & Wolf 2002). In 1997 the United Nations adopted the Convention on the Law of Non-navigational Uses of International Watercourses, though its utility is limited due to a lack of signatories (Cooley et al. 2012).

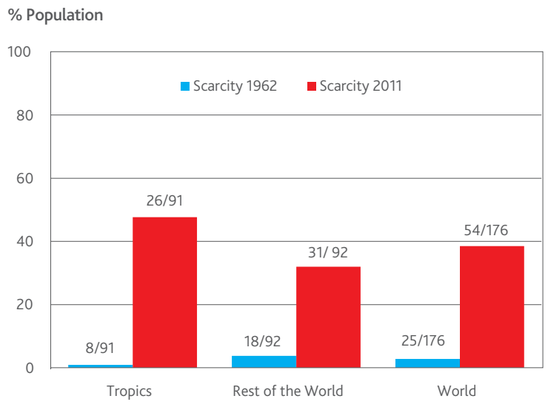
In addition to international conventions governing water rights, many nations that share transboundary water resources negotiate their own bilateral or multi-lateral agreements (Cooley et al. 2012). Some 145 such treaties were established in the 20th century. Many of these treaties are bilateral, suggesting that even when water systems span many nations the rights of all nations that may depend on the water course are not always recognised (Jagerskog & Phillips 2006). For example, the Nile River basin encompasses 12 nations and is subject to several water treaties (UNDP 2006, Ahmed et al. 2008). Some of these are bilateral, and water security has been a factor in some of the historical conflicts between these nations. Economic development and population growth in Sudan and Ethiopia are also expected to increase the draw on the Nile's waters and, without agreement from other basin states, the risk of water-related conflict is likely to increase.

Similarly, the Mekong River basin covers six nations. Four of the six nations established the Mekong Basin Commission to develop a cooperative approach to water management, although the absence of China and Burma/Myanmar is problematic, especially as they plan to develop large upstream dams which will impact water flows. This demonstrates the risks of the non-binding international framework for the consistent management of trans-border water resources (Jagerskog & Phillips 2006).

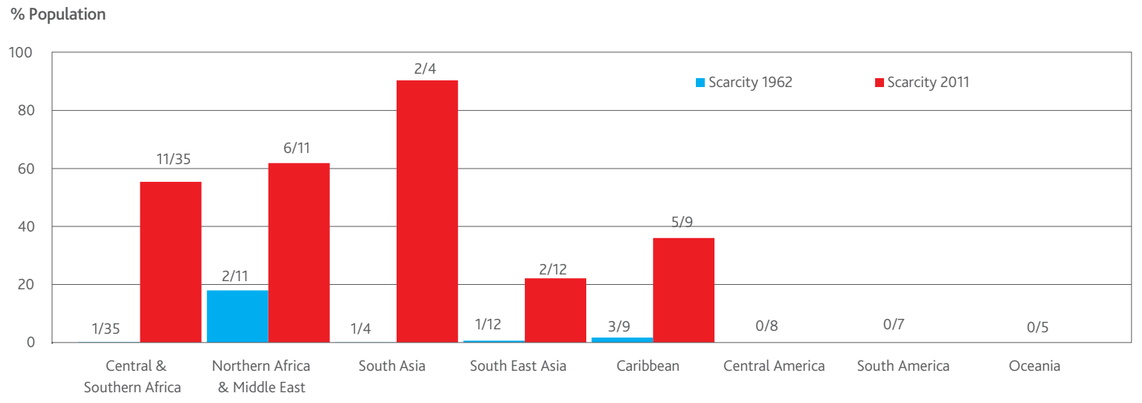
Water-related issues often occur within nations (Jagerskog & Phillips 2006). For example, competition between agricultural and municipal/industry users has been a significant issue in nations including the United States, India, Bolivia, China and Yemen (Gleick & Heberger 2012, UNDP 2006).

Figure 3.5

Proportion of population experiencing water scarcity



Source: Aquastat (FAO 2013), State of the Tropics project.



Note: Numbers above bars represent the number of nations experiencing water scarcity, and the number of nations assessed.

30% and 25% respectively (Liu et al. 2012). While dissolved inorganic nitrogen was mostly a problem in Europe in 1970, is now increasingly a global issue, with its occurrence rising steadily in South China and India (Liu et al. 2012). Similarly, phosphorus pollution has increased in systems in South Asia, Africa and South America.

Another indicator of nutrient pollution is biochemical oxygen demand (BOD), which measures the amount of oxygen used by organisms to break down organic material in water, and is an indicator of the degree of organic water pollution.

For the nations for which data are available, the Rest of the World had a BOD of 307 tonnes per day compared with 129 tonnes per day in the Tropics (see Figure 3.7). However, in the Tropics there are large variations among regions, with South East Asia reporting a BOD of 390 tonnes per day and Oceania less than five tonnes per day. In part, this reflects the level of industrialisation and urbanisation among nations and regions, even though agriculture is also a significant contributor to BOD.

Water sources that are eutrophic as a result of sewage effluent can also contain high pathogen levels which can render water unfit for human and animal consumption. This water is often used for agriculture, but there is still the risk that pathogens survive, and can be conferred to humans via produce. Surveys in Ghana's urban markets found pesticide residues, faecal coliform counts and parasite eggs on vegetable samples at levels above recommended standards (Amoah et al. 2006), and in Bangladesh sewage-related contamination of surface water in many communities has contributed to greater use of groundwater for drinking (but which has brought with it arsenic contamination problems).

Chemical pollutants can include substances such as heavy metals, hydrocarbons and petroleum products, pesticides and herbicides. Unlike biological contamination which can have widespread impacts across river basins, the effects of many chemical contaminants tend to be more regional and ecosystem dependent. However, due to their persistence they require a much greater effort to remediate and manage. For many of these substances a major concern is their ability to be incorporated in the tissues of plants and animals and accumulated in food chains to higher order consumers like humans (Banks et al. 2007).

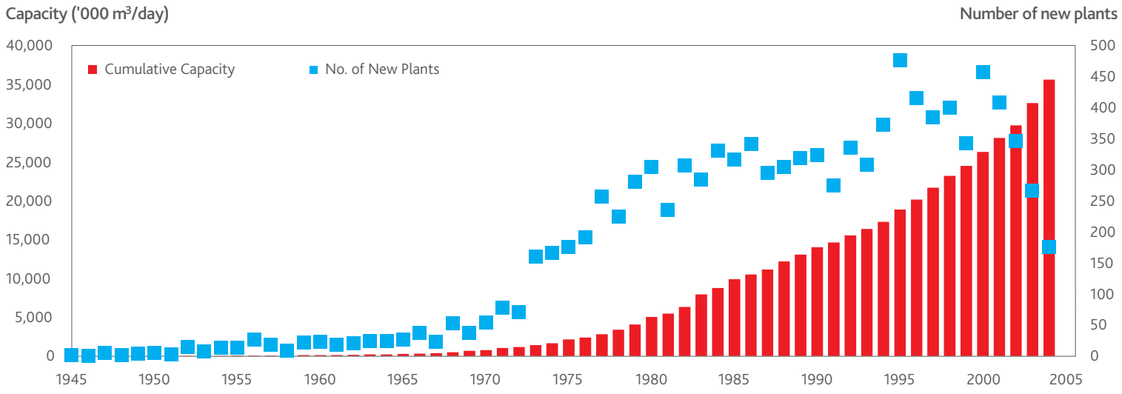
Physical contaminants include non-biodegradable rubbish like plastics, building materials, discarded fishing gear and other such items. Increased sediment loads are also an issue, although the natural levels of sediments can be highly variable between systems and seasons. River systems such as the Nile, Yangtze, Pearl, Mississippi and Irrawaddy have naturally high sediment loads that may be in the order of hundreds of millions of tonnes per year (Wang et al. 2012). However, human activities such as poor land use practices and deforestation mean additional sediment loads well above natural levels are a common problem.

Emerging water quality issues include the rise in new contaminants such as endocrine disruptors. These are increasing in waters receiving sewage and some industrial effluents. These contaminants include pharmaceuticals, hormones and phthalates, which are persistent in the environment and can have effects on biota even at very low concentrations, as well as pose health risks to humans (Fawell & Nieuwenhuiujsen 2003).

Another less recognised contributor to deteriorating water quality is over-extraction, which can see water volumes decrease or cease. Flow on effects may include stagnation, increased water temperatures, pollutant accumulation, blue-green algae contamination and loss of supply to downstream users. In Australia, reduced flow in the Murray-Darling River from a combination of drought and over-extraction between 1997 and 2006 meant that the nation's longest river failed to flow to the sea over 60% of the time (CSIRO 2008). This has had major impacts on coastal wetland ecosystems, changed the make-up of the region's biota, increased sedimentation (causing semi-permanent blockages at the river mouth), caused major water stress to users in the lower parts of the system and led to blue-green algae outbreaks (Paton et al. 2009; Paton 2010). Similar examples can be found for other systems around the world, including the Ganges, Amu Darya, Nile, Jordan, Yellow and Colorado Rivers (Revenga et al. 2000, Waughray 2011).

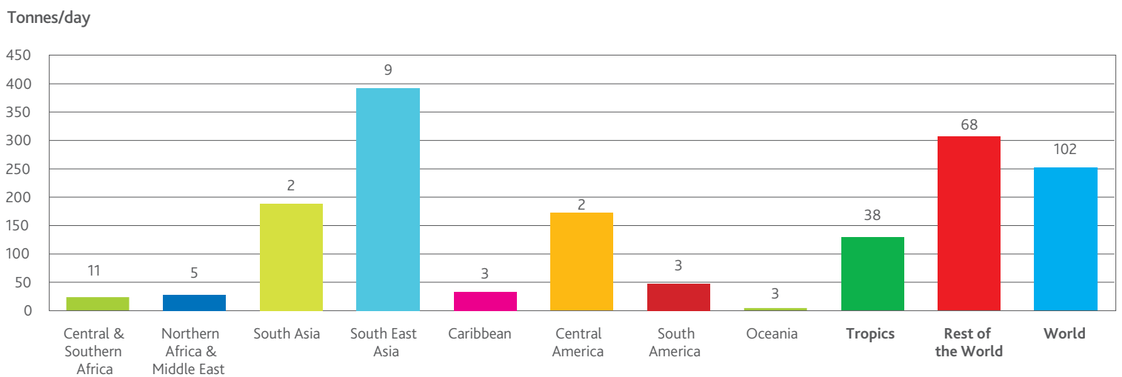
Deterioration of groundwater quality is also generally linked with over extraction, which can lead to increases in compounds and elements like fluoride and arsenic. Over extraction also increases the risk of saltwater intrusion into aquifers, reducing both the quantity and quality of fresh water available for human use (WWAP 2012).

Figure 3.6 **Global desalination capacity and number of desalination plants**



Source: Source: Gleick (2006), State of the Tropics project.

Figure 3.7 **Biochemical oxygen demand emissions**



Source: World Bank (2012), State of the Tropics.
Note: Numbers above bars represent number of nations reporting emissions.

Table 3.3 **Sectoral water withdrawals**

	Sectoral withdrawals in billion cubic metres/ year (proportion of total withdrawals %)				Water pressure (freshwater withdrawal as % of TRWR*)
	Agricultural	Industrial	Municipal	Total	
Tropics	**1,019 (81)**	**102 (8)**	**137 (11)**	**1,258**	**4.3**
Central & Southern Africa	46 (75)	4.2 (7)	11 (18)	62	1.2
Northern Africa & Middle East	47 (91)	0.9 (2)	3.5 (7)	51	16
South Asia	452 (91)	13 (2)	34 (7)	499	28
South East Asia	344 (77)	61 (14)	41 (9)	446	7
Caribbean	9.3 (63)	1.1 (8)	4.3 (29)	15	16
Central America	42 (68)	7.9 (13)	12 (19)	61	7
South America	76 (63)	12.8 (11)	31 (26)	119	0.9
Oceania	3.4 (63)	1.3 (24)	0.7 (13)	5.5	0.5
Rest of the World	**1,684 (64)**	**629 (24)**	**331 (12)**	**2,644**	**11**
World	**2,703 (69)**	**731 (19)**	**468 (12)**	**3,902**	**7.3**

Source: Aquastat (FAO 2013) and State of the Tropics.
Note: Totals may not add up due to rounding. *TRWR – Total Renewable Water Resources

Recently, increased nutrient levels detected in some aquifers, particularly shallow ones, are thought to be associated with fertiliser overuse, land fill leachates and urbanisation (Revenga et al. 2000).

Environmental flows are the quantity, quality, and timing of water flows required to maintain underlying ecosystem and human services. Maintenance of environmental flows helps ensure the sustainability of water resources through maintenance of ecosystem services including water purification and biodiversity. The underlying parameters of flow intensity, timing, water quantity and quality vary among systems and are major contributors to the biodiversity and ecological health of aquatic ecosystems. Historically, developmental requirements outweighed ecological needs for water resources (see Box 3.10), though there is an increasing recognition of the need to balance human and environmental requirements for water flows (King & Brown 2006).

One of the limitations to quantifying renewable water resources globally is the lack of adequate and consistently available data. In fact, despite the critical importance of water to all life on Earth, the number of functioning hydrological stations has decreased since 1985, which is impacting data collection and monitoring activities (Revenga et al. 2000). Addressing these issues will require considerable international effort and adequate resourcing to ensure measurable improvements (see Box 3.10).

Similarly, while data for many water pollutants may be available at local and watershed level, this is mainly in developed nations. Globally the data are fragmented with little in the way of consistent long term monitoring programs (Revenga et al. 2000). This is despite international recognition of the burden water pollution from sewage, industry and agriculture poses to society and the environment.

Looking forward

The cycling of water through the Earth's ecosystems means that we often perceive water as an infinite, renewable resource. However, it is both finite in its quantity and quality. The variable nature of the hydrological cycle, the Earth's topography and its political boundaries means that water availability is variable to both humans and the environment in many areas. The future of water use, particularly in light of the effects of a changing climate, will depend on the ability of humanity to adapt and to use and reuse water resources sustainably to ensure that both the environment and society have adequate supplies of good quality water.

Water quality issues have increased significantly in the Tropics in the last few decades. Increasing pressures from growing populations, urbanisation, industrialisation and economic development mean that urgent action is required to ensure there are adequate environmental flows and that available water resources are used sustainably. To this end, there is an urgent need for improving sustainable planning and management practices in the region.

Box 3.9 Desalination in the Middle East and Northern Africa (MENA)[6]

The Middle East and Northern Africa is one of the most water scarce regions in the world. Chronic water stress is an issue in at least 16 of the 22 MENA nations. In this region, where withdrawals exceed renewable water resources, the balance needs to be supplemented from other sources (Fichtner 2011).

Given the need to offset shortfalls in renewable water supplies, and the region's large human population and solid economic growth, MENA nations have become leaders in the use of desalination technologies (Immerzeel et al. 2011). The region now accounts for over 60% of global desalination capacity (Gleick et al. 2006, Fichtner 2011). Desalination, however, has both economic and environmental costs. Although there have been significant improvements in the productivity and efficiency of desalination practices it remains an energy intensive process. For example, according to 2006 estimates, on average around 3kWh of energy was required to produce one cubic metre of freshwater (Henthorne 2009, Immerzeel e tal. 2011).

The energy intensity of desalination contributes to greenhouse gas emissions, particularly in plants powered by fossil fuels. Several MENA nations are currently trialling pilot plants using renewable energy technologies, and are developing plans to build large-scale commercial plants using renewable energy (Fichtner 2011).

Desalination plants produce a high temperature, hypersaline water discharge that must be managed to avoid environmental impacts when released. For some desalination plants discharge streams may also include anti-fouling compounds, corrosion contaminants (heavy metals) and coagulants which affect local biota (Dawoud & Mulla 2012). In coastal areas the most common disposal method is discharge back into the ocean. For inland regions though, seawater disposal is not possible, making management of this waste stream more difficult.

Due to the density of desalination plants along the semi-enclosed Arabian Gulf and Red Sea there are concerns about the cumulative effects of multiple hypersaline brine discharges on the local ecology and water chemistry (Purnama et al. 2005, World Bank 2011). The greatest risks are likely to be on mangroves, sea grass meadows and endangered dugong populations.

Desalination plant. Image: Ryan Lackey.

[6]MENA refers to the group of 22 nations that form the Middle East and Northern Africa region as recognised by international agencies. They are: Algeria, Bahrain, Djibouti, Egypt, Gaza Strip, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank, Yemen.

Box 3.10 Integrated Water Resource Management (IWRM)

Competition for water resources has existed between nations for millennia, but competition also exists between social and environmental sectors within nations. Integrated Water Resource Management aims to promote the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of the environment. The benefits of IWRM were recognised as far back as the 1930s, though early efforts focussed on engineering solutions to supply industrial, municipal and agricultural users, with little recognition of environmental requirements.

Even in the 1970s there was little recognition of the need for environmental flows (Snellen & Schrevel 2004), and it wasn't until the 1992 Earth Summit that the global community recognised the need for an integrated approach to the development, management and use of water resources for both humanity and the environment.

Although progress has been slow in many regions (and difficult to quantify, as many effects are subtle), efforts to improve water resource management and sustainability over the past 20 years have improved outcomes in many nations, across a range of economic, social, health and environmental services. These include improved water use governance; increased stakeholder and government engagement in water management; and improved environmental governance (Poff et al. 2003, WWAP 2012). Since the 1992 Earth Summit, 80% of UN member nations have undertaken reforms to improve water management and sustainability (UNEP 2012).

Despite these efforts, most nations believe their water risks are increasing, and in all but the most developed nations, priorities remain primarily human-centric with environmental flows given a low priority (WWAP 2012). Globally the main water risks include water scarcity, extreme water events (both droughts and floods) and water quality deterioration, with demographic changes exacerbating these risks (WWAP 2012).

Water management in India. Image: Nestlé.

References

Ahmed AA, Ismail UHAE. (2008). *Sediment in the Nile River.* International Hydrological Programme, International Sediment Initiative, United Nations Educational, Scientific and Cultural Organization.

Alexander F, Nelson R. (2003). *Monitoring land degradation in the wheat-sheep zone of Western Australia.* ABARE West Australian Regional Outlook Conference, Geraldton Paper.

Alexandratos N, Bruinsma J. (2012). *World agriculture towards 2030/2050: the 2012 revision.* ESA Working paper No. 12-03. Food and Agriculture Organization, Rome.

ALI (2012). *Landcare around the world.* Australian Landcare International http://www.australianlandcareinternational.com/landcare-around-the-world/ (accessed on 16 October 2012).

Amoah P, Drechsel, Abaidoo RC, Ntow WJ. (2006). Pesticide and pathogen contamination of vegetables in Ghana's urban markets, in *Archives of Environmental Contamination and Toxicology* **50.**

Bai ZG, Dent DL, Olsson L, Schaepman ME. (2008a). Proxy global assessment of land degradation in *Soil Use and Management* **24**(3).

Bai ZG, Dent DL, Olsson L, Schaepman ME. (2008b). *Proxy global assessment of land degradation.* 1. Identification by remote sensing. Report 2008/01, ISRIC – World Soil Information, Wageningen.

Banks MS, Chesney E, Shine JP, Maage A, Senn DB. (2007). Mercury bioaccumulation and trophic transfer in sympatric snapper species from the Gulf of Mexico, in *Ecological Applications* **17**(7).

Barbier E. (2012). Carbon farming: a solution to global land degradation and poverty? The Conversation http://theconversation.edu.au/carbon-farming-a-solution-to-global-land-degradation-and-poverty-8491 (accessed on 28 September 2012).

Berry L, Olson J, Campbell D. (2003). *Assessing the extent, cost and impact of land degradation at the national level: Findings and lessons learned from seven pilot case studies.* Global Mechanism & World Bank.

Bot AJ, Nachtergaele FO, Young A. (2000). *Land resource potential and constraints at regional and country levels.* World Soil Resources Report 90. Food and Agriculture Organization, Rome.

Catacutan D, Neely C, Johnson M, Poussard H, Youl R. (2009). *Landcare: Local action – global progress.* World Agroforestry Centre, Nairob.

Cooley H, Christain-Smith J, Gleick PH, Allen L, Cohen MJ. (2012). Climate Change and Transboundary Waters, in Gleick PH. (Ed), *The World's Waters: The Biennial Report on Freshwater Resources,* Volume 7. Pacific Institute for Studies in Development, Environment, and Security. Island Press, Washington.

CSIRO (2008). *Water Availability in the Murray-Darling Basin.* A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. Commonwealth Scientific and Industrial Research Organisation, Australia.

Dawoud MA, Al Mulla MM. (2012). Environmental impacts of seawater desalination: Arabian Gulf case study, in *International Journal of Environment and Sustainability* **1**(3).

Derpsch R. (2004). *Economics of No-till farming. Experiences from Latin America.* Paper presented at the Conference on Conservation Agriculture/No-till, Nov. 18 – 23, 2004, Dnepropetrovsk.

Diaz R, Selman M, Chique C. (2011). Global Eutrophic and Hypoxic Coastal Systems. World Resources Institute. Eutrophication and Hypoxia: Nutrient Pollution in Coastal Waters http://docs.wri.org/wri_eutrophic_hypoxic_dataset_2011-03.xls (accessed in January 2013).

Diaz RJ, Rosenberg R. (2008). Spreading dead zones and consequences for marine ecosystems, in *Science* **321.**

FAO (2000). *Irrigation in Latin America and the Caribbean in figures.* Water Report 20. Food and Agriculture Organization, Rome.

FAO (2002). *World Agriculture: Towards 2015/2030.* Summary report. Food and Agriculture Organization, Rome.

FAO (2006). *The State of Food Insecurity in the World 2006: Eradicating world hunger – taking stock ten years after the World Food Summit.* Food and Agriculture Organization, Rome.

FAO (2007). *The state of food and agriculture: Paying farmers for environmental services.* Food and Agriculture Organization, Rome.

FAO (2008). *The state of food and agriculture - Biofuels: prospects, risks and opportunities.* Food and Agriculture Organization, Rome.

FAO (2011). *The State of Food and Agriculture: Women in Agriculture.* Food and Agriculture Organization, Rome.

FAO (2012a). *The State of Food Insecurity in the World: Economic Growth is Necessary but not sufficient to accelerate reduction of hunger and malnutrition.* Food and Agriculture Organization, Rome.

FAO (2012b). *Coping With Water Scarcity: An Action Framework for Agriculture and Food Security.* FAO Water Report 38. Food and Agriculture Organization, Rome.

FAO (2013). AQUASTAT Database. Food and Agriculture Organization http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (last accessed April 2013).

FAOStat (2013). FAOStat http://faostat3.fao.org/home/index.html (last accessed in July 2013).

Fawell J, Nieuwenhuijsen MJ. (2003). Contaminants in drinking water: Environmental pollution on health, in *British Medical Bulletin* **68.**

Fernandez-Gimenez ME, Ballard HL, Sturtevant VE. (2008). Adaptive management and social learning in collaborative and community-based monitoring: a study of five community-based forestry organizations in the western USA, in *Ecology and Society* **13**.

Fichtner (2011). *MENA Regional Water Outlook. Part II: Desalination Using Renewable Energy,* 6543P07/FICHT-7109954-v2. Report to the World Bank prepared by Fichtner Consulting Engineers.

Gibbs HK, Ruesch AS, Achard F, Clayton MK, Holmgren P, Ramankutty N, Foley JA. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s, in *Proceedings of the National Academy of Sciences* **107**(38).

Giordano M, Wolf AT. (2002). *Atlas of International Freshwater Agreements.* United Nations Environment Programme, Nairobi.

Giordano M. (2009). Global groundwater? Issues and solutions, in *Annual Review of Environmental Resources* **34**.

Gleick PH, Cooley H, Wolff G. (2006). With a grain of salt: An update on seawater desalination, in Gleick PH. (Ed), *The World's Water 2006-2007: The Biennial Report on Freshwater Resources.* Pacific Institute for Studies in Development, Environment, and Security. Island Press, Washington.

Gleick PH, Heberger M. (2012). Water conflict chronology, in Gleick PH. (Ed), *The World's Waters: The Biennial Report on Freshwater Resources.* Volume 7. Pacific Institute for Studies in Development, Environment, and Security. Island Press, Washington.

Gleick PH. (1993). Introduction to global fresh water issues, in Gleick PH. (Ed), *Water in Crisis: A Guide to the World's Fresh Water Resources.* Oxford University Press, New York.

Gleick PH. (2006). The World's Water 2006-2007: *The Biennial Report on Freshwater Resources.* Pacific Institute for Studies in Development, Environment, and Security. Island Press, Washington.

Gonzalez-Valero J, Chevion P. (2011). Water scarcity: Agriculture provides solutions, in Waughray D. (Ed), *Water Security: The Water-Food-Energy-Climate Nexus.* World Economic Forum. Island Press, Washington.

GO-Science (2011). *Foresight. The Future of Food and Farming.* Final Project Report. The Government Office for Science, London.

Henthorne L. (2009). Desalination – a critical element of water solutions for the 21st century, in Forare J. (Ed), *Drinking Water – Sources, Sanitation and Safeguarding.* Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden.

Holmer RJ, Drescher A. (2005). Building food-secure neighbourhoods: the role of allotment gardens in *Urban Agriculture Magazine* **15**.

Holmgren P. (2006). *Global land use area change matrix: Input to the fourth global environmental outlook* (GEO-4). FAO Working Paper 134, Food and Agriculture Organization, Rome.

Huggins DR, Reganold JP. (2008). No till. The quiet revolution, in *Scientific American* **299**(1).

IFPRI (2002). *Green revolution: Curse or blessing?* International Food Policy Research Institute. Washington DC.

Immerzeel W, Droogers P, Terink W, Hoogeveen J, Hellegers P, Bierkens M, van Beek R. (2011). *Middle-East and Northern Africa Water Outlook.* Report to the World Bank prepared by FutureWater.

Jägerskog A, Phillips D. (2006). *Human Development Report 2006. Managing Trans-boundary Waters for Human Development.* Occasional Paper 2006/9. United Nations Development Programme.

Kates R, Haarmann V. (1992). Where the poor live: Are the assumptions correct? in *Environment* **34.**

King J, Brown C. (2006). Environmental flows: striking the balance between development and resource protection, in *Ecology and Society* **11**(2).

Koh LP, Ghazoul J. (2008). Biofuels, biodiversity and people: Understanding the conflicts and finding opportunities, in *Biological Conservation* **141.**

Lambin EF, Geist HJ, Lepers E. (2003). Dynamics of land-use and land-cover change in tropical regions, in *Annual Review of Environmental Resources* **28.**

Lepers E, Lambin EF, Janetos AC, DeFries R, Achard F, Ramankutty N, Scholes RJ. (2005). A synthesis of information on rapid land-cover change for the period 1981-2000, in *BioScience* **55.**

Liu C, Kroeze C, Hoekstra AY, Gerbens-Leenes W. (2012). Past and future trends in grey water footprints of anthropogenic nitrogen and phosphorus inputs to major world rivers, in *Ecological Indicators* **18**.

Lonergan S. (1998). The role of environmental degradation in population displacement, in *Environmental Change and Security Project Report* **4.**

Lopez-Gunn E, Llamas MR, Garrido A, Sanz D. (2011). Groundwater management, in Wilderer P. (Ed), *Treatise on Water Science, Volume 1.* Oxford Academic Press.

Maitima JM, Mugatha SM, Reid RS, Gachimbi LN, Majule A, Lyaruu H, Pomery D, Mathai S, Mugisha S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa, in *African Journal of Environmental Science and Technology* **3.**

MEA (2005). *Ecosystems and Human Well-being: Synthesis.* Millennium Ecosystem Assessment. Island Press, Washington DC.

Middleton NJ, Thomas DSG. (1992). *World atlas of desertification.* United Nations Environment Programme, London.

Mitchell D. (2008). *A Note on Rising Food Prices.* World Bank Policy Research Working Paper 4682. World Bank, Washington DC.

Molden D, Amarasinghe U, Hussain I. (2001). *Water for Rural Development: Background Paper on Water for Rural Development Prepared for the World Bank.* Working Paper 32. International Water Management Institute, Colombo.

Motes WC. (2010). Modern agriculture and its benefits- trends, implications and outlook. Global Harvest Initiative, Pre-publication draft, 3-16-10.

References | Continued

Mueller ND, Gerber JS, Johnston M, Ray DK, Ramankutty N, Foley, JA. (2012) Closing yield gaps through nutrient and water management, in *Nature* **490**(7419).

Myers N. (2002). Environmental refugees: a growing phenomenon of the 21st century, in *Philosophical Transactions of the Royal Society* B **357.**

Myers N, Kent J. (2001). Food and hunger in sub-Saharan Africa, in *The Environmentalist* **21.**

Nellemann C, MacDevette M, Manders T, Eickhout B, Svihus B, Prins AG, Kaltenborn BP (Eds) (2009). *The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment.* United Nations Environment Programme, Nairobi.

Nielsen TT, Adriansen HK. (2005). Government policies and land degradation in the Middle East, in *Land Degradation & Development* **16**.

OCHA (2011). *Humanitarian requirements for the Horn of Africa drought July 2011.* United Nations, Version 1.B, Geneva.

OECD/ FAO (2012), *OECD-FAO Agricultural Outlook 2012-2021.* OECD Publishing & FAO.

Omonode RA, Smith DR, Gal A, Vyn TJ. (2011). Soil nitrous oxide emissions in corn following three decades of tillage and rotation treatments, in *Soil Science Society of America Journal* **75**.

Pardey PG, Alston JM, Chan Kang C. (2012). *Agricultural production, productivity and R&D over the past half Century: An emerging new world order.* Invited plenary paper presented at the International Association of Agricultural Economists Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

Paton DC, Rogers DJ, Hill BM, Bailey CP & Ziembicki MR. (2009). Temporal changes to spatially stratified waterbird communities of the Coorong, South Australia: implications for the management of heterogenous wetlands, in *Animal Conservation* **12**

Paton DC. (2010). At the end of the river: the Coorong and Lower Lakes. ATF Press, Hindmarsh.

Peskett L, Slater R, Stevens C, Dufey A. (2007). *Biofuels, agriculture and poverty reduction.* Project AG0397, Report to United Kingdom Department for International Development, UK.

Poff NL, Allan JD, Palmer MA, Hart DD, Richter BD, Arthington AH, Rogers KH, Meyer JL, Stanford JA. (2003). River flows and water wars: emerging science for environmental decision making, in *Frontiers in Ecology and the Environment* **1**(6).

Prince SD, Brown De Colstoun E, Kravitz LL. (1998). Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification, in *Global Change Biology* **4**.

Purnama A, Al-Barwani HH, Smith R. (2005). Calculating the environmental cost of seawater desalination in the Arabian marginal seas, in *Desalination* **185**.

Raleigh C.(2011). The search for safety: The effects of conflict, poverty and ecological influences on migration in the developing world, in *Global Environmental Change* **21S.**

Rathmann R, Szklo A, Schaeffer R. (2010). Land use competition for production of food and liquid biofuels: An analysis of the arguments in the current debate, in *Renewable Energy* **35.**

Reganold JP, Elliott LF, Unger YL. (1987). Long-term effects of organic and conventional farming on soil erosion, in *Nature* **330**(6146).

Revenga C, Brunner J, Henninger N, Kassem K, Payne R. (2000). *Pilot Analysis of Global Ecosystems: Freshwater Systems.* World Resources Institute, Washington.

Safriel U, Adeel Z. (2005). Dryland systems, in Hassan R, Scholes R, Ash N. (Eds), *Ecosystems and Human Well-being: Current State and Trends.* Island Press, Washington DC.

Salman SMA. (2007). The United Nations Watercourses Convention Ten Years Later: Why Has its Entry into Force Proven Difficult?, in *Water International* **32**(1).

Seufert V, Ramankutty N, Foley JA. (2012). Comparing the yields of organic and conventional agriculture, in *Nature* **485**(7397).

Shiklomanov IA. (1993). World fresh water resources, in Gleick PH. (Ed), *Water in Crisis: A Guide to the World's Fresh Water Resources.* Oxford University Press, New York.

Shiklomanov IA. (2000). Appraisal and Assessment of World Water Resources, in *Water International* **25**(1).

Snellen WB, Schrevel A. (2004). *IWRM: For Sustainable Use of Water. 50 Years of International Experience with the Concept of Integrated Water Management.* Background Document to the FAO/ Netherlands Conference on Water for Food and Ecosystems. Ministry of Agriculture, Nature and Food Quality, Netherlands.

Tauli-Corpuz V, Tamang P. (2007). *Oil Palm and other commercial tree plantations, monocropping: Impacts on indigenous peoples' land tenure and resource management systems and livelihoods.* Permanent Forum on Indigenous Issues, Sixth session, New York, 14-25 May 2007.

UN (2013). *Resolution adopted by the General Assembly. Sixty-sixth session,* Agenda item 19, A/ RES/66/288*. United Nations, New York.

UNCCD (2012). *Zero net land degradation: A sustainable development goal for Rio+20.* United Nations Convention to Combat Desertification, Bonn.

UNDP (2006). *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis.* United Nations Development Programme, New York.

UNDP (2012). *African Human Development Report 2012 – Towards a Food Secure Future.* United Nations Development Programme, New York.

UNEP (2007). *Global environment outlook GEO-4.* United Nations Environment Programme. Progress Press, Malta.

UNEP (2012). *The UN-Water Status Report on the Application of Integrated Approaches to Water Resources Management.* United Nations Environment Programme, Nairobi.

UNEP-GEF (2006). *Land degradation as a global environmental issue: A synthesis of three studies commissioned by the Global Environment Facility to strengthen the knowledge base to support the land degradation focal area.* Scientific and Technical Advisory Panel Global Environment Facility, GEF/C.30/Inf.8.

UN-Water (2008). *Transboundary Waters: Sharing Benefits, Sharing Responsibilities.* Thematic paper. United Nations Office to Support the International Decade for Action 'Water for Life' 2005-2015 (UN-IDfA), Zaragoza.

Van Lynden GWJ, Oldeman LR. (1997). *Assessment of the status of human-induced soil degradation in South and Southeast Asia.* International Soil Reference & Information Centre, Wageningen.

Veenhuizen R. (Ed) (2006). *Cities farming for the future – Urban agriculture for green and productive cities.* RUAF Foundation, International Development Research Centre and International Institute of Rural Reconstruction, Philippines.

Vorosmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Liermann CR, Davies PM. (2010). Global threats to human water security and river biodiversity, in *Nature* **467.**

Wang Z, Yu GA, Huang HQ. (2012). Gender of deltas and parasitizing rivers, in *International Journal of Sediment Research* **27.**

Waughray D. (Ed) (2011). *Water Security: The Water-Food-Energy-Climate Nexus.* World Economic Forum. Island Press, Washington.

Wessels KJ, Prince SD, Malherbe J, Small J, Frost PE, Van Zyl D. (2007). Can human-induced land degradation be distinguished from the effects of rainfall variability? A case study in South Africa, in *Journal of Arid Environments* **68**.

Wessels KJ, van den Bergh F, Scholes RJ. (2012). Limits to detectability of land degradation by trend analysis of vegetation index data, in *Remote Sensing of Environment* **125.**

WMO (1997). *Comprehensive Assessment of the Freshwater Resources of the World.* World Meteorological Organization, Geneva.

WMO (2005). *Climate and land degradation.* WMO-No. 989. World Meteorological Organization, Geneva.

World Bank (2011). *Renewable Energy Desalination: An Emerging Solution to Close Middle East and North Africa's Water Gap.* World Bank Synthesis Report – Draft (Conference Edition).

World Bank (2012). *Organic Pollutants* http://data.worldbank.org/indicator/EE.BOD.TOTL.KG/countries (accessed on 22 January 2013).

WRI (2000). *A Guide to World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life.* World Resources Institute, Washington.

WRI, UNDP, UNEP, World Bank (2011). *World Resources 2010–2011: Decision Making in a Changing Climate—Adaptation Challenges and Choices.* World Resources Institute, Washington DC.

WWAP (2009). *The United Nations World Water Development Report 3: Water in a changing World.* United Nations Educational, Scientific and Cultural Organization (Paris) & Earthscan (London).

WWAP (2012). *The United Nations World Water Development Report 4: Managing water under uncertainty and risk (Volume 1).* United Nations Educational, Scientific and Cultural Organization, Paris.

Zezza A, Tasciotti L. (2010). Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries, in *Food Policy* **35**.

Zika M, Erb K-H. (2009). The global loss of net primary production resulting from human-induced soil degradation in drylands, in *Ecological Economics* **69**.

Pygmy seahorse, Philippines.
Image: Klaus Stiefel.

Humpack whale.
Image: Mark Ziembicki.

Chapter 4

Oceans

'Don't bargain for fish which are still in the water.'

Indian Proverb

Image: Shutterstock.

Summary of ocean indicators

Indicator		The Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Wild Marine Catch* 1950 to 2010 (million tonnes)		**2-32.2**	0.3-2.3	0.1-1.0	0.6-4.3	0.8-18.2	0.03-0.2	0.03-0.7	0.2-5.0	0.03-0.6	**14.8-45.1**	**16.8-77.3**
Aquaculture Production* 1950-2010 (thousand tonnes)		**156 – 21,849**	0.4 – 351	0.0 – 27.1	32.2 – 4,182	123 – 16,273	0.0 – 36.7	0.0 – 176	0.0 – 790	0.07 – 12.7	**448 – 38,086**	**604 – 59,936**
Coral Reefs	Coral Reef Distribution %	**95**	6	4	5	27	3	2	1	47	**5**	**100**
	Reefs at Risk** 1998-2010	**29-47**	33-64	18-33	19-21	58-61	53-65	27-32	34-54	7-28	**13-28**	**27-45**
	Coral Disease^	**2,949/44**	21/5	335/2	31/2	226/7	832/11	733/6	483/3	288/8	**1,535/11**	**4,484/53**
Mangroves	Decrease in Mangrove Area 1980-2005 ('000 km2)	**175-143**	34.8-30.2	1.98-1.41	9.4-9.3	64.2-47.2	6.2-6.05	16.6-11.6	21.2-18.8	20.6-18.6	**10.1-6.80**	**185-150**
	Mangrove Diversity % of total species#	**99**	22	4	52	71	8	15	16	70	**26**	**100**

Red: Situation is deteriorating

* Wild marine catch and aquaculture production not identified as improving or deteriorating as defining "good" or "bad" will depend on perspective;
** % of reefs at high risk from integrated local threats; # numbers will not equal 100 as many species are found >1 region;
^ number of coral diseases reports / number of nations reporting disease.

Oceans comprise 76% of the Tropics. They are generally shallower and warmer than in other parts of the world, and also tend to be lower in nutrients hence support lower densities of marine organisms. However, although lower in overall fish biomass the Tropics' share of the overall global wild marine fish catch is increasing. This is due in part to the extensive coral and mangrove ecosystems in the Tropics and overfishing in other regions. Coral reefs and mangrove systems support a large proportion of tropical fisheries as well as providing a number of other ecosystem services to society.

Oceans, and in particular coastal marine waters, are fundamental to the health and well-being of many communities in the Tropics. A large proportion of the human population in the Tropics is directly dependent on marine resources, particularly on fisheries, for sustenance. For many tropical nations, valuable income is also generated from coral reef associated tourism. Oceans also play a vital role in terms of the protective, regulatory and supporting services they provide, such as their role in acting as a carbon sink, in climate regulation and nutrient cycling.

Headline indicator

Wild marine catch: Fish are the primary source of animal protein for many coastal communities worldwide. Communities that rely on small-scale fisheries are largely located in the Tropics and about half the wild marine fish catch is taken by these small-scale operations. Sustainable management of this resource is essential to maintain the ecological integrity of oceans as well as providing a sustainable resource for coastal communities into the future.

Supplementary indicators

Aquaculture production
Aquaculture is the cultivation of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants under controlled conditions. Increased aquaculture production is associated with a transition to more sustainable fishing practices. Assuming continued population growth and constant per capita demand for seafood, responsible aquaculture represents the best hope of both meeting demand and halting the decline of wild stocks.

Corals: Most coral reef systems are located in the Tropics and provide a range of goods and services to tropical nations both directly and indirectly. For many tropical island nations, coral reefs are important for fisheries, provide protection to coasts and are an important source of income through tourism.

Mangroves: Mangroves are important nurseries and habitats for marine life and act as filters of terrestrial pollutants, protecting nearby coral reef and seagrass systems.

Links to other dimensions

Renewable water resources, land degradation, agriculture, aquaculture, protected areas, biodiversity, carbon dioxide and greenhouse gas emissions.

Is it getting better?

Wild marine catch
Globally, wild marine catch quadrupled between the 1950s to when it peaked in the mid-1990s. Since then catches have declined or stabilised despite increasing fishing effort. However, in the Tropics marine fish catch has increased over the past 50 years. Human population growth, particularly in tropical coastal communities, and increasing affluence, is forecast to further increase pressures on marine fish stocks.

Aquaculture production
In 2010, the Tropics produced 36% of reported global aquaculture production, up from 26% in 1950. The rapid growth in aquaculture in the Tropics, particularly high intensity mono-cultures, has had some negative environmental effects including impacts on water quality and the introduction of invasive species. However, there are major improvements being made in productivity and environmental practices and greater emphasis on sustainable poly-cultures, particularly in the Tropics.

Corals
Threats to coral reef systems increased markedly between 1998 and 2010 with over half the reefs in the Tropics now considered to be at medium or high risk of damage. Coral reefs in all tropical regions are suffering from increased threats locally and globally. Primary local threats include coastal development, overfishing/destructive fishing, pollution and sedimentation. Increased water temperatures and ocean acidification are the greatest global threats. Loss of coral reef systems is having wider ecosystem and human well-being ramifications because of declining fish populations and erosion of protective services offered to coastal communities.

Mangroves
The Tropics host nearly 95% of the world's mangroves by area and 99% of mangrove species. Mangroves have decreased in area since 1980 with all tropical regions suffering declines. The greatest threats to mangroves include illegal forestry, coastal development, aquaculture and pollution. Loss of mangroves increases the risk of adverse impacts of extreme weather events on coastal communities, and contributes directly to losses of fisheries resources. Some tropical nations have recognised the value of mangrove ecosystems and are improving legislative protection as well as initiating reforestation efforts to improve coastal mangrove systems.

Vietnam. Image: Dave Mills, Worldfish.

Wild marine catch

The oceans cover 71% of the Earth's surface and contain around 97% of its water (NOAA 2011). It is estimated that 25% of all species diversity exists in the oceans, of which 91% is still undescribed (Mora at al. 2011).

Oceans and marine life support many elements that are critical for human life. Marine organisms are significant contributors to the oxygen cycle and oceans play a major role in influencing the Earth's climate and the water cycle. Many human activities are affecting the health of oceans – both directly and indirectly. The impact of increased anthropogenic carbon dioxide emissions is the most pervasive. These emissions are changing ocean acidity and contributing to climate change, with associated effects on sea levels, precipitation patterns, the incidence of extreme weather events and potential changes to ocean circulatory patterns (UNEP 2007).

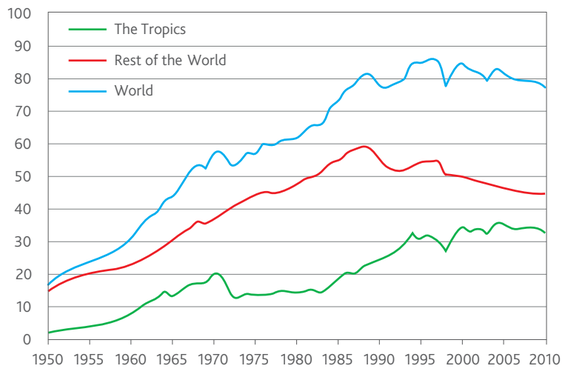
Urbanisation is also having significant impacts in many coastal ecosystems. Coastal development such as dredging, reclamation and the construction of physical barriers (such as sea walls) can disrupt currents, sediment flow and discharge, with impacts on sensitive coastal ecosystems.

The ocean's marine life represents an important resource which provides food, medicine, and raw materials that support human life and economic activities. In 2007, fish accounted for 16% of the global population's intake of animal protein, and 20% in low-income food-deficit (LIFD) nations (FAO 2010a). Most of these nations are in the Tropics. As around half the global wild marine catch is in small-scale fisheries[7], sustainable fish stocks are critical to the lives of millions of people in developing nations.

For many developing nations rising incomes are contributing to increased demand for seafood. In others, ongoing poverty means there is a high reliance on subsistence fishing as the primary protein source (Delgado et al. 2003). As the global population increases there will be greater demand for seafood, and a need for more sustainable approaches to fishing and aquaculture. Persistent over-fishing has had long-term impacts on the productivity of marine ecosystems, notably in areas where poverty overshadows environmental concerns, and where unregulated and illegal fishing is prevalent. As such, the sustainable management of wild marine stocks is a critical issue for the wellbeing of many small-scale fishing communities. Collapse of these fisheries would have significant food security implications.

To some extent aquaculture is reducing pressure on wild fish stocks, but the benefits are offset by the extensive use of fishmeal (see Box 4.1). Globally, aquaculture's proportion of total fisheries production is increasing rapidly. However, in many developing nations much of the production is increasingly high-value fish destined for export markets rather than for local consumption, meaning that food security is an ongoing issue, even in many fish-producing nations.

Figure 4.1 **Wild marine catch**



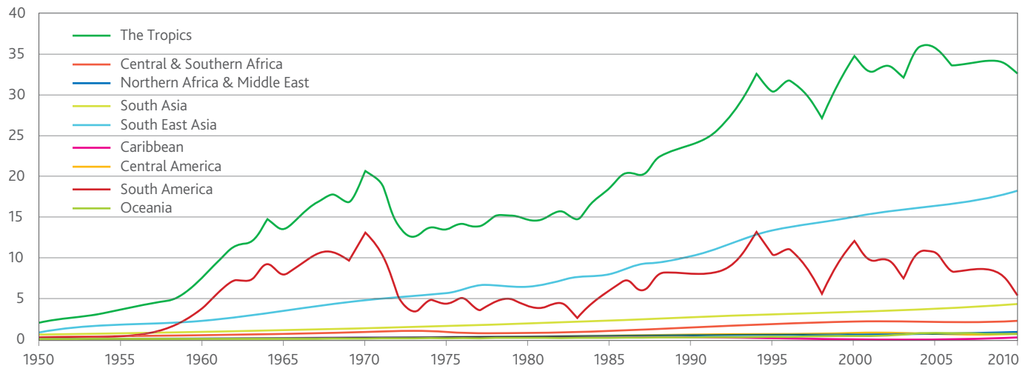
Source: FAO (2013), State of the Tropics project.

Marine catch [8]

Global fisheries production (excluding aquatic plants) increased from 18 million tonnes in 1950 to 154 million tonnes in 2011. Over this period the wild marine catch increased from 16 to 79 million tonnes, but its proportion of the global catch fell from 89% to 51%. At the same time aquaculture's contribution to global production increased from 3% in 1950 to 41% in 2011. The wild marine catch increased rapidly from the 1950s to the late-1980s, driven by a combination of rapid human population growth, subsequent rises in food demand, coupled with technological advances that improved the precision and efficiency of fishing effort and made commercial fishing in deeper offshore waters viable.

The Tropics accounted for almost two million tonnes of the marine wild catch in 1950 (12%), increasing to 32 million tonnes in 2010 (42%) (see Figure 4.1). The proportion of the wild marine catch from the Tropics has increased rapidly since the late 1980s, reflecting both the steady decline in the catch in the Rest of the World (notably in northern Europe and North America), and increased production in the Tropics. In the Tropics, South East Asia and South America are the major producers (see Figure 4.2). In South East Asia the wild marine catch increased from less than one million tonnes in 1950 to more than 18 million tonnes in 2010. The majority of the increase was in Indonesia (up by 4.7 million tonnes), China (3.0 million tonnes), Philippines (2.2 million tonnes) and Vietnam (2.0 million tonnes). The combination of strong population growth and rising living standards in these nations contributed to strong demand for fisheries output.

Figure 4.2 **Wild marine catch – the Tropics**



Source: FAO (2013), State of the Tropics project.

The rapid increase in production in the Tropics to 1970 was driven by Peru's anchoveta catch. Between 1950 and 1970 Peru's marine catch increased at an average rate of almost 30% per annum, from 75,000 tonnes in 1950 to 12.5 million tonnes in 1970. Between 1960 and 1970 anchoveta accounted for 98% of Peru's wild marine catch. Overfishing and the disruptive El Niño and La Niña weather patterns contributed to the fishery's collapse in the early 1970s, and almost two decades of poor catches followed. Production has since started to recover, supported by improved fisheries management (see Box 4.1).

In the Rest of the World the wild marine catch peaked in 1988 at 59 million tonnes, and has since fallen by 640,000 tonnes per annum on average, to around 45 million tonnes in 2010. Over the same period the wild marine catch in the Tropics increased by 450,000 tonnes per annum. Nonetheless, since the peak in the global catch in 1996, the rate of increase in the Tropics has fallen considerably, from an average rate of 5.1% per annum in the 14 years to 1996, to 0.1% per annum in the 14 years to 2010.

Up to the mid-1990s increases in catch were supported by the exploitation of new fisheries. For example, there was a rapid expansion of commercial fishing into the open oceans in the 1980s and 1990s (Swartz et al. 2010). Slower growth in the rate of expansion (and the marine catch) since then reflects that most commercially viable wild fisheries have now been exploited.

The moderation in growth of fisheries since the mid-1990s also reflects international efforts to improve fisheries management as the serious ecological and socio-economic consequences of over-exploitation in broad scale fisheries is increasingly recognised. Efforts in this area aim to prevent over-exploitation of species, maintain

[7] There is no clear definition of what a small-scale fishery is, but they are characterised as requiring only a small capital investment to operate in, use low technology gear and vessels (often non-motorised) and catch fish primarily for subsistence or local markets.

[8] Data are sourced from the Food and Agriculture Organization (FAO). The data are considered to be the best available, though are subject collection and reporting limitations. For example, it is widely acknowledged that the small-scale fisheries catch is significantly under-reported in official statistics.

Box 4.1 Anchoveta fishing in Peru

Off the coast of Peru is one of the world's most productive fishing areas. The coastal upwelling created as the cold Humboldt current collides with the continental shelf forces nutrient rich cool water to the surface feeding a rich phytoplankton and zooplankton 'soup' which is a major source of food for a variety of animals, including anchoveta (Aranda 2009).

The extreme abundance of anchoveta and their proximity to the coast has made their capture, processing and export a major economic activity in Peru. Nonetheless, the fishery is susceptible to El Niño events which cause ocean currents to change direction, surface temperatures to rise, and the upwelling to stop. In the absence of this food source the anchoveta and other animals either migrate, or feed at greater depth where they are not accessible to fishers.

The Peruvian anchoveta fishery began in the early 1950s and is one of the most important fisheries in the world in terms of landings and fishmeal production (The Economist 2011). Once it was identified as a valuable economic resource, landings of Peruvian anchoveta increased rapidly, from 1,200 tonnes in 1951 to more than 6.6 million tonnes in 1963, with the majority of the catch processed for fishmeal export. By 1963 Peru was the world's largest producer of fishmeal.

Between 1951 and 1964 the fleet increased from 25 to 1,744 vessels (Aranda 2009). Alongside poorly defined fisheries management principles, rapid fleet development reflected an 'open access' environment where there were no or limited restrictions to access rights. As a result, a significant over capacity occurred where fishers invested in larger and more modern vessels and equipment to ensure larger individual shares.

By 1965 scientists recognised the risks of over-exploitation and recommended the introduction of a total allowable catch of seven million tonnes. Nonetheless, in 1971 catches reached 12.3 million tonnes – the highest level ever reached for a single-species fishery in the world. In 1972 the industry was hit by a particularly strong El Niño event, and during 1972-73 anchoveta landings collapsed to less than two million tonnes.

The government nationalised the industry in 1973 to rationalise activity and preserve the resource. However, subsidising the fishing fleet during consecutive years of poor catch was impossible and led to the industry being denationalised in 1976. Anchoveta stocks began to recover in the early 1980s but another strong El Niño event in 1982-83 affected production and stocks did not recover through the 1980s. By the late 1980s, twenty years of poor catch was reflected in the age and condition of the remaining fishing fleet which numbered less than 400 vessels.

In the 1990s the privatisation of state-owned fishing assets saw strong investment to upgrade the fleet and its capacity, despite the introduction of laws in 1992 designed to prevent capacity building. The ensuing over-capacity led to the development of a range of policies aimed to ensure the industry's sustainability. Vessel restrictions were introduced in 1998, and in 2008 individual vessel quotas (IVQ) were introduced.

The IVQ model allocates temporary access rights to a vessel and a fishing license. Should a boat be withdrawn, its rights can be accumulated to other boats belonging to the same boat owner, but there is no increase in vessel numbers. A key aim of the IVQ model is to reduce over-capacity and move towards a smaller, more efficient fleet. Other policy changes include an enforced sustainable quota aimed at ensuring five million tonnes of anchoveta are left each year as spawning stock, and mandatory installation of satellite-tracking devices on vessels (The Economist 2011).

Recognition that over-exploitation of anchoveta could lead to the collapse of a nationally significant industry was a key factor in introducing more sustainable fishing practices in Peru. After accounting for the El Niño impact in 1998, the benefits of this approach are reflected in the relatively stable catch over the past 20 years.

Anchoveta fishing boat. Image: Derek Law.

biodiversity and ensure a sustainable food supply (Mora et al. 2009). Nonetheless, overfishing – when production exceeds the capacity for replacement by reproduction and growth – remains common. Fisheries typically progress through sequential stages of development, going from being undeveloped to developing, fully exploited, overfished, collapsed, and then if possible to recovery (Sea Around Us Project 2011).

The Food and Agricultural Organization of the United Nations (FAO) estimates that the proportion of underexploited or moderately exploited stocks declined from 40% of species/stocks in the mid-1970s to 15% in 2008, and that the proportion of overexploited, collapsed or recovering stocks increased from 10% to 32% (FAO 2010a)[9]. The proportion of fully exploited stocks has been relatively stable at about 50% since the 1970s. FAO estimates that in 2008:

- 3% of stocks were underexploited and 12% moderately exploited, and therefore, able to produce more than their current catches;
- 53% were fully exploited, with current catches at or near their maximum sustainable production; and
- 28% were overexploited, 3% collapsed and 1% recovering from depletion, and therefore yielding less than their maximum potential production.

Other research suggests the situation may be considerably worse, with 33% of stocks over-exploited and 24% collapsed in 2008 (Froese et al. 2012).

In 2006 the proportion of stocks in the Tropics and the Rest of the World that were overexploited or collapsed was estimated to be roughly similar, at around 45% (Sea Around Us Project – unpublished data). Nonetheless, it is likely that poorer data availability in the Tropics combined with higher levels of illegal, unreported and unregulated fishing mean that, relative to the Rest of the World, there is considerable under-reporting in official catch statistics for the Tropics.

The increased proportion of overexploited, collapsed or recovering stocks combined with limited scope to expand into new fisheries means that many wild marine fisheries will not be able to increase production until effective management plans are put in place to rebuild overfished stocks (FAO 2010a).

Fishing communities

Capture fisheries represent the most intensive use of wild species by humans, providing food security and income for millions of people (BIP 2012). Many of the world's fisheries are severely overfished due to both small-scale, subsistence fishers and large-scale, commercial fishing operations.

Small-scale fisheries account for more than half of the global fish catch and employ more than 90% of the world's 35 million capture fishers (FAO 2010a). Almost all of the catch from small-scale fisheries is used for human consumption, and many of the communities that rely on these fisheries are in the Tropics – in Asia, Africa, Latin America, the Caribbean and Oceania.

Despite the significant contribution of small-scale fisheries to food security, data on catch is lacking and the economic contribution fisheries provide to communities is poorly understood. For example, research undertaken in a number of tropical nations suggests that poor data for small-scale fisheries contributes to a large underestimate of marine catch with actual catches being between 1.7 to 6.2 times higher than official estimates (Zeller et al. 2006, Jacquet et al. 2010, Ramdeen et al. 2013). This lack of reliable information compromises the effectiveness of fisheries management and increases the likelihood of fishing access being over-licensed, to the detriment of marine ecosystems and national food security.

Compared to large-scale commercial fisheries, small-scale fisheries receive little attention from policy-makers. The communities supported by small-scale fisheries are typically poor, have insecure access rights to fishery resources and are not adequately represented in decision-making processes. In the short term these communities are likely to be the most affected by the implementation of sustainable fisheries management, but have much to gain in the long run if more equitable fisheries management can be achieved. The FAO is currently taking leadership to address these issues (see Box 4.2).

The development of large, capital-intensive, commercial offshore fleets using modern technologies to target fish is affecting small-scale fisheries, often reducing the volume of stock accessible to coastal subsistence fishers using small and often non-motorised craft. Reflecting the small-scale and localised nature of fishing in Africa and Asia, production in these regions is less than 2.5 tonnes per fisher per annum, compared with 24 tonnes per fisher in Europe's more industrialised fisheries (FAO 2010a).

The increase in distant-water fishing contracts, which allow foreign nations to fish other nation's waters, are also affecting local fishing communities in many developing nations. Licence fees for these contracts are typically paid to central governments, and the fishing communities that bear the major costs of these contracts – through reduced fish stocks and habitat destruction – typically see limited benefits from the allocation of contract revenues.

Marine catch and biodiversity

Fishing occurs in most marine environments ranging from coastal habitats including mangroves and seagrass beds, to coral reefs and deep sea habitats. These habitats are impacted to varying degrees by a range of factors including pollution from land-based sources, destructive

[9] FAO notes that probably only around 10% of the exploited fish stocks are assessed. Although the assessed stocks account for almost 80% of declared landings, for the large majority of exploited fish stocks there is little or no information on their status.

fishing practices and overfishing. These factors are in turn likely to be exacerbated by climate change, which may not have an immediately obvious effect but will accumulate over time if not addressed. For example, the International Panel on Climate Change's high carbon dioxide emission scenarios suggest that drastic changes in tropical oceans and coastal habitats would occur by the end of the century. Resulting habitat degradation and environmental change could reduce fisheries productivity in the Tropics by up to 50%, especially in near shore, shallow water environments such as coral reefs (Pratchett et al. 2011).

One reason for the declining marine catch is the 'tragedy of the commons' where, in the absence of clearly defined property rights, anyone with access to a shared resource has an interest in over-exploiting it, and it is in no individuals interest alone to maintain it. As witnessed in the Peruvian anchoveta fishery (see Box 4.1) this can lead to significant over capacity as fishers have incentives to invest in larger and more modern vessels to ensure larger individual shares. Without intervention, collapse of the resource is inevitable, with significant socio-economic and ecological consequences.

The tragedy of the commons effect has been exacerbated by government subsidies – notably in Europe and East Asia – which can act to support otherwise marginal fisheries. Globally, capacity enhancing fishing subsidies for items such as fuel and boat construction or renovation was estimated at US$16.2 billion in 2003 (Sumaila et al. 2010), and is contributing to fleet capacity that is significantly greater than is needed to fish sustainably (Schorr 2004).

An indicator of the direct impact of overfishing is the Marine Trophic Index (MTI). Until the early 1980s, the MTI indicated that global fisheries catch increasingly consisted of smaller fish that are lower in the food web (BIP 2012). This process, known as 'fishing down marine food webs', is a major issue as it demonstrates that larger predators are caught preferentially in such numbers that their stocks do not recover.

The loss of top predators and the reduction of the trophic structure have consequences for ecosystem stability and function, and threaten biodiversity more broadly.

Although there are large regional variations in the MTI, overall it has been stabilising or improving since the mid-1980s. While this is promising, the Fishing-in-Balance Index suggests that the improvement largely reflects the spatial expansion of fishing effort (Kleisner & Pauly 2011). That is, the expansion of fishing effort into areas where higher level predators have not previously been targeted is contributing to increases in the MTI.

The condition of recently exploited deep water habitats is also starting to cause concern as there is a greater awareness of the impact of modern fishing techniques on these previously inaccessible ecosystems. Deep ocean species are increasingly targeted as more accessible fish stocks are depleted and more strictly regulated. Species from deep water habitats are particularly vulnerable to overfishing because they tend to be slow growing and long lived compared with species from shallower waters. Although improving, a lack of data for these environments means that fishing's impacts are poorly understood at present.

Environmentally destructive fishing practices that have degraded marine habitats have further impacted fisheries over the past twenty years. The use of destructive fishing gear and practices – such as bottom trawlers, dynamite and poison – are still widely employed, even though their damaging impacts are well understood.

Another major issue is by-catch, which is the unintentional taking of non-targeted species including marine mammals, turtles and birds. It is estimated that 27 million tonnes of fish are discarded each year in commercial fisheries (Alverson et al. 1994). These practices impact biodiversity and compromise the productivity of global fisheries and the viability of marine ecosystems.

Looking forward

As human populations continue to grow, the future benefits that fishery resources can provide will depend largely on how well they are rebuilt and managed (Sumaila et al. 2012). A key challenge will be maintaining marine biodiversity and ecosystem services while also developing sustainable marine fishing practices.

New approaches to fisheries management being developed include the ecosystem approach to fisheries management (EAF) and co-management. EAF has a greater focus on ecosystem health and sustainability, and gives greater prominence to the 'precautionary approach' in fisheries management. The EAF also aims to deliver food and income security in an equitable manner. Practical issues associated with the effective implementation of EAF are being addressed (Paterson & Petersen 2010), though there are particular challenges in developing cross-border institutional and governance frameworks that address complex economic, social and environmental policy issues (FAO 2010b).

Widespread acceptance of ecosystem and co-management approaches to fisheries management represents a shift away from traditional single-species management tools such as maximum sustainable yield (Botsford et al. 1997). However, marine environments are complex, and fishing occurs at multiple scales, targets a wide variety of species and uses many different types of fishing gear. As such, a range of methods and management tools are needed for appropriate, sustainable fisheries management.

[10] The ecosystem approach to fisheries management (EAF) presents a more holistic approach than traditional fisheries management methods, and strives to take into account the structure and functioning of ecosystems and their components, as well as the needs and desires of societies in the context of sustainable use of marine resources. In addition to sustainability, the concept of equity is given prominence.

Box 4.2 Small scale fisheries

In 1995 FAO developed the Code of Conduct for Responsible Fisheries in response to growing concerns over the sustainability of global fishery resources. The code explicitly recognises the importance of small-scale fisheries in poverty alleviation and food security, and acknowledges the right of small-scale fishers to secure a livelihood and preferential access to traditional fishing grounds. Threats to communities relying on these fisheries extend beyond reduced fish catch due to increased competition with external fishers, and include the impacts on fisheries from pollution, coastal development and other land based practices (FAO & WFC 2009).

The 29th session of the Committee of Fisheries of the FAO agreed that, in view of the important role played by small-scale fisheries, FAO should continue to give priority to small-scale fisheries and ensure adequate visibility for them, particularly in relevant international forums that deal directly or indirectly with these fisheries. The Committee also approved development of a new international instrument on small-scale fisheries to complement the existing Code of Conduct for Responsible Fisheries, with input from all relevant stakeholders (FAO 2011).

Fishing, Philippines. Image: Richard Messenger.

Aquaculture production

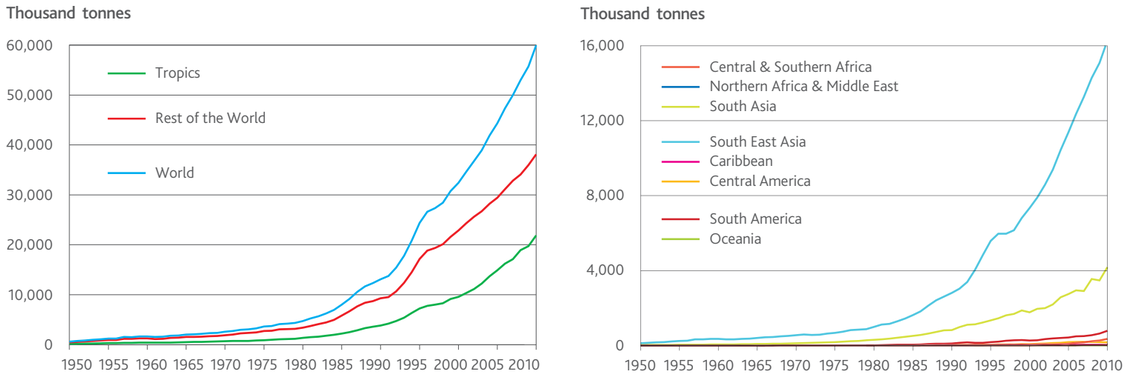
For millennia wild capture fisheries have been complemented by aquaculture. Large-scale commercial aquaculture is a relatively young industry, having only developed since the 1950s, but the earliest records of aquaculture date back more than 4,000 years to Egypt and China (Nash 2011). Like agriculture, aquaculture has undergone a productivity revolution in recent decades, however, unlike agriculture these advances are not slowing down.

As wild fish stocks have become depleted the importance of aquaculture has increased. Since the 1950s aquaculture production has increased significantly. In 2010, 60 million tonnes were produced representing 41% of global fisheries output (FAO 2012). Rapid growth in aquaculture production has contributed to global per capita consumption of aquaculture products more than doubling over the past 50 years, from 9 kilograms in 1961 to almost 19 kilograms in 2011 (FAO 2012, WHO 2013, FAOSTAT3 2013). For farmed fish, consumption has grown by an estimated 7% per year since 1980, from 1.1 kg to 8.7 kg per capita in 2010 (FAO 2012). It is often assumed that rapid increases in aquaculture production will reduce pressures on wild stocks, but population growth and extensive use of wild stock-derived fishmeal in aquaculture mean that fishing of many wild stocks remains unsustainable. On the positive side, production of species for which no feed is required (i.e. filter-feeding bivalves and carp) represents at least one third of all aquaculture production (FAO 2012).

Aquaculture practices can be separated into three main types depending on the level of technology and management that is used: extensive, semi-intensive and intensive. Extensive practices typically use low technology approaches over large areas with minimal external inputs including feeds, low stocking density and production rates. Frequently these systems will raise more than one species, or complement agricultural production. This is a very common practice in many parts of Asia, with the culturing of fish in rice paddies a part of integrated management on many farms. Semi-intensive culturing increases the focus to aquaculture as the primary economic process, but often includes a multi-species approach to diversify risk and allow for seasonal variation in production. In contrast, commercial intensive aquaculture focuses on providing large amounts of external inputs (feeds, oxygen etc) with high density monocultures, usually directed at high value species such as prawns or shrimp, and which are often destined for export markets.

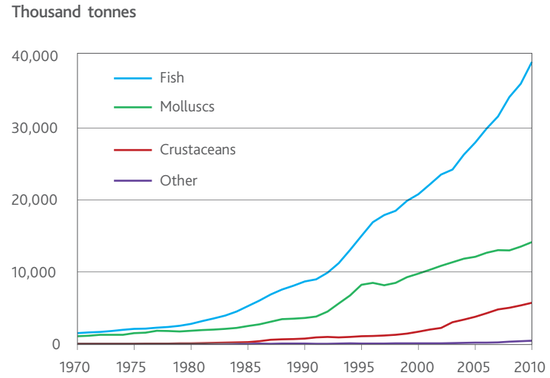
The rapid growth in aquaculture output, especially since 1980, has had both positive and negative effects on the wider environment. High intensity commercial monocultures can have impacts on downstream water quality and adjacent ecosystems. Other environmental and social impacts include the introduction of exotic species and diseases, the impact of poor water quality on the health of aquaculture stock and the displacement of small-scale fisheries.

Figure 4.3 **Aquaculture food production**



Source: FAO FishStatJ (2013), State of the Tropics project.
Note: Production data excludes aquatic plants and non-food production.

Figure 4.4 **Global aquaculture production by species group**



Source: FAO FishStatJ (2013), State of the Tropics project.

Trends

Marine and inland aquaculture production (excluding plant products) has increased considerably over the past 60 years, from 604,000 tonnes in 1950 to 60 million tonnes in 2010 (see Figure 4.3), with aquatic plants contributing another 19 million tonnes in 2010. In 2010, the Tropics produced 36% of reported global aquaculture production, up from 26% in 1950.

In the Tropics, South East Asia and South Asia are the largest aquaculture producers, with the top six aquaculture producing nations in the world[11] coming from these two regions (FAO 2012). In 1950 South East Asia produced 123,000 tonnes and South Asia 32,000 tonnes. By 2010 this had increased to 16 million tonnes and 4 million tonnes respectively (see Figure 4.3). The lowest aquaculture producers in 2010 were Oceania (12,700 tonnes), Northern Africa & Middle East (27,000 tonnes) and the Caribbean (36,700 tonnes). Although coming to commercial aquaculture production quite late, by 2010 South America was the third largest producer in the Tropics.

Worldwide, aquaculture production has increased almost 100 fold since 1950. With the exception of the decade to 1960 the Tropics has reported faster growth in the rate of aquaculture production than in the Rest of the World. Oceania and the Caribbean were the only two regions to report any decrease in production during this period, with Oceania having a 17% decrease in production between 1970 and 1980, and the Caribbean a 7% reduction between 2000 and 2010.

Globally, most aquaculture production consists of fish and molluscs, and to a lesser extent, crustaceans (see Figure 4.4 and Figure 4.5). Between 1970 and 2010 fish production increased from less than 1.5 million tonnes to 39 million tonnes, and mollusc production from 1.1 million tonnes to 14.2 million tonnes. Production of crustaceans, particularly shrimp and prawns, has increased rapidly, and more than tripled in the ten years to 2010, from 1.7 million to 5.7 million tonnes (see Figure 4.4), and its proportion of total global aquaculture production increased from 5.2% to 9.6%.

Freshwater fishes comprise the bulk of aquaculture, and production has increased from 49% to 57% between 1980 and 2010. Cyprinids (carp and barbels) accounted for around 27% of all aquaculture production worldwide. Marine molluscs are the second largest sectoral group, though their proportion of production has decreased from 38% in 1980 to 23% in 2010. Similarly, brackish water fish production halved over this period, while marine fish increased from 4% to 6% of production and crustacean production increased by a factor of four. In 1980, marine mollusc aquaculture was dominated by oysters and mussels at 50% and 30% of total quantity respectively, but by 2010 this had reduced to 33% and 13%. Over the same period clams/cockles increased from 15% to 35% of total mollusc production (FAO FishStatJ 2013).

In addition to increasing rapidly, the source of crustacean production has changed. In 1980, 81% of crustacean production was in brackish water culture, but by 2010 this had fallen to 47%, with the proportion from freshwater culture increasing from 16% to 41% (FAO FishStatJ 2013). Shrimp/prawn culture remains the dominant crustacean group across all three water types, representing 83% of crustacean production in 1980, although this decreased to 66% in 2010 (FAO FishStatJ 2013). This decrease has in part been due to disease outbreaks and severe weather events, as well as production diversification to other species (FAO 2012). Shrimp and prawn farming are very important in the Tropics, particularly in South East Asia and South America. Most shrimp are farmed in China, Thailand, Indonesia, India, Vietnam, Brazil, Ecuador, and Bangladesh.

[11] The FAO reports that China is the biggest aquaculture producer, followed by India, Vietnam, Indonesia, Thailand and Bangladesh.

Box 4.3 Rice-fish culture

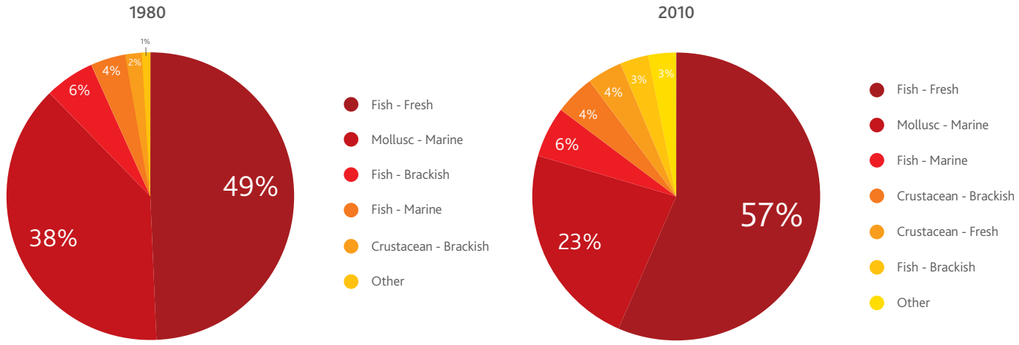
Fish is the major product in freshwater aquaculture, representing almost 92% of the 37 million tonnes generated from freshwater aquaculture in 2010 (FAO 2012). Much of this production is undertaken on by small-scale farms as extensive or semi-intensive co-production with other agricultural practices. One of the most common forms is rice-fish farming where fish are cultured in rice paddies. This type of production has a long history in Asia and in many other parts of the world (Halwart & Gupta 2004). However, the Green Revolution that began in the 1960s saw a shift from traditional to monoculture industrial farming practices, and by 2002 only about 10% of the area suitable for co-production aquaculture in the Mekong Delta was being used, with similar rates identified in other Asian nations (Berg 2002, Prein 2002).

In recent years focus has returned to rice-fish farming and other integrated agriculture/ aquaculture programs. Rice-fish farming combined with integrated pest management (IPM) typically requires lower fertiliser, pesticide and herbicide use with associated broader environmental benefits. In parts of Thailand, where declining soil fertility and poor water availability has reduced rice productivity, rice-fish farming combined with farming of other livestock such as ducks, chickens and pigs has improved economic, social and environmental outcomes and increased food security (Halwart & Gupta 2004, Tipraqsa et al. 2007). Similarly, in the Mekong Delta, rice-fish IPM farming produces similar yields to rice only farming, with lower production costs and greater product diversification (Berg 2002, Prein 2002). There are small losses of cultivatable land associated with rice-fish co-production because of the need to incorporate drains and shelters, but if managed properly, these losses are offset by overall yield improvements (Halwell 2008).

Rice-fish co-production also has other health and social benefits. For example, there are lower mosquito larvae densities in rice-fish paddies compared to paddies without fish. One survey in central Java found the prevalence rate of malaria decreased dramatically from 16.5% to 0.2% after the introduction of rice-fish farming, with continued low malaria rates five years after its inception (Halwart & Gupta 2004, Nalim 1994). Similar benefits have been demonstrated elsewhere including the reduction of diseases such as schistosomiasis (which have an aquatic snail as a host), and decrease in aquatic rice pests and many aquatic weeds (Halwart & Gupta 2004).

Rice fish harvesting, Cambodia. Image: Jharendu Pant.

Figure 4.5 **Global aquaculture production by species group and environment (% of total production)**



Source: FAO FishStatJ (2013) and State of the Tropics project.

Production

Around 600 species of fish, crustaceans, molluscs, other invertebrates, plants and algae are cultured in freshwater, brackish and marine systems (FAO 2012). Of these, freshwater and marine aquaculture accounted for 62% and 30% of production in 2010, and brackish production 8% (FAO FishStatJ 2013). Despite having the lowest production, brackish aquaculture accounts for almost 13% of the economic value of aquaculture production, while marine aquaculture accounts for 29% and freshwater 58% of value (FAO FishStatJ 2013). The high value production from brackish aquaculture is due to the importance of prawn/shrimp, which is a key export commodity, and in 2010 represented almost 15% of the total value of international fish trade (FAO 2012).

Approximately one-third of aquaculture production is non-intensive in nature, and requires no additional feed supply. This is an effective means of generating a reliable protein source with relatively low environmental impacts, particularly in low income regions (FAO 2012). For aquaculture taxa such as molluscs and algae no supplementary feeding is required, while for 'coarser' fish species like carp and tilapia – which are commonly cultured at the small scale for local or regional markets – only minimal low grade feeding is required.

In many developing nations rural agriculture-aquaculture co-production not only provides a vital protein source and food security, but aquaculture products can aslo act as an additional revenue source or 'cash crop' in many households (Wijkström 2009). For example, in South East Asia farmers engaged in aquaculture generally report higher household incomes and perform relatively well with respect to other social and environmental indicators (Wijkström) (see Box 4.3).

The aquatic plant/ algae market is also valuable, particularly because it can be produced in tandem with other aquaculture products (see Box 4.4). Aquatic plant production in 2010 was 19 million tonnes and was valued at US$5.6 billion (FAO FishStatJ 2013). China, Indonesia and the Philippines are the three largest producers of aquatic plants, responsible for almost 90% of global production. Much of this is utilised as food products in Asia, with the remainder used for fibre and for animal and biofuels production (Wersal & Madsen 2012).

While the growth in aquaculture for food consumption is well-established, other segments of the aquaculture industry – such as low volume, high value ornamental fish and pearls – are developing rapidly. In 2010, global ornamental fish production was around 41,000 tonnes, with an estimated value of US$695 million (FAO 2013). Similarly, in the Indo-Pacific region, pearl farming, which is ecologically sustainable and of high value, has developed rapidly (Cartier & Ali 2012). Pearl farming in particular is a valuable source of income for many small communities in this region.

With increased aquaculture production has come a corresponding increase in demand for 'seed stock' or juveniles for grow out. To help meet this demand there is increasing hatchery and nursery production, especially for the high value species like Atlantic salmon, barramundi and shrimp,

along with increased research and development into captive breeding to reduce the reliance on wild juvenile stocks (Mair 2002, CSIRO 2013).

Aquaculture risks

The rise of the aquaculture industry over the past 60 years has played an important role in providing food and income for many nations, particularly in the Tropics. However, the exponential rise in production, particularly from high intensity commercial production, has increased environmental and social impacts, especially in low income nations (Allison 2011). The aquaculture industry will need to address a range of issues to be sustainable, including those associated with disease outbreaks, coastal habitat losses, competition with urbanisation, climate change, food and economic security and inter-industry conflicts. However, the industry is making advances in productivity, plant based feeds, multi-species aquaculture, the growing use of filter feeders to improve water quality and improving livelihoods in poor regions.

While yield from wild capture fisheries has been relatively stable since the late-1980s, aquaculture production has increased rapidly, and now accounts for almost 47% of global fish consumption (FAO 2012). Aquaculture does protect some wild fish stocks, but, like livestock, it also consumes products that are sourced from wild fisheries, particularly fishmeal and fish oil. The demand from the aquaculture and livestock industries for these products has increased demand for forage/reduction fishes (which include anchovies, herring, mackerel, sardines etc) and trawl by-catch (Regnier & Schubert 2013, Naylor et al. 2009). Where wild catch fishing targets these fish it is putting pressure on the sustainability of wild stocks and, in some regions, is also affecting small-scale fisheries and subsistence fishers that rely on these fish.

In 2006, the aquaculture industry consumed the equivalent of 23.8 million tonnes of live weight equivalent fish in the form of feed inputs, representing 87% of the wild catch of small pelagic forage fish species (Tacon & Metian 2009). In 2009, aquaculture consumed 63% of global fishmeal production and 81% fish oil production, up from 10% and 17% respectively in 1990 (Fishmeal Information Network 2013, Chamberlain 2011). This rising demand is leading to increased competition between fish for domestic consumption and fish for commercial fishmeal production (Regnier & Schubert 2013, Naylor et al. 2000).

In parts of Asia these small forage fish are an important protein component for low socio-economic groups. Increased competition between low income communities and the aquaculture market for these fish is contributing to food security risks (FAO 2006, Tacon & Metian 2009). Commercial fishing effort targeted at supplying feedstock for fishmeal is also recognised as being a major factor in the overexploitation of these fish stocks, particularly in Asian coastal waters (Naylor et al 2000,

Table 4.1 Change in aquaculture production

Region	Production thousand tonnes (% change on previous decade)						
	1950	1960	1970	1980	1990	2000	2010
Tropics	**156**	**411 (164)**	**678 (65)**	**1,332 (96)**	**3,801 (185)**	**9,568 (152)**	**21,849 (128)**
Central & Southern Africa	0.4	2.4 (507)	4.1 (74)	6.9 (66)	13.2 (92)	51.5 (291)	351 (582)
Northern Africa & Middle East	0	0 (0)	0.1 (n.a.)	0.2 (49)	0.3 (130)	3.2 (822)	27.1 (758)
South Asia	32.2	56.9 (77)	119 (109)	304 (156)	823 (171)	1,780 (116)	4,182 (135)
South East Asia	123	351.3 (185)	554 (58)	997 (80)	2,814 (182)	7,344 (161)	16,273 (122)
Caribbean	0	0 (0)	0.4 (n.a.)	2.3 (565)	12 (414)	39.6 (231)	36.7 (-7)
Central America	0	0.1 (n.a.)	0.5 (440)	7.6 (1561)	27.6 (262)	74.4 (169)	176 (136)
South America	0	0 (0)	0.1 (n.a.)	13.8 (11,120)	109 (687)	266 (144)	790 (197)
Oceania	0.1	0.1 (69)	0.2 (62)	0.2 (-17)	1.99 (1218)	8.84 (343)	12.7 (44)
Rest of the World	**448**	**1,245 (178)**	**1,889 (52)**	**3,374 (79)**	**9,273 (175)**	**22,850 (146)**	**38,086 (67)**
World	**604**	**1,655 (174)**	**2,567 (55)**	**4,706 (83)**	**13,074 (178)**	**32,419 (148)**	**59,936 (85)**

Source: FAO FishStatJ (2013), State of the Tropics project.
Note: Totals may differ slightly due to rounding. Data exclude non-food and aquatic plant production.

Box 4.4 Integrated multi-trophic aquaculture

The development and growth of large scale, intensive industrial aquaculture has led to increased environmental risks. These include the release of nutrients and wastes into the wider environment, genetic contamination from aquaculture stocks into wild populations, accidental release of potentially invasive species, and increased disease risk to farmed species and their wild relatives (Halwell 2008). Rapid growth in the industry has raised awareness of the issues of sustainability and impacts on wider ecosystem services, especially from industrial scale or intensive aquaculture (Troell et al. 2009).

Traditionally, multi-species aquaculture has been practised throughout the Tropics in freshwater and brackish ponds. In Indonesia, for example, milkfish, a variety of shrimp, mullet and barramundi are often farmed together. This type of farming, which is generally on a small-scale, has been sustainable for hundreds of years and needs fewer inputs than intensive shrimp farming (Troell 2009).

The development of large-scale integrated multi-trophic aquaculture (IMTA) systems is a recent development specifically designed to address some of the issues faced by intensive commercial aquaculture projects (Halwell 2008). These systems use multiple species from different trophic levels to reduce waste and maximise nutrient processing. For example, high value fish species like salmon, fed on pellets, are co-cultured with shellfish which act as filter feeders to remove particulates from the water. Algae can also be actively cultured to remove dissolved nutrients from the water. The outcome is improved water quality and environmental conditions as well as diversified production (Chopin 2006, Chopin et al. 2012).

This type of development is relatively new and its techniques are still evolving. The benefits of this approach have been recognised and adopted by the largest salmon producer in eastern Canada, several commercial operations in northern Europe, and many small-scale operations in other parts of the world (Halwell 2008). In the Tropics these techniques are still largely experimental, but a wide range of options are being explored (Troell 2009). In Vietnam for example, lobster farmed together with green mussels show better growth and health outcomes, with improved water quality around co-cultured cages (Pham 2004). As the benefits of this approach are recognised a greater number of farmers are adopting the practise of integration (Troell, 2009).

This approach is considered one of the few cost effective means of addressing eutrophication and nutrient wastes from aquaculture in coastal ecosystems. It also allows a greater level of water re-use in recirculating systems due to lower contaminant levels. There are also suggestions that, subject to appropriate management, this type of aquaculture has the potential to generate carbon credits through increased carbon sequestration in biomass production and, for algae components, a feedstock for biofuel production (Chopin et al. 2010).

Box 4.5 Aquaculture and coexistence

In Bangladesh land-based shrimp production is a high value export commodity, with production increasing over the past 20 years. Over that period increased soil salinisation has reduced the productivity of neighbouring agricultural lands (Karim 2006), with severely reduced rice yields and the complete loss of wheat, jute and sugarcane production. Local farmers believe shrimp farming is the major cause of more saline soils. Therefore, while aquaculture producers have received increased income from their activities, other farmers and many in the local community have experienced reductions in income and wellbeing, which has led to conflict between the two groups (Karim 2006).

Similar conflicts have arisen in other parts of the Tropics, especially where mangrove forests have been converted to shrimp farms. Although shrimp farming provides much needed income for a small number of people within a community, many of the ecosystem services provided by mangrove forests are lost to the greater community (see Mangroves indicator). These losses include deterioration in water quality, biodiversity loss, increased soil and water acidification, reduced flood control, loss of fish and shrimp nursery habitat, decreased coastal protection and increased disease risk (Gowing et al. 2006).

Shrimp farms. Image: Eric Carlson.

FAO 2006). This has flow-on impacts on the sustainability of fisheries, as well as to local, small-scale fishers. In addition, for a number of aquaculture species, including tuna, shrimp and eel, juveniles or 'seed' often need to be sourced from wild stocks, putting pressure on natural systems (Naylor et al. 2000).

The growing move to intensive aquaculture, and in particular mono-aquaculture, leads to other environmental risks including disease and loss of water quality. Disease risks are greater in intensive farm systems, and have been responsible for major losses in recent years across South America, Europe, Asia and Africa. For example, in 2011, disease outbreaks virtually wiped out marine shrimp farm production in Mozambique (FAO 2012). In tropical regions with higher water temperatures and faster growth rates, disease progression in aquaculture farms tends to be more rapid, and losses are typically greater (Leung & Bates 2013).

Overfeeding and waste products from intensive aquaculture can also have downstream impacts on water quality, resulting in development of eutrophic, hypoxic or dead zones. These issues have resulted in tighter environmental controls in many nations, and the development of integrated multi-trophic aquaculture programs to address water quality issues. However, in regions with poor environmental governance, water quality issues have the potential to impact the wider environment and ecosystem services provided to communities. Unless adequately addressed, modelling suggests that these risks will increase with projected climate change scenarios.

In the future, aquaculture will be increasingly vulnerable to climate change. Changing weather patterns, greater frequency of extreme weather events, increasing sea level and physiological stress from increased water temperatures and decreased oxygen levels have been identified as risks to aquaculture (Barange & Perry 2009). There is also evidence that ocean acidification is affecting larval development in marine shellfish aquaculture (Barton et al. 2012). With marine shellfish contributing 23% of total aquaculture production in 2010 (see Figure 4.4) this could have a major effect on total output.

The aquaculture industry is expected to continue to grow, but there are likely to be increased environmental and other constraints on future development, especially for intensive aquaculture ventures and in coastal areas. For land-based aquaculture, in areas where the supply of cultivatable land is limited, a range of social and economic factors with the potential to create conflict between competing activities will also need to be addressed (see Box 4.5).

Even though there are risks, aquaculture is a diverse activity. More than 220 species of finfish and shellfish are currently farmed and many of these have a very low environmental impact. Filter feeders such as clams, oysters, mussels and algae can have positive effects on water quality and surrounding ecosystems and require very few inputs.

Looking forward

Based on current consumption rates, it is estimated that global fisheries production will need to increase by 60% by 2050 to meet demand (Regnier & Schubert 2013). Sustainable aquaculture has the potential to provide this resource to ensure a future viable protein supply (Halwell 2008). Fish convert energy more efficiently than livestock and produce substantially less greenhouse gases (McMichael et al. 2007). Improvements being made in productivity and environmental practices around large scale farming enterprises will be important for future food supply and livelihoods in the Tropics. Additionally, aquaculture-derived stock has the potential to support and restore wild fisheries stocks.

However, appropriate management is fundamental to ensure that the environmental and social costs do not outweigh the benefits (Halwell 2008). The key constraints that are likely to affect future development include the sustainability of external feedstocks (fish meal and fish oil), water quality and quantity, climate change effects and energy supply. Appropriate governance and integrated management practices will be fundamental to the future expansion and success of aquaculture to minimise conflicts or exploitation between aquaculturists and other sectors of the wider community.

Coral reefs

Coral reefs are one of the most complex and diverse ecosystems on Earth. They are complex calcium carbonate structures found in warm, shallow marine waters between the latitudes of approximately 30 degrees north and south of the equator. Corals do exist outside these latitudes, but do not form coral reefs. Coral reefs cover only about 1.2% of the continental shelf area but are estimated to support 25% of all marine species (Spalding et al. 2001) and, there is strong interdependence between corals and many other species such as reef fishes that inhabit them. This co-dependency between corals and their associated biota is critical to coral resilience, although the exact mechanisms are poorly understood (Pratchett et al. 2012).

Coral reefs and the marine life they support have been exploited by humans for millennia. For much of this time exploitation has been at sustainable levels. However, growing human populations and market demand is leading to unsustainable resource extraction in many areas. Combined with other anthropogenic impacts such as increased sedimentation, nutrient loads and climate change, the health and resilience of coral reefs are increasingly threatened (Cesar et al. 2003).

Approximately 28% of coral reefs are located in protected areas. However, more than half of these are in Australia (Burke et al. 2012). Many protected areas are small and fragmented, but if adequately protected they can provide community benefits that go well beyond the immediate area of protection (Spalding et al. 2001).

Coral reef distribution and biodiversity

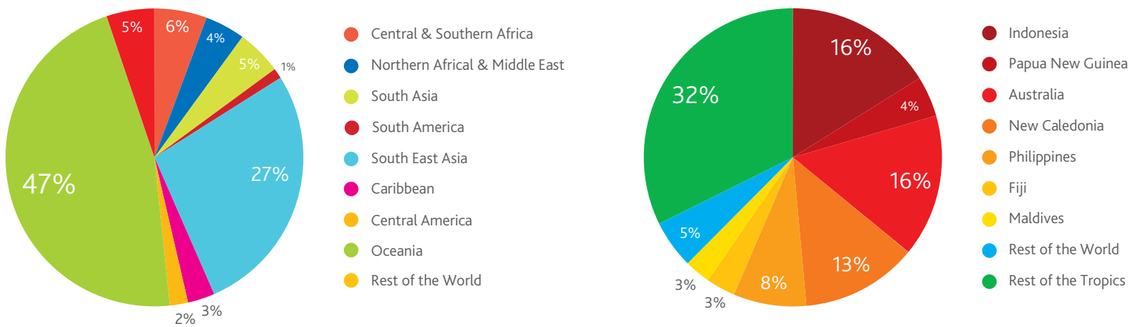
Globally, coral reefs cover approximately 300,000km^2 (see Figure 4.6), of which 95% is in the Tropics. Oceania alone accounts for 47% of global reefs. In Oceania, Australia accounts for 15% of global reefs, New Caledonia 13%, Papua New Guinea 4%, and Fiji 3%. South East Asia has 27% of global coral reefs with Indonesia having 16% and Philippines 8%.

The greatest coral diversity hotspot is in the South East Asia/ Western Pacific region bounded by Indonesia, the Philippines, Papua New Guinea and the Solomon Islands. This region has around 83% of the range of Indo-Pacific corals and reef fishes and is collectively known as the Coral Triangle (Veron 2000). Another coral reef hotspot is the Red Sea, which has a large number of endemic corals.

Change in coral reef health status

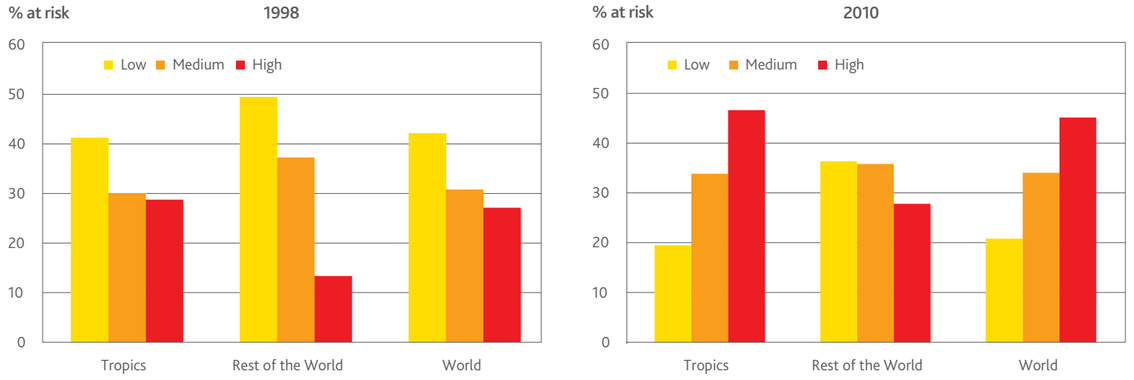
Globally both the range and intensity of threats to coral reefs is increasing. Threats are both of local origin (largely a consequence of local human activities), and of broader global origin such as those posed by ocean acidification and increased thermal stress. Reef health is also affected by coral diseases and predators such as the crown-of-

Figure 4.6 **Distribution of coral reefs by area**



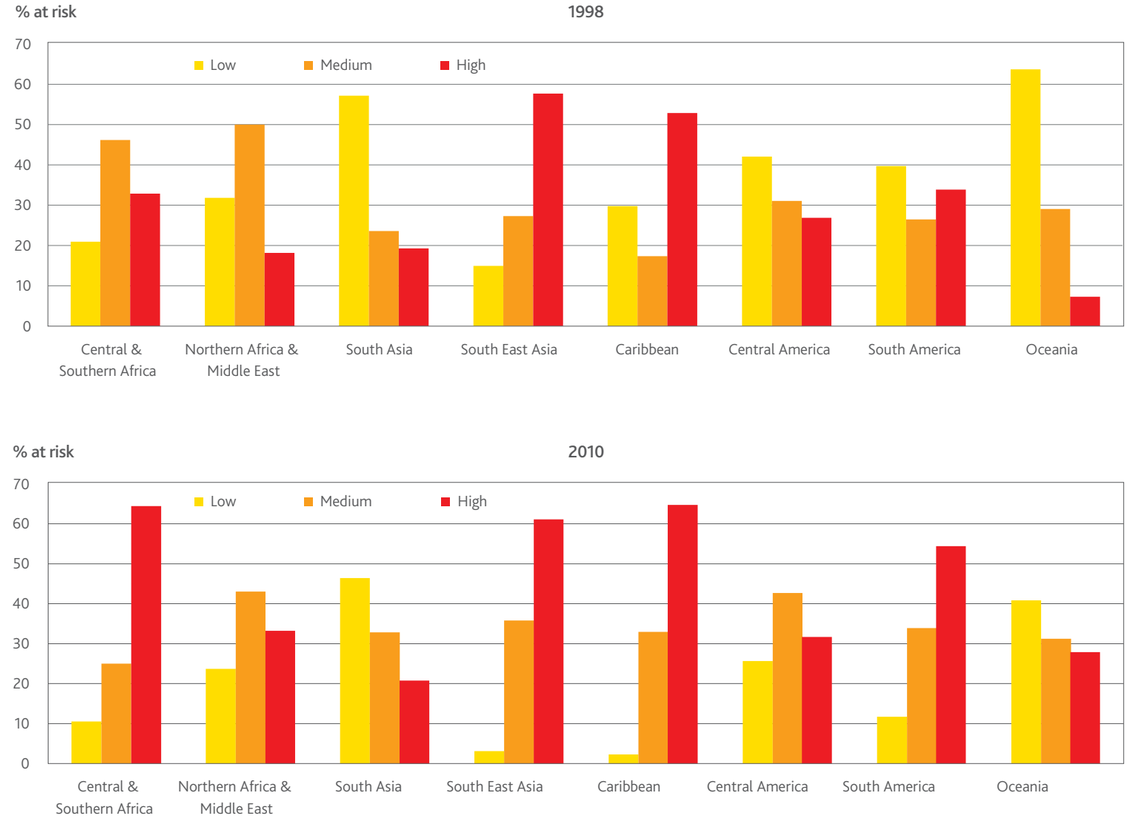
Source: Spalding et al. (2001), State of the Tropics project.
Note: Totals may not sum due to rounding.

Figure 4.7 Level of risk of coral reefs from integrated local threats



Source: Bryant et al. (1998), Burke et al. (2011), State of the Tropics project.

Figure 4.8 Level of risk of coral reefs from integrated local threats by region in the Tropics



Source: Bryant et al. (1998), Burke et al. (2011), State of the Tropics project.

thorns starfish whose population outbreaks may also be linked to anthropogenic threats (Hughes 2009, Fabricius et al. 2010, Haapkyla et al. 2011).

An integrated analysis[12] of four local threats (classified as marine pollution, overfishing and destructive fishing, increased coastal development and terrestrial sedimentation) suggests that worldwide, the proportion of coral reefs at high risk increased from 27% in 1998 to 45% in 2010 (see Figure 4.7). The proportion of corals at high risk in the Rest of the World doubled from 13% to 28% but due to their relatively small area, most of the global change was due to the increase in the Tropics. Only 20% of reefs worldwide are now considered to be at low risk from local impacts compared with 42% in 1998.

Regionally, local threats to corals have increased markedly since 1998. In 1998, more than 40% of reefs in four of the eight tropical regions were classed as being at low risk from the four local impacts (see Figure 4.8). By 2010 only Oceania and South Asia had more than 40% of coral reefs at low risk. Central & Southern Africa had the largest increase in the proportion of reefs at high risk, almost doubling from 33% to 65% between 1998 and 2010. The risks to corals also increased markedly in the Caribbean and South East Asia, with less than 5% now considered at low risk and more than 60% considered at high risk.

Of the Oceania nations Australia has the greatest area of coral reefs (see Figure 4.6) with 67% considered at low risk from local threats. Similarly, in the South Asia region 66% of the Maldives coral reefs are assessed as at low risk from local threats. At the other end of the scale, in Indonesia only 4% of coral reefs are considered at low risk from local threats, and in the Philippines it is less than 1%.

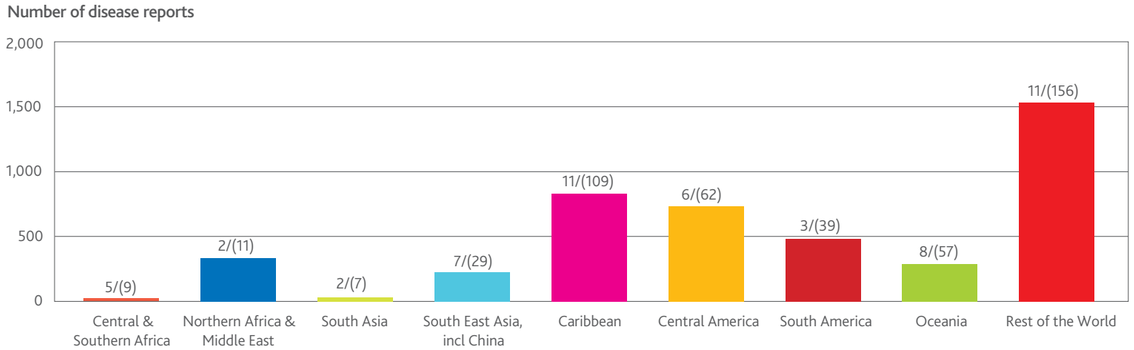
Studies in the Caribbean have documented losses of 80% of coral cover between 1977 and 2002. Since the 1990s though, the rate of loss has slowed (Gardner et al. 2003). There are indications some reefs in the region are now recovering, although a number of reefs are considered beyond recovery and many are still vulnerable.

In South East Asia the greatest local threats to coral reefs are overfishing and destructive fishing, with almost 85% of reefs threatened by these hazards (Burke et al. 2012). Destructive fishing includes the use of poisons or explosives, which often results in significant collateral damage and slow recovery rates for both corals and reef animals (Saila et al. 1993). As this region also forms part of the Coral Triangle, significant biodiversity is at risk from these widespread threats.

Currently 45% of world reefs are considered at high risk, largely due to local threats including fishing, water quality, coastal development and tourism (see Figure 4.7). The impacts of global scale threats will further compound local threats

[12] The integrated local threat is determined by aggregating the risk posed by a) overfishing and destructive fishing; b) coastal development; c) marine pollution; d) sedimentation. The integrated local threat was assessed as per Reefs at Risk (Bryant et al. 1998) and Reefs at Risk Revisited (Burke et al. 2011). In the 2011 data set reefs assessed at very high risk were aggregated with reefs at high risk to allow direct comparison with 1998 data.

Figure 4.9 **Reports of coral disease by region***



Source: Source: Burke et al. (2011), State of the Tropics project.
*Number above bar is number of nations within region reporting disease and number in parentheses is number of separate reported studies undertaken in the region (that is, the reporting effort). Total number of nations reporting disease is 53, as two nations (Saudi Arabia & USA) have disease reports in both the Tropics and the Rest of the World.

and it is estimated that up to 75% of all coral reefs will be at high risk by 2050 (Burke et al. 2011).

Threats to coral reefs

Climate change is a major threat to the resilience of coral reefs (Hughes 2009, Marshall & Schuttenberg 2006). While corals are not excessively vulnerable to sea level change, rising ocean temperatures and ocean acidification pose major threats (Hughes 2009). As many coral species are considered to be close to the limit of their thermal tolerance, even modest increases in temperature can be critical (Burke et al. 2011). Increased water temperature is a major cause of coral bleaching[13], with the frequency of bleaching incidents increasing in recent decades. In 1997-98 a strong El Niño event led to high rates of coral bleaching in many parts of the Pacific and Indian Oceans, with recovery rates variable among locations (Wilkinson 2002). Ocean acidification occurs when excess CO_2 from the atmosphere dissolves in seawater. This affects the ability of corals to form a calcium carbonate skeleton and will hinder coral reefs in their ability to recover from disturbance such as storms.

Two major biological stresses to corals are disease and crown-of-thorns starfish (COTS) outbreaks (Wilkinson 1998). The crown-of-thorns starfish is a large coral eating seastar which occurs naturally at low densities and normally has little impact on coral reefs. However, outbreaks occur when the population of COTS exceeds the rate at which corals can recover from feeding. COTS outbreaks tend to be recurrent but there are indications that they may be linked to nutrient enrichment of coastal waters from terrestrial activities such as agriculture (Hughes 2009).

Disease is another notable threat to corals. Increased reporting of coral disease in recent decades has been linked to increases in water temperature, nutrients and sediment (Goldberg & Wilkinson 2004, Marshall & Schuttenberg 2006, Boyett et al. 2007).

Worldwide there have been almost 4,500 reports of disease in corals, with 96% of these made since 1970 (Burke et al. 2011). Almost 35% of reports have been from 11 nations outside of the Tropics (see Figure 4.9). The Caribbean and Central America have reported many more instances of coral disease than the Indo-Pacific, with around 82% of corals in the Caribbean considered vulnerable to disease (Goldberg & Wilkinson 2004) (see Figure 4.9). Both Central & Southern Africa and South Asia have had very low reports of disease (21 and 31 respectively) though this is most likely due to the lack of studies as only 9 and 11 studies were reported for these regions respectively (Harvell et al. 2007). As South Asia has a high proportion of reefs at low risk from local threats (see Figure 4.8) they may also have a lower disease risk. Research has demonstrated that mutualism among corals and reef fishes can have a beneficial effect in inhibiting disease spread (Pratchett et al. 2012), suggesting that disease resilience in part relies on healthy fish populations (Cole et al. 2009).

[13]Many tropical, reef building corals have a symbiotic relationship with marine algae, which can provide up to 90% of coral energy needs. Coral bleaching occurs when certain conditions (especially high water temperatures) stress the coral and it expels algae from its tissues. This results in decreased growth, reproduction and increased susceptibility to disease.

Box 4.6 Tourism – Are reefs being loved to death?

Tourism is the largest sector of the global economy, accounting for 8% of employment, 35% of export services and 5% of global GDP (Honey & Krantz 2007). With growth of 3.5% per annum expected through to 2030, tourism will continue to be a major industry, especially in the Tropics (UNWTO 2012a).

Many nations, and particularly small island nations, are dependent on coral reefs for a large proportion of their economic activity (Burke et al. 2011), and reef-related tourism is expanding rapidly (Cesar et al. 2003). More than 38% of the Maldives GDP is from tourism (Loper et al. 2008), with over 60% of tourists visiting for scuba diving on reefs.

It is clear that a healthy coral reef system is essential if this industry is to continue. While the Maldives has no reefs under formal protection, there are a number of informal protections in place which ensure this key tourism drawcard remains viable.

Reef-related tourism can place reefs at risk of being 'loved to death', or can provide the economic incentive for better management of reefs. High intensity tourism can impact reefs in a similar manner to other unsustainable activities such as destructive fishing.

Risks from tourism include building infrastructure that removes coastal vegetation and increases nutrient and sediment loads, marine pollution from tourism activities, overfishing to supply tourist food requirements and high intensity visits to dive sites (Tratalos & Austin 2001). The exclusivity of some tourism developments are also having negative social impacts, with local communities frequently excluded or disenfranchised (Loper et al. 2008).

Encouragingly, increasing recognition of the importance of sustainable ecotourism is contributing to greater efforts by businesses and governments to engage communities and to protect reefs, while still providing opportunities for jobs and economic development.

Although there has been a long history of fishing on coral reefs, most of this effort was from small-scale subsistence fishing which did not compromise the trophic structure of the reef. As coastal populations increase, many nations have become increasingly reliant on fishing for subsistence or income, with flow on effects to reefs (Loper et al. 2008). In addition, the export of fish products to meet the demands of other nations has led to unsustainable fishing activities on many reefs, resulting in decreases and/or local extinctions of top order predators, altered food webs and the loss of key species (Hughes 2009). With these shifts in trophic structures there have been changed pressures on coral reefs. For example, a combination of overfishing of herbivorous fishes and increased nutrient loads can result in a shift from a coral dominated system to an algal one (Jessen et al. 2012).

Sustained and ongoing degradation of coral reefs largely manifests as reduction in live coral cover and habitat complexity, and reduces local biodiversity and productivity. Consequently, it is expected that maximum fisheries production on coral reefs in the Pacific will decline by 30-50% during this century due to both ongoing habitat degradation and direct climate impacts on key fisheries species (Pratchett et al 2011).

Benefits of coral reefs

The links between coral reef systems, coastal communities, fisheries, mangrove systems, sandy beaches and tourism means that the health and integrity of each component part is necessary for the whole system to be sustainable. Coral reefs provide ecosystem services estimated to be worth around $6,000 per hectare per year (Costanza et al. 1997). This value does not include the potential benefit from biotechnologies in the form of pharmaceuticals and other products derived from reef organisms that are being explored and developed for commercial purposes (Bruckner 2002) (Hughes 2009).

Like mangroves, coral reefs protect adjacent coastal communities from the worst effects of severe storm and cyclonic events (UNEP-WCMC 2006). Destruction of fringing coral reefs reduces these benefits to adjacent coastal areas. Estimates in the Dominican Republic suggest that loss of coral could result in a 65 -100% increase in beach erosion on its shores, which would have flow-on effects to the tourist industry (Wielgus et al. 2010).

Effectively managed marine protected areas (MPA) not only protect the immediate zone inside the protected area but also have positive effects outside. Increased fish abundance in areas outside the protected zones is an important means of ensuring community fisheries can be maintained whilst protecting key habitats (Almany et al. 2007). Effective management of protected areas is critical to this success. Australia has demonstrated how successful MPAs can be through a centralised system of planning, legislation and enforcement (Miller & Sweatman 2004), although increasing coastal development is causing concern in parts of the community (see Box 4.7).

Local, community-based management programs can also be effective in protecting the integrity of coral systems (Fox et al. 2012). In many tropical nations, particularly island nations, fish and shellfish provide up to 90% of dietary protein (Loper et al. 2008). Coral reef systems have provided many of these subsistence fishers with a regular supply of protein for generations. Many of these communities recognise the importance of coral reefs, and manage them through local community arrangements to ensure resource sustainability (Loper et al. 2008).

Table 4.2 **Great Barrier Reef marine park zoning**

GBR Zoning	IUCN Equivalent Category	Area (km2)	% of Park
Preservation & Scientific Research Zones	IA	865	0.2
Marine National Park & Commonwealth Islands Zones	II	114,715	33.3
Buffer & Conservation Park Zones	IV	15,040	4.4
Habitat Protection & General Use Zones	VI	213,780	62.1

Source: GBRMPA (2005)

Looking forward

Coral reef systems are a significant part of the Earth's biodiversity that have persisted and adapted to changing conditions over time. However, current threats acting in combination at local and global scales are affecting coral reef health and resilience. Appropriate risk management at the local level, in conjunction with global efforts to mitigate climate change impacts, is essential to ensure the ongoing survival of diverse coral reef systems. Protection will require the collective effort of numerous stakeholders to ensure viable coral reef communities survive for future generations.

Box 4.7 The Great Barrier Reef – an exercise in multiple user management?

The Great Barrier Reef (GBR) is the largest coral reef ecosystem in the world, covering 346,000km^2 off the east coast of Australia. It was declared a national park in 1975 and a World Heritage Area in 1981 (GBRMPA 2012a). The GBR contains over 2,500 individual reefs, 900 islands and extensive areas of mangroves and seagrasses. It is rich in marine biodiversity, with over 5,000 species of molluscs, 1,500 species of fish and 400 species of coral (CRCReef 2006). It is considered one of the best managed coral reef systems in the world although it faces increasing pressures, particularly from coastal development (UNESCO 2012a).

Like many marine protected areas the GBR is managed for multiple uses, rather than as a strict nature reserve. Accordingly, it is zoned into different management categories that, similar to the IUCN, define the level of protection (see Table 4.2).

Due to its proximity to the Australian coast the GBR is subject to run-off from urban, industrial and agricultural activities, which affects water quality on the reef. In 2012, UNESCO assessed whether management and conservation of the GBR is likely to maintain it as an area of 'outstanding universal value' (UNESCO 2012b) and identified that the region faces significant threats requiring improved strategic management. Climate change, catchment run-off, coastal development, dredging, port development, shipping and extractive uses were identified as the most important threats (UNESCO 2012a).

To address these concerns a strategic assessment has been undertaken by the federal and state governments to identify better ways to manage future development sustainably, and maintain the 'outstanding universal value' of the GBR (GBRMPA 2012b).

Image: Mark Ziembicki.

Coral Reef, Solomon Islands.
Image: Mark Ziembicki.

Mangroves

Mangroves are trees and shrubs that inhabit the coastal intertidal zones of estuaries, lagoons and rivers where fine sediments accumulate. They are adapted to live in saline conditions where gas exchange is limited and where they are exposed to the daily rhythm of the tides. About 96% of the world's mangroves occur in the Tropics with a few species extending to sub-tropical and temperate latitudes as far as 32 degrees North and 38 degrees South (Spalding et al. 1997). Mangroves are one of the most productive and biologically complex ecosystems on Earth (Duarte 2009). They provide important ecosystem services including nursery habitat for fish and crustaceans and food sources for a variety of animals. They also act to build up land by trapping sediment, help to filter pollutants and stabilise and protect coastal land from erosion.

Mangroves have long been utilised by people (Spalding et al. 2010), and many local coastal communities remain reliant on the resources mangrove forests provide. Despite this long association, mangroves are generally undervalued by the broader community and are often considered inhospitable areas of little economic value (FAO 2007). Due to the relative lack of interest in mangrove forests, global information on mangrove extent and health is fragmented. The first global dataset was produced in 1980 but provided records for less than half the nations that have mangrove forests (FAO 2007). The most recently collated global dataset is more comprehensive but controversy remains over its accuracy (Giri et al. 2011; Gilman et al. 2008).

The main causes of mangrove loss in the 20TH century were increased demand for land for industrial and urban development and aquaculture (FAO 2007). More recently, increased recognition of the ecosystem services offered by mangroves has led to a decrease in the rate of loss, although only a few nations have achieved increases in mangrove area. Greater recognition of their importance has resulted in increased levels of protection. An estimated 25% of mangrove area is now set aside in protected areas (Spalding et al. 2010). However, the actual level of protection can vary markedly and only a small proportion of mangroves are found in nature reserves with strict protection and limited access.

In addition to direct losses, degradation of mangrove habitat arguably poses a greater problem because of the large area over which it occurs and the lack of recognition of the issue (Spalding et al. 2010). Land use changes adjacent to mangroves increase sediment loads, nutrients, change tidal flows and hydrology, and increase chemical discharges. These stressors may not kill trees outright but can damage them and reduce overall mangrove health and viability (Spalding et al. 1997; FAO 2007; Spalding et al. 2010).

Mangroves cover only 0.1% of the Earth's land surface, making it one of the rarer forests of the world. There are some 80 species of mangroves from two dozen plant families. Species distribution varies markedly across the general range of mangroves (Spalding et al. 2010) although they can be separated into two distinct zones. One is centred on the Indo-West Pacific (South East Asia, South Asia, Australia and Papua New Guinea) which comprises some 68 species and the other centred on the Atlantic-East Pacific (North, Central & South America and Western Africa) which has around 15 species (Spalding et al. 2010; Duke 2011).

South East Asia and Oceania have the highest biodiversity with around 70% of all mangrove species present in their regions. In contrast, despite having the second and third greatest mangrove area globally, Central & Southern Africa and South America have only 22% and 16% of mangrove species respectively.

Trends

It is estimated that up to half the world's mangroves were lost prior to 1980 when the first global estimates were reported (Spalding et al. 1997). In 1980, the Food and Agriculture Organization (FAO) estimated there were 185,000km^2 of mangroves worldwide. By 2005, the area decreased by 19% to 150,000km^2 (FAO 2007). More recent studies suggest these losses may have been even greater with some estimates as high as 35% over the same time period. Either way it suggests that mangroves are one of the more threatened ecosystems in the world (UNEP 2012a; Valiela et al. 2009).

In 2005, the Tropics had almost 96% of the area of global mangroves, with the largest holdings in South East Asia (31.5% of the total) and Central & Southern Africa with 20.2% (see Table 4.3).

The proportion of mangrove loss in the Tropics between 1980 and 2005 was 18% compared with 33% for the Rest of the World (see Figure 4.10). However, given that the Tropics account for 96% of all mangroves, the total area lost in the Tropics was much greater. In 1980 the Rest of the World had an estimated 10,100km^2 of mangrove forests which decreased to 6800km^2 by 2005. Over the same period, the mangrove area in the Tropics decreased from 175,000km^2 to 143,000km^2.

Central America, Northern Africa & Middle East and South East Asia had the greatest proportional decrease in mangroves between 1980 and 2005, losing between 27% and 30% of their mangroves. Oceania, Central & Southern Africa and South America lost between 10% and 13%, and the Caribbean and South Asia lost 2% or less.

The proportional loss of mangroves in South East Asia was similar across a number of nations. Major causes of mangrove deforestation include illegal forestry, charcoal production, coastal development and strong growth in the aquaculture industry, with increased coastal human populations also a threat (see Box 4.9) (Spalding et al. 2010).

In the Rest of the World, Pakistan had the greatest loss of mangrove area between 1980 and 2005, losing almost 55% of their mangroves, through a combination of overgrazing, changes in hydrology, increased industrial activity and logging. Losses of 30% have been reported in other nations, though many of these have small and fragmented mangrove stands (less than 100km^2) which are more vulnerable to storm damage, erosion and pollution than larger and less fragmented mangrove areas.

The relative proportions of mangrove area in each Tropics region as a total of global mangrove area have changed noticeably since 1980, reflecting variations in rates of loss. Between 1980 and 2005, South Asia increased its overall proportion of global mangrove area while in South East Asia the proportion fell from 34.7% to 31.5% (see Table 4.3). At the nation level, Indonesia had the greatest area of mangroves in the world in 1980 (23%), but has also seen some of the greatest losses with an average annual decrease of approximately 520 km^2 per year between 1980 and 2005. These losses are largely the result of clearing for aquaculture and logging. An estimated 90% of mangroves on the island of Java have been lost to aquaculture or agriculture since 1980 (Spalding et al. 2010).

The rates of mangrove loss in both the Tropics and the Rest of the World have slowed since 2000, but proportionally, are still significantly greater than for global forests generally (Spalding et al. 2010). Both reduced losses and increased reforestation activities are contributing to lower loss rates.

At 20%, Central and Southern Africa had the second highest proportion of global mangrove area in 2005 (see Table 4.3) In this region, Nigeria accounted for the largest extent of mangroves with almost 10,000km^2 which represents the third largest area of mangroves in the world (FAO 2007). The Nigerian mangroves were also considered among the best in the Central and Southern African region, with stands in the Niger delta extending up to 40 kilometres inland, although industrial pollution is starting to impact them (FAO 2007; Spalding et al. 2010).

South Asia and the Caribbean had the smallest losses in both area and percentage terms between 1980 and 2005, losing less than 0.1% of area annually. Between 2000 and 2005 mangrove losses were negligible in South Asia, with losses of 0.01% of area. The mangrove area in Bangladesh actually increased from 4280km^2 in 1980 to 4760km^2 in 2005, offsetting losses in other nations in South Asia. Despite the high reliance of communities in Bangladesh on mangrove forest resources for their livelihoods, a combination of sustainable resource use and active revegetation programs have maintained forest integrity and increased the overall area (FAO 2007).

Table 4.3 Mangrove area

	1980		2005		1980 to 2000		2000 to 2005	
	Area (km^2)	%	Area (km^2)	%	Annual loss (km^2)	Annual loss (%)	Annual loss (km^2)	Annual loss (%)
Tropics	**175,063**	**94**	**143,151**	**96**	**1,349**	**0.8**	**492.7**	**0.7**
Central & Southern Africa	34,787	19	30,256	20	204	0.6	45.3	0.3
Northern Africa & Middle East	1,984	1	1,413	1	22	1.1	12.5	1.6
South Asia	9,443	5	9,328	6	6	0.1	0.4	0.01
South East Asia	64,238	35	47,218	31	699	1.1	304	1.2
Caribbean	6,187	3	6,046	4	6	0.1	1.4	0.04
Central America	16,617	9	11,568	8	216	1.3	72.6	1.2
South America	21,183	11	18,763	13	112	0.5	17.7	0.2
Oceania	20,624	11	18,559	12	84	0.4	39.2	0.4
Rest of the World	**10,100**	**5**	**6,796**	**4**	**157**	**1.6**	**16.3**	**0.5**
World	**185,163**	**100**	**149,947**	**100.0**	**1,506**	**0.8**	**509.0**	**0.66**

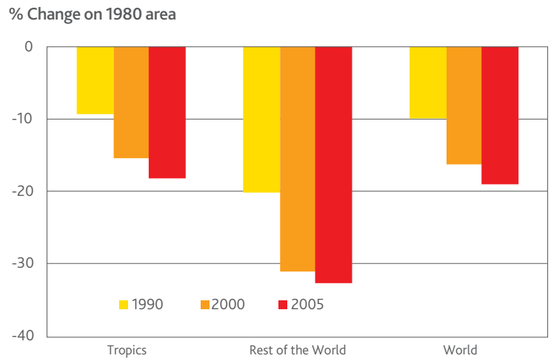
Source: FAO (2007), State of the Tropics project.

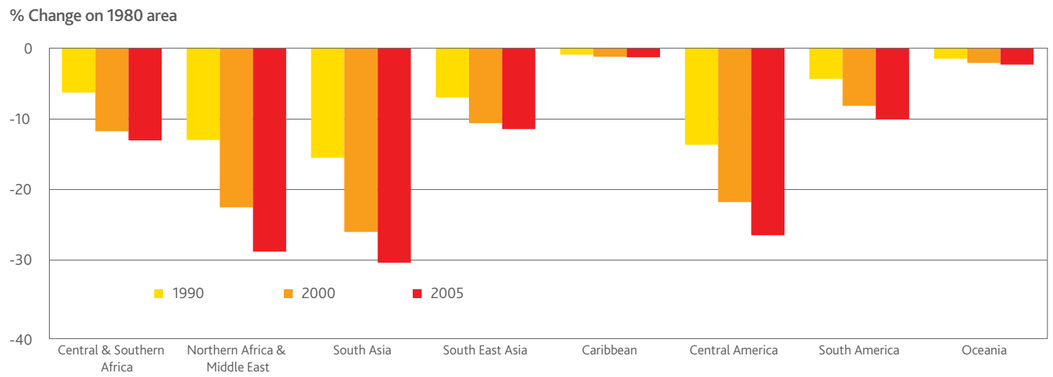
In the Caribbean, around 400km² of reforestation in Cuba in recent years has helped to offset losses in other nations. In addition, legislative reform and an increase in the number of protected areas now provides greater protection to coastal and mangrove environments in Cuba, which has the largest area of mangroves in the region (Spalding et al. 2010).

Northern Africa & Middle East, South East Asia, and Central America lost more than 20% of their mangrove forests between 1980 and 2000. In Central America the rate of loss has slowed since 2000, but it has increased in both Northern Africa & Middle East (1.6% per annum) and South East Asia (1.2% per annum).

The Rest of the World had the greatest average annual percentage loss (1.6%) between 1980 and 2000, and the fourth greatest annual loss in area (157km²), equating to a 30% reduction in mangrove area. However, the rate of loss has slowed markedly between 2000 and 2005.

Figure 4.10 **Percentage change in mangrove area since 1980**





Source: FAO (2007), State of the Tropics project.

Risks to mangrove ecosystems

The inaccessibility of many mangrove regions has meant that, historically, their extents were often estimated or extrapolated from topographic data sets leading to considerable variability in estimates depending on assumptions used (Spalding et al. 1997; FAO 2007; Spalding et al. 2010). In recent times, satellite imagery and remote sensing techniques have improved accuracy, though there are still constraints, particularly with measuring small mangrove areas (McLeod & Salm 2006). Nonetheless, remote sensing offers the most reliable time series data (McLeod & Salm 2006).

In the eyes of people in many parts of the world, mangroves have often been associated with pests and diseases, particularly mosquito-borne diseases. However, while mangroves are natural habitats for mosquitos and other organisms, human activities have often amplified potential issues. For example, where malaria is endemic in coastal mangrove systems, the creation of clearings in and adjacent to mangroves is known to have increased mosquito habitat and malarial risk to communities living close to disturbed areas (Yasuoka & Levins 2007). Flying foxes are mangrove inhabitants, and are host to a number of emerging diseases with the potential to significantly affect humans. With continued human encroachment on these bat habitats, the risk of human infections is also increasing (Breed et al. 2010). Historically, such concerns over disease and pests have been used to justify the draining and removal of mangroves.

As the world's population increases, urbanisation is creating significant pressures on sensitive coastal ecosystems. Between 1990 and 2005, the number of people living within 100 kilometres of the coast increased by 22% globally, or an average of 1.5% per annum (UNEP 2012b). In the Tropics the increase has been even greater, with a 29% increase overall, or almost 2% per year. This rapid population growth is placing significant pressures on mangrove systems, notably through logging and clearing for residential and industrial development (Alongi 2002).

Logging and conversion for aquaculture are the greatest and most immediate threats to mangroves. These two activities have been responsible for approximately 26% and 38% of the global mangrove losses to date (Polidoro et al. 2010). Once cleared, many areas are used for agricultural or urban purposes with little opportunity for mangrove regeneration (Alongi 2002). Other threats come from increased pollution and declining water quality associated with urbanisation and industrial activity (Alongi 2002). Longer term, climate change has the potential to further degrade mangrove systems and reduce their area through sea level rise, changing salinity and the increased frequency of severe storms (Alongi 2008).

On a positive note, the number of protected areas that include mangrove forests is increasing. Between 1997 and 2010, the number of protected areas with significant mangrove stands increased from 700 to over 1200 (Spalding et al. 1997; Spalding et al. 2010). Nevertheless, mangrove forests have decreased in area in most nations and many mangrove forests are

Box 4.8 Mangroves and tsunamis

The 2004 tsunami devastated large parts of coastal South and South East Asia with an estimated death toll in excess of 200,000 people (Tanaka et al. 2007). In the area of greatest intensity, neither mangroves nor other coastal barriers could have prevented the destruction. Away from the epicentre, however, multiple factors affected the intensity and extent of damage from the tsunami.

The most important factors that mitigated impacts to an extent were adjacent ocean depth and distance from the coast, but shoreline protection offered by mangroves and coral reefs systems were also important mitigating factors (Alongi 2008). In the Indian district of Cuddalore, mangroves and other coastal trees protected villages located behind them, while adjacent villages without such protection were severely damaged or destroyed (Danielsen et al. 2005). Modelling data suggests that dense stands of mangroves (100 metres wide) can attenuate tsunami wave energy by up to 90% (UNEP-WCMC 2006; Alongi 2008).

Mangrove seedlings. Image: Helen Buckland.

considered threatened (Spalding et al. 2010). It is estimated that mangrove forests may be critically endangered in 26 of the 120 nations where they occur (Duke et al. 2007).

High rates of loss across regions have resulted in 16% of all mangroves species listed as threatened by the International Union for Conservation of Nature (IUCN) (Polidoro et al. 2010). Within specific regions, due to a combination of low biodiversity and high rates of loss, four of the 10 mangrove species in Central America are now threatened with extinction. Although South East Asia has much greater biodiversity and area of mangroves, high rates of loss have led to 14% of mangroves being classified as threatened. Of those, two species are considered critically endangered with estimates of less than 500 trees remaining for each (Polidoro et al. 2010).

Benefits of mangroves

Mangroves are very effective at dissipating wave energy particularly - storm wave energy. Analyses after the 2004 Asian tsunami found that dense mangrove and coastal forests greatly mitigated wave damage in many areas (Alongi 2008) (see Box 4.8). Mangroves also improved human survival by reducing buffeting effects on people trapped in the run-out surge, providing cushioned landing areas and trapping debris (Tanaka et al. 2011).

Similar effects have also been seen with cyclonic events. Bangladesh has recognised the role mangroves can play in protecting communities from cyclone-related storm surge and has established several mangrove reforestation programs in vulnerable areas (Spalding et al. 1997).

Despite the general perception that mangroves are low value wastelands, they are in fact highly productive and valuable systems. Research suggests mangroves and estuaries are the most productive systems in the world (Costanza et al. 1997, UNEP-WCMC 2006), generating goods and services worth US$10,000 – $22,800 per hectare annually. In comparison, tropical forest values are estimated at US$2000 per hectare per annum; lakes and rivers at $8500; and grasses/rangelands at $200 (Costanza et al. 1997).

Mangrove ecosystem provide food and timber as well as waste waster treatment, nutrient cycling, erosion and sediment control and coastal stabilisation (Linden & Jernelov 1980, Valiela et al. 2009). Mangroves provide key nursery habitats for many commercial fisheries species and their ability to trap and filter sediments makes them important for improving water quality and mitigating pollution in adjacent ecosystems. Many of these services tend to be unnoticed or undervalued in the general community. Although not included in the above valuation of ecosystem services, mangroves are also very important in carbon sequestration (Warren-Rhodes et al. 2011), and can accumulate up to 55 times more carbon per square metre than tropical rainforests (Pidgeon 2009).

Many subsistence communities still rely heavily on mangroves for their primary protein in the form of shellfish, prawns and fish (Chan 1986; Bandaranayake 1998, Spalding et al. 2010). Leaves, bark and other products from the trees are used to treat illnesses, as pesticides and for other pharmaceutical purposes, while the timber is harvested for construction, fuel and other purposes (Bandaranayake 1998, Spalding et al. 2010). In Bangladesh, it is estimated that up to one-third of the population (approximately 52 million people) is dependent either directly or indirectly on mangroves for some part of their income (Linden & Jernelov 1980).

On a commercial level, mangroves are still harvested for timber in many nations, often in an unsustainable manner (Linden & Jernelov 1980; Alongi 2002). Many commercial fisheries target species that rely on mangrove habitats for all or part of their life cycle. For example, the 2008 catch in Australia's northern prawn fishery was valued at $73 million, of which 80% was from banana prawns, a species that relies on mangroves as nursery habitat in its larval phase (AFMA 2012).

Looking forward

Mangroves are a key ecosystem that has been extensively degraded by human activities such as logging, aquaculture and coastal development. Compounding these impacts are risks from climate change and rising sea levels. While policy makers in many nations are becoming increasingly aware of the importance of mangroves, a wider understanding of the important ecosystem services and benefits they deliver could help change public perceptions and improve protection activities. Bangladesh offers a potential example for a way forward. Despite having one of the highest levels of human population density on Earth, it has demonstrated that the integrity and extent of mangroves can be maintained even with major reliance on the ecosystem through a combination of sustainable resource use, careful forestry management and revegetation programs. Ultimately, a balance between local community needs, sustainable resource management and protection are required to ensure the ongoing health and effectiveness of mangrove systems.

Box 4.9 Burma/Myanmar's forests & the challenge of rapid political and economic change

Burma/Myanmar has some of the largest tracts of forests remaining in Asia (FAO 2010), and is considered among the world's 'hottest hotspots' for species diversity and endemism (Myers et al 2000). The nation's forest cover however, is disappearing rapidly; between 1990 and 2010 alone the nation's forest cover was reduced by a fifth from 58% to 47%.

Symptomatic of these rapid changes and the challenge the country faces is the plight of the mangrove forests of the Ayeryarwady Delta. The delta is one of Burma/Myanmar's most significant natural areas, hosting diverse mangroves and more than 30 species of endangered fauna, including a critically endangered sub-population of the Ayeryarwady dolphin. Additionally, the mangroves support important natural resources and rural livelihoods, including fertile farmland and fisheries for an estimated 7.7 million people, as well as providing water regulation services and coastal protection against erosion and extreme weather events.

The mangrove forests of the Ayeryarwady Delta have experienced the highest rate of deforestation in the country with an estimated loss in area of 64% between 1978 and 2011 (Webb et al. 2014). At current rates they could be lost entirely in the next two decades. Much of this loss has been driven by conversion of forest to agriculture, encouraged by government-subsidised programs for small-scale farmers to grow rice. The area now supports 35% of the country's rice production.

Since 2010 unprecedented and broad-ranging political and economic reforms have begun transforming the country with the government promising greater transparency and equitable management of Burma/Myanmar's natural resources. However, with these changes come new threats. Economic and policy reforms aiming to promote private and foreign investment have increased interest from overseas investors and multi-national companies. According to a recent report, government-awarded economic concessions to local and foreign companies are already driving deforestation (Woods & Canby 2011). It reports that concessions are on the rise, and that by mid-2013 the government had given firms a total of 2.1 million hectares of land, much of it in heavily forested regions, for development into plantations. The mangrove forests of the Ayeryarwady Delta are among the areas targeted with agro-industrial companies expressing an interest in land for large-scale plantations, including replacing forests with sugar for export, for example.

Despite the threats there are notable opportunities for curbing the destruction of Burma/Myanmar's forests as a result of greater engagement with the international community. In April 2014, the country introduced a long overdue export ban on raw logs which is expected to reduce the impact of illegal logging (Ferrie 2004). The country's donors are also committing to unprecedented levels of aid, and substantial investment is expected for direct conservation actions. Improving the country's protected area system is a priority. According to the World Bank, only 6.3% of the nation's forests are protected, and current regulations to protect forests are poorly enforced. In the Delta, there is equally scope for community-based reforestation and forest management programs, which could rehabilitate mangroves and help to fulfill demand for fuelwood.

The unprecedented and profound social, political and economic changes that are rapidly taking place in Burma/Myanmar are likely to determine the future of one of the most important and intact forest regions in the Tropics.

Ayeryawady Delta. Image: Thomas Brauner.

References

AFMA (2012). ***NFP at a Glance.*** Australian Fisheries Management Authority http://www.afma.gov.au/managing-our-fisheries/fisheries-a-to-z-index/northern-prawn-fishery/at-a-glance/ (accessed on 24 July 2012).

Allison EH (2011). *Aquaculture, fisheries, poverty and food security*. Working paper 2011-65. Worldfish Center, Penang, Malaysia.

Almany GR, Berumen ML, Thorold SR, Planes S, Jones GP. (2007). Local replenishment of coral reef fish populations in a marine reserve, in ***Science* 316.**

Alongi DM. (2002). Present state and future of the world's mangrove forests, in ***Environmental Conservation* 29.**

Alongi DM. (2008). Mangrove forests: Resilience, protection from tsunamis and responses to global climate change, in ***Estuarine, Coastal and Shelf Science* 76.**

Alverson DL, Freeberg MH, Pope JG, Murawski SA. (1994). ***A Global Assessment of Fisheries Bycatch and Discards.*** Technical Paper No. 339. Food and Agriculture Organization, Rome.

Aranda M. (2009). Evolution and state of the art of fishing capacity management in Peru: The case of the anchoveta fishery, in ***Pan-American Journal of Aquatic Sciences* 4**(2).

Bandaranayake WM. (1998). Traditional and medicinal uses of mangroves, in ***Mangroves and Salt Marshes* 2.**

Barange M & Perry RI (2009). Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In Cochrane K, De Young C, Soto D & Bahri T (Eds). ***Climate change implications for fisheries and aquaculture: overview of current scientific knowledge.*** FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO.

Barton A, Hales B, Waldbusser GG, Langdon C & Feely RA (2012). The Pacific oyster, ***Crassostrea gigas,*** shows negative correlation to naturally elevated carbon dioxide level: Implications for near-term ocean acidification effects. ***Limnological Oceanography***, 57: 698-710.

Berg H (2002). Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam – economic and ecological considerations. ***Ecological Economics***, 41: 95-107.

BIP (2012). ***Marine Trophic Index.*** Biodiversity Indicators Partnership http://www.bipindicators.net/indicators/hl_marinetrophicindex (accessed on 31 January 2012).

Botsford LW, Castilla JC, Peterson CH. (1997). The management of fisheries and marine ecosystems, in ***Science* 277.**

Boyett HV, Bourne DG, Willis BL. (2007). Elevated temperature and light enhance progression and spread of black band disease on staghorn corals of the Great Barrier Reef, in ***Marine Biology* 151.**

Breed AC, Field HE, Smith CS, Edmonston J, Meers J. (2010). Bats without borders: Long-distance movements and implications for disease risk management, in ***EcoHealth* 7.**

Bruckner AW. (2002). Life-saving products from coral reefs, in ***Issues in Science and Technology* 18.**

Bryant D, Burke L, McManus J, Spalding M. (1998). ***Reefs at Risk.*** World Resources Institute, Washington.

Burke L, Reytar K, Spalding M, Perry A. (2011). ***Reefs at Risk Revisited.*** World Resources Institute, Washington.

Burke L, Reytar K, Spalding M, Perry A. (2012). ***Reefs at Risk Revisited in the Coral Triangle.*** World Resources Institute, Washington.

Cartier L & Ali S (2012). Pearl farming as a sustainable development path. Solutions, 3: 30-34. http://www.thesolutionsjournal.com/node/1139 Accessed: 22 March 2013.

Cesar H, Burke L, Pet-Soede L. (2003). ***The Economics of Worldwide Coral Reef Degradation.*** Cesar Environmental Economics Consulting, Arnhem.

Chamberlain A (2011). Fishmeal and fish oil – the facts, figures, trends, and IFFO's responsible supply standard. International Fishmeal & Fish Oil Organisation. http://www.iffo.net/downloads/ Datasheets%20Publications%20SP/FMFOF2011.pdf

Chan HT. (1986). Human habitation and traditional uses of the mangrove ecosystem in peninsular Malaysia, in Kunstadter P, Bird ECF, Sabhasri S. (Eds), ***Man in the Mangroves – The Socio-Economic Situation of Human Settlements in Mangrove Forests.*** United Nations University Press, Tokyo.

Chopin T (2006). Integrated multi-trophic aquaculture: What it is, and why you should care……and don't confuse it with polyculture. ***Northern Aquaculture***, July/August 2006: **4**.

Chopin T, Cooper JA, Reid G, Cross S & Moore C (2012). Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of aquaculture by extractive aquaculture. ***Reviews in Aquaculture,* 4**: 209-220.

Chopin T, Troell M, Reid GK, Knowler D, Robinson SMC, Neori A, Buschmann AH & Pang S (2010). Integrated multi-trophic aquaculture. Part II. Increasing IMTA adoption. ***Global Aquaculture Advocate***, Nov/Dec 2010: 17-20.

Cole AJ, Chong-Seng KM, Pratchett MS, Jones GP. (2009). Coral feeding fishes slow progression of black-band disease, in ***Coral Reefs* 28.**

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J et al. (1997). The value of the world's ecosystem services and natural capital, in ***Nature* 387.**

CRCReef (2006). Reef Facts: Plants and animals on the Great Barrier Reef http://www.reef.crc.org.au/discover/plantsanimals/facts_plantanimal.htm (accessed on 22 August 2012).

CSIRO (2013). Tiger prawn farming. http://www.csiro.au/en/Outcomes/Food-and-Agriculture/tiger-prawn-farming.aspx Accessed: 8 April 2013.

Danielsen F, Sorensen MK, Olwig MF, Selvam V, Parish F, Burgess ND, Hiraishi T, Karunagaran VM, Rasmussen MS, Hansen LB et al. (2005). The Asian tsunami: A protective role for coastal vegetation, in ***Science* 310.**

Delgado CL, Wada N, Rosegrant MW, Meijer S, Ahmed M. (2003). ***Fish to 2020: Supply and Demand in Changing Global Markets.*** International Food Policy Research Institute & World Fish Center.

Duarte CM. (Ed) (2009). ***Global Loss of Coastal Habitats: Rates, Causes and Consequences.*** BBVA Foundation.

Duke NC. (2011). Mangroves, in Hopley D. (Ed), ***Encyclopedia of Modern Coral Reefs:*** Structure, Form and Process. Springer: Dordrecht, Netherlands.

Duke NC, Meynecke J-O, Dittman S, Ellison AM, Anger K, Berger U, Cannicci S, Diele K, Ewel KC, Field CD et al. (2007). A world without mangroves, in ***Science* 317.**

The Economist (2011). ***Fishing in Peru – the next anchovy.*** Print edition, 5 May 2011.

Fabricius KE, Okaji K, De'ath G. (2010). Three lines of evidence to link outbreaks of the crown-of thorns seastar ***Acanthaster planci*** to the release of larval food limitation, in Coral Reefs **29.**

FAO (2006). ***The state of world fisheries and aquaculture.*** Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2007). ***The World's Mangroves*** 1980-2005. FAO Forestry paper 153. Food and Agriculture Organization, Rome.

FAO (2010a). ***The State of World Fisheries and Aquaculture 2010.*** Food and Agriculture Organization, Rome.

FAO (2010b). ***Report of the Annual Forum of the EAF-NANSEN Project. Theme: The Ecosystem Approach to Fisheries – Opportunities for Africa.*** Food and Agriculture Organization, Rome.

FAO (2011). ***Report of the twenty ninth session of the Committee on Fisheries. Rome, 31 January–4 February 2011.*** FAO Fisheries and Aquaculture Report No. 973. Food and Agriculture Organization, Rome.

FAO (2012). ***The state of world fisheries and aquaculture 2012.*** Food and Agriculture Organisation of the United Nations, Rome.

FAO (2013). ***Capture Fisheries.*** Food and Agriculture Organization http://www.fao.org/fishery/capture/en (last accessed in February 2013).

FAOSTAT3 (2103). Seafood Consumption kg/capita/year. http://faostat3.fao.org Accessed: 27 March 2013.

FAO FishStatJ (2013). Source: http://www.fao.org/fishery/statistics/software/fishstatj Accessed: 4 March 2013

FAO, WFC (2009). ***Small Scale Capture Fisheries: A Global Overview with Emphasis on Developing Countries. A Preliminary Report of the Big Numbers Project.*** Food and Agriculture Organization & World Fish Center.

Ferrie J (2014) Myanmar's log export ban to hurt businessmen but help forests. ***Reuters US Edition*** http://www.reuters.com/article/2014/03/20/us-myanmar-forests-idUSBREA2J27K20140320 (accessed April 2014)

Fox M, Naisilisili W, Batibasaga A, Jupiter S. (2012). Opportunities and Challenges of Managing Spawning Aggregations in Fiji, in ***Proceedings of the 12th International Coral Reef Symposium,*** Cairns, Australia, 9 13 July 2012.

Froese R, Zeller D, Kleisner K, Pauly D. (2012). What catch data can tell us about the status of global fisheries, in ***Marine Biology* 159.**

Gardner TA, Cote IM, Gill JA, Grant A, Watkinson AR. (2003). Long-term region-wide declines in Caribbean corals, in ***Science* 301.**

GBRMPA (2005). ***Report on the Great Barrier Reef Marine Park Zoning Plan 2003.*** Great Barrier Reef Marine Park Authority, Townsville.

GBRMPA (2012a). ***Heritage.*** Great Barrier Reef Marine Park Authority http://www.gbrmpa.gov.au/about-the-reef/heritage (accessed on 22 August 2012).

GBRMPA (2012b). ***Strategic Assessment.*** Great Barrier Reef Marine Park Authority http://www.gbrmpa.gov.au/outlook-for-the-reef/strategic-assessment (accessed on 22 August 2012).

Gilman EL, Ellison J, Duke NC, Field C. (2008). Threats to mangroves from climate change and adaptation options: A review, in ***Aquatic Botany* 89.**

Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Duke NC. (2011). Status and distribution of mangrove forest of the world using earth observation satellite data, in ***Global Ecology and Biogeography* 20**(1).

Goldberg J, Wilkinson C. (2004). Global threats to coral reefs: Coral bleaching, global climate change, disease, predator plagues, and invasive species, in Wilkinson C. (Ed), ***Status of Coral Reefs of the World: 2004.*** Global Coral Reef Monitoring Network & Australian Institute of Marine Science, Townsville.

Gowing JW, Tuong TP & Hoanh CT (2006). Land and water management in coastal zones: Dealing with agriculture-aquaculture-fishery conflicts. In Hoanh CT, Tuong TP, Gowing JW & Hardy B (Eds). ***Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts.*** CAB international, Oxon, UK.

Haapkyla J, Unsworth RKF, Flavell M, Bourne DG, Schaffelke B, Willis BL. (2011) Seasonal rainfall and runoff promote coral disease on an inshore reef, in ***PLoS ONE* 6.**

Halwart M & Gupta MV (Eds.) (2004). Culture of fish in rice fields. FAO & The WorldFish Center. Rome.

Halwell B (2008). Farming fish for the future. Worldwatch Report 176. Worldwatch Institute, Washington.

References | Continued

Harvell D, Jordan-Dahlgren E, Merkel S, Rosenberg E, Raymundo L, Smith G, Weil E, Willis B. (2007). Coral disease, environmental drivers and the balance between coral and microbial associates, in *Oceanography* **20.**

Honey M, Krantz D. (2007). *Global Trends in Coastal Tourism.* Centre on Ecotourism and Sustainable Development & World Wildlife Fund for Nature, Washington.

Hughes T. (2009). Confronting the global decline of coral reefs, in Duarte C. (Ed), *Global Loss of Coastal Habitats: Rates, Causes and Consequences.* BBVA Foundation.

Jacquet J, Fox H, Motta H, Ngusaru A, Zeller D. (2010). Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania, in *African Journal of Marine Science* **32.**

Jessen C, Roder C, Villa Lizcano J, Voolstra CR, Wild C. (2012). Top-Down and Bottom-Up Effects on Red Sea Coral Reef Algae, in *Proceedings of the 12th International Coral Reef Symposium,* Cairns, Australia, 9 13 July 2012.

Karim MR (2006). Brackish-water shrimp cultivation threatens permanent damage to coastal agriculture in Bangladesh. In Hoanh CT, Tuong TP, Gowing JW & Hardy B (Eds). *Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts.* CAB international, Oxon, UK.

Kleisner K, Pauly D. (2011). The Marine Trophic Index (MTI), the Fishing in Balance (FiB) Index and the spatial expansion of fisheries, in Christensen V, Lai S, Palomares MLD, Zeller D, Pauly D. (Eds), *The State of Biodiversity and Fisheries in Regional Seas.* Fisheries Centre Research Reports 19(3). Fisheries Centre, University of British Colombia.

Leung TLF & Bates AE (2013). More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security. *Journal for Applied Ecology*, 50: 215-222.

Linden O, Jernelov O. (1980). The mangrove swamp: an ecosystem in danger, in *Ambio* **9**.

Loper C, Pomeroy R, Hoon V, McConney P, Pena M, Sanders A, Sriskanthan G, Vergara S, Pido M, Ron Vave R et al. (2008). *Socioeconomic Conditions along the World's Tropical Coasts: 2008.* Conservation International.

Mair G (2002). Genes and fish: Topical issues in genetic diversity and breeding. *Aquaculture Asia*, **7**.

Marshall P, Schuttenberg H. (2006). Adapting coral reef management in the face of climate change, in Phinney JT, Hoegh-Guldberg O, Kleypas J, Skirving W, Strong A. (Eds), *Coral Reefs and Climate Change: Science and Management.* American Geophysical Union, Washington.

McLeod E, Salm RV. (2006). *Managing Mangroves for Resilience to Climate Change.* International Union for Conservation of Nature, Gland.

Miller I, Sweatman H. (2004). Status of coral reefs in Australia and Papua New Guinea in 2004, in Wilkinson C. (Ed), *Status of Coral Reefs of the World: 2004.* Global Coral Reef Monitoring Network & Australian Institute of Marine Science, Townsville.

Mora C, Myers RA, Coll M, Libralato S, Pitcher TJ, Sumaila RU, Zeller D, Watson R, Gaston KJ, Worm B. (2009). Management effectiveness of the world's marine fisheries, in *PLoS Biology* **7**.

Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B. (2011). How many species are there on earth and in the ocean?, in *PLoS Biology* **9**.

Nalim S (1994). The impact of fish in enhancing rice field ecosystem. In De La Cruz CR (ed.) Role of fish in enhancing rice field ecology and in integrated pest management. *Summary report of the 3rd Asian Regional Rice-Fish Farming Research and Development Workshop, 6-11 June 1993, Indonesia.* International Center for Living Aquatic Resources Management Conference Proceedings. **43**.

Nash CE (2011). *The history of aquaculture.* Blackwell Publishing , Iowa, US

Naylor RL, Goldburg RJ, Primavera JH, Kautsky N, Beveridge MCM, Clay J, Folke C, Lubchenco J, Mooney H & Troell M (2000). Effect of aquaculture on world fish supplies. *Nature,* **405**: 1017-1024.

Naylor RL, Hardy RW, Bureau DP, Chiu A, Elliott M, Farrell AP, Forster I, Gatlin DM, Goldburg RJ, Hua K, Nichols PD (2009). Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy Sciences*, **106.**

NOAA (2011). *Ocean.* National Oceanic and Atmospheric Administration, United States Department of Commerce http://www.noaa.gov/ocean.html (accessed on 27 January 2012).

Paterson B, Petersen S. (2010). EAF implementation in Southern Africa: Lessons learnt, in *Marine Policy* **34**.

Pham TD, Hoang DH, Du JT, Thi VTH (2004). Combined culture of mussel: a tool for providing live feed and improving environmental quality for lobster aquaculture in Vietnam In. KC Williams (ed) *Spiny lobster ecology and exploitation in the South China Sea region*. CSIRO, Australia.

Pidgeon E. (2009). Carbon sequestration by coastal marine habitats: Important missing sinks, in Laffoley D d'A, Grimsditch G. (Eds), *The Management of Natural Coastal Carbon Sinks.* International Union for Conservation of Nature, Gland.

Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellison JC, Farnsworth EJ, Fernando ES, Kathiresan K, Koedam NE et al. (2010). The loss of species: Mangrove extinction risk and geographic areas of global concern, in *PLoS ONE* **5**.

Pratchett M, Hoey A, Coker D, Gardiner N. (2012). Interdependence between Reef Fishes and Scleractinian Corals, in *Proceedings of the 12th International Coral Reef Symposium,* Cairns, Australia, 9 13 July 2012.

Pratchett MS, Munday PL, Graham NAJ, Kronen M, Pinica S, Friedman K, Brewer T, Bell JD, Wilson SK, Cinner JE et al. (2011). Vulnerability of coastal fisheries to climate change, in Bell JD, Johnson JE, Hobday AJ. (Eds), *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change.* Secretariat for the Pacific Community, Noumea.

Prein M (2002). Integration of aquaculture into crop–animal systems in Asia. *Agricultural Systems,* 71: 127-146.

Ramdeen R, Smith N, Frotté L, Lingard S, Harper S, Zeller D, Pauly D. (2013). Reconstructed Total Catches by the Marine Fisheries of Countries of the Wider Caribbean (1950-2010), in *Proceedings of the 65nd Meeting of the Gulf and Caribbean Fisheries Institute,* Santa Marta, Colombia, 5-9 November 2012.

Regnier E & Schubert K (2013). Consumer preferences, aquaculture technology and the sustainability of fisheries. CES Working paper. Documents deTravail du Centre d'Economie de la Sorbonne. Halshs-00786112. Source: http://halshs.archives-ouvertes.fr/docs/00/78/61/12/PDF/13002.pdf Accessed: 4 April 2013.

Saila SB, Kocic V Lj, McManus JW. (1993). Modelling the effects of destructive fishing practices on tropical coral reefs, in *Marine Ecology Progress Series* **94**.

Schorr D. (2004). *Healthy Fisheries, Sustainable Trade: Crafting New Rules on Fishing Subsidies in the World Trade Organization.* World Wide Fund for Nature.

Sea Around Us Project (2011). *Stock Status Plots.* http://www.seaaroundus.org/doc/methods/SSP_methods-April-2011-final.pdf (accessed on 30 January 2012).

Spalding M, Blasco F, Field C. (1997). *World Mangrove Atlas.* International Society for Mangrove Ecosystems, Okinawa.

Spalding M, Kainuma M, Collins L. (2010). *World Atlas of Mangroves*. Earthscan, London.

Spalding MD, Ravilious C, Green EP. (2001). *World Atlas of Coral Reefs.* Prepared at the United Nations Environment Programme World Conservation Monitoring Centre. University of California Press, Berkeley.

Sumaila R, Khan A, Dyck AJ, Watson R, Munro G, Tydemers P, Pauly D. (2010). A bottom-up re-estimation of global fisheries subsidies, in *Journal of Bioeconomics* **12**.

Sumaila UR, Cheung W, Dyck A, Gueye K, Huang L, Lam V, Pauly D, Srinivasan T, Swartz W, Watson R, Zeller D. (2012). Benefits of rebuilding global marine fisheries outweigh costs, in *PLoS ONE* **7**.

Swartz W, Sala E, Tracey S, Watson R, Pauly D. (2010). The spatial expansion and ecological Footprint of Fisheries (1950 to Present), in *PLoS ONE* **5**.

Tacon AGJ & Metian M (2009). Fishing for feed or fishing for food: Increasing global competition for small pelagic forage fish. *Ambio*, **38**.

Tanaka N, Jinadasa KBSN, Mowjood MIM, Fasly MSM. (2011). Coastal vegetation planting projects for tsunami disaster mitigation: Effectiveness evaluation of new establishments, in *Landscape and Ecological Engineering* **7**.

Tanaka N, Sasak, Y, Mowjood MIM, Jinadasa KBSN, Homchuen S. (2007). Coastal vegetation structures and their functions in tsunami protection: Experience of the recent Indian Ocean tsunami, in *Landscape Ecology and Engineering* **3**.

Tipraqsa P, Craswell ET, Noble AD & Schmidt-Vogt D (2007). Resource integration for multiple benefits: Multifunctionality of integrated farming systems in Northeast Thailand. *Agricultural Systems*, **94**.

Tratalos JA, Austin TJ. (2001). Impacts of recreational SCUBA diving on coral communities of the Carribean island of Grand Cayman, in *Biological Conservation* **102**.

Troell M (2009). Integrated marine and brackishwater aquaculture in tropical regions: research implementations and prospects. In D Soto (ed). *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper No. 529 Rome, FAO.

UNEP (2007). *Global Environment Outlook* 4. United Nations Environment Programme, Malta.

UNEP (2012a). *Global Mangrove Extent Much Smaller than Previously Estimated.* United Nations Environment Programme http://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=58 (accessed on 19 July 2012).

UNEP (2012b). *Population within 100 kilometres of Coast, World, 1990 1995 2000 2005.* United Nations Environment Program http://geocommons.com/overlays/1887 (accessed on 13 July 2012).

UNEP-WCMC (2006). *In the Front Line: Shoreline Protection and Other Ecosystem Services from Mangroves and Coral Reefs.* United Nations Environment Programme & World Conservation Monitoring Centre, Cambridge.

UNESCO (2012a). *MISSION REPORT Reactive Monitoring Mission to Great Barrier Reef (Australia) 6th to 14th March 2012.* United Nations Education, Scientific and Cultural Organization World Heritage Centre & – IUCN http://whc.unesco.org/document/117104 (accessed on 22 August 2012).

UNESCO (2012b). *Reactive Monitoring Mission to the Great Barrier Reef World Heritage property (Australia).* United Nations Education, Scientific and Cultural Organization & International Union for Conservation of Nature.

UNWTO (2012a). *UNWTO Tourism Highlights, 2012 Edition.* United Nations World Tourism Organization. Madrid *UNWTO (2012b). Tourism and Millennium Development Goals.* United Nations

Webb, E.L., Jachowski, N.R.A, Phelps, J., Friess, D.A., Than, M.M., Ziegler, A.D. (2014). Deforestation in the Ayeyarwady Delta and the conservation implications of an internationally-engaged Myanmar. *Global Environmental Change* **24.**

Wersal RM & Madsen JD (2012). Aquatic plants: Their uses and risks. A review of the global status of aquatic plants. International Plant Protection Convention, FAO, Rome, Italy

Wijkström UN (2009). The use of wild fish as aquaculture feed and its effects on income and food for the poor and the undernourished. In Hasan MR & Halwart M (Eds) *Fish as feed inputs for aquaculture: practices, sustainability and implications.* FAO, Fisheries and Aquaculture Technical Paper. No. 518. Rome

References | Continued

WHO (2013). Global and regional food consumption patterns and trends. http://www.who.int/nutrition/topics/3_foodconsumption/en/print.html Accessed: 27 March 2013.

Woods, K., Canby, K., (2011). *Baseline study 4, Myanmar: overview of forest law enforcement, governance and trade.* Forest Trends, European Forest Institute – FLEGT Asia Regional Office, Kuala Lumpur.

World Tourism Organization http://www.unwto.org/tourism&mdgsezine/ (accessed on 22 August 2012).

Valiela I, Kinney E, Culbertson J, Peacock E, Smith S. (2009). Global losses of mangroves and salt marshes, in Duarte C. (Ed), *Global Loss of Coastal Habitats: Rates, Causes and Consequences.* BBVA Foundation.

Veron JEN. (2000). *Corals of the World (3 volumes).* Australian Institute of Marine Science, Townsville.

Warren-Rhodes K, Schwarz AM, Ng-Boyle L, Albert J, Agalo SS, Warren R, Bana A, Paul C, Kodosiku R, Bosma W et al. (2011). Mangrove ecosystem services and the potential for carbon revenue programmes in Solomon Islands, in *Environmental Conservation* **38**.

Wielgus JE, Torres CR, Burke L. (2010). *Coastal Capital: Dominican Republic. Case Studies on the Economic Value of Coastal Ecosystems in the Dominican Republic.* Working Paper. World Resources Institute, Washington DC.

Wilkinson C. (2002). Coral bleaching and mortality – the 1998 event four years later and bleaching to 2002, in Wilkinson C. (Ed), *Status of Coral Reefs of the World: 2002.* Global Coral Reef Monitoring Network & Australian Institute of Marine Science, Townsville.

Wilkinson C. (Ed) (1998). *Status of Coral Reefs of the World:* 1998. Global Coral Reef Monitoring Network & Australian Institute of Marine Science, Townsville.

Yasuoka J, Levins R. (2007). Impact of deforestation and agricultural development on anopheline ecology and malaria epidemiology, in *American Journal of Tropical Medicine and Hygiene* **76**.

Zeller D, Booth S, Davis G, Pauly D. (2006). Re-estimation of small-scale fishery catches for U.S. flag associated island areas in the western Pacific: the last 50 years, in *Fisheries Bulletin* **105**.

Stilt fishermen
Image: Adam Brill

Limpets.
Image: Mark Ziembicki.

Sand monitor.
Image: Mark Ziembicki.

Chapter 5

Biodiversity

'If enough species are extinguished, will the ecosystems collapse, and will the extinction of most other species follow soon afterward? The only answer anyone can give is: possibly. By the time we find out, however, it might be too late. One planet, one experiment.'

E. O. Wilson, 1992

Western tarsier.
Image: Mark Ziembicki.

Summary of biodiversity indicators

Indicator		The Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Threatened Species	Amphibians*	**43**	35	1	57	30	74	62	38	12	**25**	**41**
	Birds*	**12**	10	3	7	10	7	6	12	10	**9**	**13**
	Mammals*	**26**	23	9	30	31	17	18	20	24	**15**	**25**
	Reptiles*	**27**	36	9	22	21	47	19	24	32	**20**	**26**
	Plants*	**67**	61	29	47	52	72	59	68	53	**42**	**60**
Protected Area 1990-2010	Terrestrial Protected Area**	**10.4-15.4**	14.9-16.0	5.2-5.9	5.2-5.4	8.4-13.2	9.1-10.6	7.4-15.7	12.1-26.3	4.3-5.5	**7.2-10.4**	**8.3-12.2**
	Marine Protected Area**	**1.7-6.1**	0.8-3.8	2.5-3.2	1.2-1.5	0.6-2	2.3-4.4	2.4-17.0	5.5-23.8	3-9.6	**3.5-7.5**	**2.6-6.8**
	Combined Protected Area**	**8.9-13.9**	14.4-15.5	5.1-5.8	4.7-5	4.6-7.8	5.2-7.1	6.5-15.9	11.8-26.2	3.8-7	**6.8-10.1**	**7.6-11.6**
Primary Forest	Decrease in Primary Forest Area 1990-2010#	**867-780**	42-31	18-16	10.5-10.4	71-65	0.2-0.2	30-25	662-603	34-28	**324-323**	**1,191-1,102**

Red: Situation is deteriorating
Green: Situation is improving

* Represents the percentage of species threatened in each group by the number of species assessed.
**Area protected as percentage of total land area and/or territorial waters. #Change in area of primary forest in million hectares.

Biodiversity refers to the variety of life on Earth; plants, animals, and micro-organisms and the ecosystems in which they live, whether large or small, common or rare. It is influenced by natural factors including temperature, water availability, and climate. Pressures from human interactions, including exploitation and pollution can have substantial impacts on biodiversity. Change in biodiversity is considered a measure of the health of an ecosystem, and reflects the response of the plant and animal communities to the internal and external pressures being placed upon them.

Maintaining biodiversity not only requires the capacity to protect animal and plant species, but also the environments they inhabit. Maintaining high biodiversity environments like primary forests by informal or formal protected area status is a well-recognised means of achieving this, as it not only confers protection on key species, but also on the ecosystems on which they rely.

Diverse natural ecosystems provide benefits vital for life on Earth and the quality of human life. People rely on biodiversity for sustenance, health, wellbeing and enjoyment. Human communities derive all food and many medicines and industrial products from wild and domesticated components of biological diversity. Biodiversity is also the basis for many other economic, cultural and recreational activities. The integrity of many ecosystem regulatory services which support humanity, such as the provision of clean water for example, relies on healthy and diverse environments.

Headline indicator

Threatened Species: The number of threatened species is a measure of how much biodiversity is being threatened as a consequence of natural or anthropogenic changes to the environment. Major loss in numbers of plant or animal species can have wider effects on natural and human systems.

Supplementary indicators

Terrestrial & Marine Protected Areas: Formal declaration of protected area status creates a level of national and local responsibility to manage the area to preserve important ecological, social and cultural features for future generations. These conservation efforts also protect important ecosystem services such as provision of clean water and air quality, and biodiversity values which in turn provide benefits to the wider community outside the protected area.

Extent of Primary Forests: Primary forests refers to forests in their original condition that are largely undisturbed by human impacts. They are the most biologically diverse forests. Disturbances from natural or anthropogenic sources affect both biodiversity and the ecosystem services these forests provide. Formal international / national recognition and protection offers the best opportunity to preserve the vital components of these systems. Changes in area of primary forest and the proportion of these forests under formal protection are additional indicators of biodiversity status.

Links to other dimensions

Land degradation, corals, mangroves, wild marine catch, agriculture, Carbon dioxide and greenhouse gas emissions, renewable water resources, aquaculture, health, air-quality, economic output, poverty.

Is it getting better?

Threatened species
Extinction rates are increasing globally and are well above natural background rates. However, our knowledge of the status of most of the Earth's biodiversity is limited and highly fragmented. The most comprehensive assessments of threatened species status that have been completed are based on limited data sets with a disproportionate focus on temperate regions and terrestrial vertebrates. The Tropics stand to lose more than other regions given higher levels of biodiversity. Amphibians (frogs, salamanders, etc) are the most vulnerable among the animal groups while cycads are the most threatened plant group. The lack of comprehensive data for many other important groups including insects, molluscs, most plants and reptiles is a major limitation to understanding the full extent of global risk to species.

Terrestrial & marine protected areas
Increasing the number of protected areas is one way of helping improve the threat status of many species. Although global targets have not been met for all bioregions, efforts at national and regional levels provide some optimism. The Tropics have a greater proportion of terrestrial area under formal protection. However, effective management is variable and many protected areas are still subject to illegal encroachment and exploitation. Formal protection of marine areas is lower globally, and the extent of area under protection in the Tropics is lower than for the Rest of the World, although the gap is narrowing.

Extent of primary forests
The extent of primary forests in the Tropics is decreasing rapidly with associated increased risks to biodiversity. Rates of loss have seemingly slowed since the year 2000 in Central America, South America, South East Asia and Northern Africa & Middle East. However, they have increased in Oceania. Furthermore, and disconcertingly, technological advances based on improvements in remote sensing suggest that losses may be under reported in some regions.

Red leaf monkey. Image: Mark Ziembicki.

Biodiversity and threatened species

Biodiversity underlies all the ecosystem services that provide benefits to people including clean air and water, food, economic resources and aesthetic and cultural values (Vié et al. 2009). In 1997, the economic value of global ecosystem services was estimated at around US$33 trillion (James et al. 1999). The importance of global biodiversity – and the risks to it – were officially recognised in 1992 at the United Nations Conference on Environment and Development, and with the subsequent adoption of the Convention on Biological Diversity (CBD) (see Box 5.1).

The CBD represents a turning point in global awareness of the importance of conserving biological diversity, which has its origins in the establishment of the International Union for Conservation of Nature and Natural Resources (IUCN) in 1948. The IUCN was established under the auspices of UNESCO to gain international support for habitat and species protection, with a major focus on protecting nature from damaging human activities (Christofferesen 1997). It is the oldest and largest global conservation network with membership including over 1,000 non-governmental organisations and 218 national and state government agencies.

Six scientific commissions have been established under IUCN to assess the state of the world's natural resources and provide policy and technical advice on conservation issues. The Species Survival Commission provides technical advice on species conservation, and produces the IUCN Red List of Threatened Species (Red List), which is the international standard for species extinction risk. By 2012, IUCN had assessed over 59,000 plant and animal species for the Red List. Whilst this represents less than 4% of described species it is the best estimate of the state of species biodiversity that currently exists (IUCN 2011, Butchart et al. 2006).

In the 1980s a new concept for species risk assessment known as biodiversity hotspots was developed (see Table 5.2). Based on conservation planning principles these hotspots are characterised by high levels of endemism and habitat loss and, as such, are areas that are especially vulnerable. Hotspots cover about 2.3% of the global land area but are home to 50% of plant species and 77% of animal species (Mittermeier et al. 2011) and, significantly, almost one third of the human population. Looking forward, strong population growth in many hotspot areas will place these areas under increased pressures.

Trends

Current knowledge regarding biodiversity extent and risk is fragmented, though there is a bias towards greater understanding of species in temperate regions, terrestrial vertebrates and those species more intensively used by humans. Tropical and aquatic systems along with plants, invertebrates and micro-organisms have significant knowledge gaps in both species descriptions and threat risk (see Box 5.2). Although there are several ways to assess biodiversity and associated risks, species lists are commonly used as they are easier to identify and quantify than habitats and ecosystems (Vié et al. 2009).

Although the Tropics has 40% of the world's surface area (land and water), it hosts approximately 80% of the range of terrestrial biodiversity (Isaac & Turton 2009), 21 of 35 global biodiversity hotspots (Mittermeier et al. 2011) and more than 90% of reef-building coral and mangrove biodiversity. However, the drivers of these high levels of tropical biodiversity are complex, and are subject to considerable debate among ecologists (Rosenweig 1995).

It is estimated that 77% of the world's mammal species are present in the Tropics (compared to 44% in the Rest of the World), 91% of the world's birds (44%), 74% of its reptiles (38%) and 84% of its amphibian species (20%) (Vié et al. 2009). Tropical forests are also recognised as having the greatest level of terrestrial biodiversity across a number of measures including the level of endemism and species richness. Tropical islands are also characterised by very high levels of endemism due to their geographical isolation.

Among tropical regions, South America, Central America and South East Asia have particularly high vertebrate biodiversity (see Table 5.1). Globally, four of the five nations with the highest number of amphibian species are in South America, with Mexico having the fifth highest amphibian (and fourth greatest mammal) diversity. South America is also home to the greatest bird diversity. Of the South East Asian nations, Indonesia has very high biodiversity ranking first in mammal diversity and fifth for number of bird species. While the amphibian diversity in South and Central America tends to reflect very high levels of endemism, the proportion of endemic birds and mammals among the top five nations is lower (see Table 5.1).

In contrast to vertebrate diversity, high conifer and cycad diversity occurs in both tropical and temperate regions. China, followed by the United States of America, have the highest conifer diversity, with several nations in the Tropics also home to high numbers of conifer species. Similarly, high cycad diversity occurs in several tropical nations (most notably, Australia, Mexico, China and Vietnam). A feature of conifer and cycad diversity in these nations is a high level of endemism. Globally, of the vertebrate species assessed under the IUCN to 2012, birds have the lowest proportion of threatened species with 13% considered at risk, while amphibians have the greatest proportion of species at risk with 41% (see Table 5.2). The Rest of the World has a lower proportion of vertebrate species at risk, ranging from 9% of birds to 25% of amphibians, compared with the Tropics at 12% for birds and 43% for amphibians (see Table 5.2).

Regionally, Northern Africa & Middle East has the lowest proportion of threatened vertebrate species ranging from 1% of amphibians to 9% of mammals. Oceania is the only other tropical region to have less than 15% of amphibians under threat, while South Asia, the Caribbean and Central America have a lower proportion of bird

Palm cockatoos. Image: Mark Ziembicki.

Box 5.1 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was adopted in 1992. Key factors leading to its creation included growing recognition that:

- Biological diversity is a global asset vital to humanity's ongoing economic and social wellbeing; and
- Human activities are increasing the risk of extinctions.

The Convention's objectives are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the use of genetic resources. Importantly, the Convention recognises the need to reconcile conservation and socio-economic development needs. The Convention has been officially adopted by 193 nations excluding, most notably, the United States of America (CBD 2012a).

Accelerated rates of species extinction have important implications for economic and social development as around 40% of the world's economy and 80% of the needs of the poor are derived from biological resources. A richer diversity of life also suggests greater opportunities for medical discoveries, economic development and adaptive responses to challenges such as climate change.

In 2002 world leaders agreed to substantially reduce the rate of biodiversity loss by 2010, and set specific targets to meet this goal (OECD 2002). Global Biodiversity Outlook 3 reports that targets have not been met, and that 'trends' suggest that the state of biodiversity is declining, the pressures upon it are increasing, and the benefits derived by humans from biodiversity are diminishing, but that the responses to address its loss are increasing. The overall message is that despite the many efforts taken around the world to conserve biodiversity and use it sustainably, responses so far have not been adequate to address the scale of biodiversity loss or reduce the pressure' (CBD 2010a).

species at risk (between 6% and 7%) compared with other tropical regions.

The threat to plants is less well known given that worldwide only 5% of described plant species have been assessed (IUCN 2012b). Of the 16,000 plants that have been assessed, 60% are considered threatened (see Box 5.2). In the Tropics 67% of assessed plants are considered at risk, compared with 42% in the Rest of the World. Regionally, Northern Africa & Middle East and South Asia have less than 50% of assessed plants under threat (29% and 47% respectively), compared with 72% for the Caribbean (see Table 5.2).

Species threats

The primary threats to biodiversity include habitat loss/degradation, overexploitation, disease, introduced/ invasive species, pollution and climate change. While the extinction threat facing many species is undisputed, the underlying causes of threat are often complex, multiple and synergistic, complicating biodiversity conservation and management. Extinction risks also vary across ecosystems, with some systems more vulnerable than others.

Although the Tropics is home to most of the world's species, it has some of the greatest human pressures with a greater proportion of the world's poor, high population growth and greater levels of conflict than temperate regions. Compared with other regions many tropical ecosystems are poorly understood, and significant knowledge gaps still exist. Additionally, around 90% of the annual $6-7 billion spent on biodiversity conservation is raised and used in developed nations (James et al. 1999, Brooks et al. 2006, Birdlife International 2013), despite implementation costs often being cheaper in developing nations. All of these factors combine to put great pressure on tropical biodiversity.

Habitat loss due to land use change (e.g. agriculture) and resource extraction (e.g. forestry and mining), is a leading threat to biodiversity. Even if the geographic footprint of these activities is small, clearly defined and regulated, new transport linkages can rapidly open up large areas of virgin habitat to other destructive activities (Chomitz et al. 2007; Laurance et al. 2009). In the Tropics, an increasing proportion of land use change for agriculture and resource extraction is to produce goods such as beef, biofuels, coffee, chocolate, timber and mining resources for export markets, particularly to developed nations (Chomitz et al. 2007). In this sense, while many developed nations may boast of improvements in their own national conservation efforts, their ecological footprints are in fact growing as they export their impacts to poorer nations.

In the Tropics, habitat loss resulting from logging and other land use change has resulted in significant international attention. However, rainforests are not the only ecosystems suffering substantial habitat loss. While there has been a sustained effort to slow deforestation and land use change in the Amazon, the neighbouring Brazilian cerrado has been subject to major land use changes, with more than half of the area transformed to pasture and cropping over the past 35 years (Klink & Machado 2005). Biologically this region is the richest tropical savannah in the world, is home to 20% to 50% of Brazil's vertebrate species (Klink & Machado 2005) and is recognised as one of the world's biodiversity hotspots (see Figure 4.11).

Importantly, it is not only the total extent of habitat loss that can influence extinction rates but also the fragmentation of habitat. Fragmentation is a major issue in tropical forests and savannahs where roads and land clearing create forest fragments that isolate animal and plant populations (Canale et al. 2012, Laurance et al. 2002). These effects are not spread evenly across species groups either, with beetles, birds and primates more vulnerable to fragmentation, while frogs and small mammals tend to be more resilient (Laurance et al. 2002).

Disease is also an increasingly significant cause of species extinction, especially among amphibians. Spread of the chytrid fungal disease from southern Africa has led to significant declines in frog populations in Australia, New Zealand, Central America, California and South America (Weldon et al. 2004, Hoffmann et al. 2010). The pathogenic spread of this disease has also been linked with climate change, demonstrating that multiple factors can combine to hasten population declines (Pounds et al. 2006). Similar issues have been seen with the spread of canine distemper to a number of carnivores including ferrets, lions and seals.

Introduced and invasive species also contribute to extinction risks through competition, predation, disease and displacement. Their impacts are particularly acute on islands or geographically isolated nations (e.g. Australia, Madagascar), where they have had devastating impacts on native and endemic species. Indeed, their impacts may also combine with other threats and often exceed those of single significant drivers such as habitat loss (Woinarski et al. 2011), which is the main threat to species in most other regions (Brooks et al. 2002). The spread of invasive species cost the global economy an estimated US$1.4 trillion in 2000 or around 4% of the global GDP. (Pimental et al. 2001). Management of invasive species is difficult and expensive because they often have high reproductive rates, are tolerant of a wide range of conditions, and have few natural controls in their new environments, all of which help them to out-compete local species.

Pollution as a threat can be population-specific or a landscape issue depending on the pollutant. Aquatic systems can be particularly vulnerable to physical and chemical pollutants including nutrient overloads, heavy metals, hydrocarbons and pesticides. These pollutants may have short-term (pulse) or longer term (press) effects. Some pollutants also have wider effects through bioaccumulation up food chains. Examples include mercury accumulation in higher order fishes, and pesticide accumulation in predatory birds.

Box 5.2 The other 99%

Sufficient information was available to assess and rate around 60,000 species in the IUCN Red List database in 2012 (IUCN 2012b). This represents only 4% of described species and less than 1% of the species estimated to exist. At present only mammals, birds, amphibians, horseshoe crabs, tropical reef building corals, conifers and cycads have been comprehensively assessed (that is, more than 90% of known species of these taxa have been allocated an IUCN status) (IUCN 2012b). In contrast, less than 1% of invertebrates have been described let alone assessed (Lunney & Ponder 1999), and only 5% of plants have been assessed (IUCN 2012b).

The primary reason for the low number of properly assessed species is the lack of knowledge of the basic biology and status of most species which makes it difficult to adequately meet data requirements under IUCN standards (Lunney & Ponder 1999; Dunn 2005). This applies even for taxa that are important to humans such as insects, molluscs and crustaceans. Assessment of species status and threat risk is particularly challenging for many of these taxa that require specialist taxonomic expertise (at a time of decreasing budgets and resources for taxonomists) and the logistical difficulties of working in the geographically isolated and physically challenging regions that many are found in.

Leaf mimicking grasshopper. Image: Mark Ziembicki.

Table 5.1 **Nations with the greatest biodiversity**

Rank	Amphibians	Birds	Mammals	Conifers	Cycads
1	Brazil (798/496/116)	Colombia (1,799/65/86)	Indonesia (670/258/183)	China (130/56/34)	Australia (69/69/18)
2	Colombia (714/333/214)	Peru (1,772/106/93)	Brazil (648/183/82)	United States (98/39/14)	Mexico (44/36/38)
3	Ecuador (467/155/171)	Brazil (1,704/197/122)	China (551/82/74)	Mexico (80/30/16)	South Africa (38/29/24)
4	Peru (461/217/96)	Ecuador (1,578/32/69)	Mexico (523/157/100)	Indonesia (54/6/6)	Vietnam (25/12/16)
5	Mexico (364/245/211)	Indonesia (1,561/369/115)	Peru (467/217/53)	New Caledonia (45/44/17)	China (20/12/12)
	World* (6,347/1,905)	**World* (9,990/1,222)**	**World* (5,488/1,141)**	**World* (620/172)**	**World* (289/150)**

Source: Vié et al. (2009), State of the Tropics project.
Note: Numbers in parentheses are the number of species described/ number of endemic species/ number of species considered threatened.
*Number of endemic species not listed for World.

Box 5.3 Biodiversity hotspots

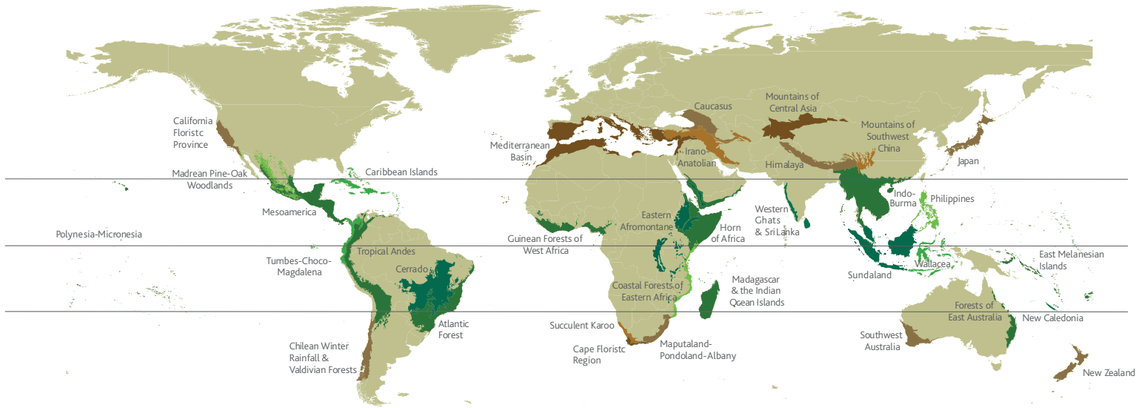
Given resource constraints the conservation of biodiversity may be framed by the question: where would a given effort contribute the most towards slowing the rate of extinction? Answering this question requires an understanding of species' distributions and endemism – the degree to which species are found only in a given place. This may be thought of as a measure of 'irreplaceability', since endemic species cannot be found anywhere else.

British ecologist Norman Myers developed the concept of biodiversity hotspots in 1988 in response to these challenges. Biodiversity hotspots are characterised by exceptional levels of plant endemism and significant levels of habitat loss. To qualify as a hotspot, a region must contain at least 1,500 endemic species of vascular plants (> 0.5% of the world's total), and have lost at least 70% of its original habitat. By 2000, 25 hotspots were identified across the globe, with the subsequent addition of a further nine hotspots. Combined, the 34 hotspots now cover only 2.3% of the Earth's land surface, yet between them are home to 50% of the world's plant species and 42% of its terrestrial vertebrate species. Overall around 77% of the Earth's terrestrial vertebrates can be found in these hotspots.

As Figure 5.1 illustrates, 21 of the 35 hotspots are located in the Tropics. That is, many significant tropical ecosystems with extraordinary biodiversity are under threat from human impacts. Habitat destruction and overexploitation are the major threats to biodiversity. Rapidly growing human populations and extreme poverty in tropical regions are major drivers of these pressures. As such, improving environmental outcomes in large part depends on addressing social and economic issues.

As available funds for conservation efforts are limited, the concept of biodiversity hotspots assists decision makers to allocate funds to maximise environmental benefits. The idea of biodiversity hotspots is also easy to identify with, hence is useful for mobilising public interest in biodiversity and conservation issues. Furthermore, it highlights the extent of the biodiversity conservation challenge. Unless we are successful in protecting this small fraction of the planet's land area, we will lose more than half of our natural heritage.

Figure 5.1 **Biodiversity hotspots**



Source: Conservation International

Another emerging threat to species is anthropogenic climate change. Projections of climate change impacts suggest that 18 to 35% of species may be at risk of extinction by 2050 (Thomas et al. 2004). Species with very fragmented or restricted distributions will be particularly at risk. In conjunction with overexploitation, habitat loss, disease, and invasive species, climate can also act to change a species' risk profile. Indeed, how these threats combine and interact under the increasing impacts of climate change requires further investigation. Management of these combined impacts will ultimately determine the fate of much of the world's biological diversity (Brook et al. 2008).

Biodiversity conservation and management

There are two general approaches to biodiversity conservation and management. Single-species conservation approaches, often thought of as crisis management in the case of highly endangered species, often focus on 'charismatic mega-fauna' such as elephants, pandas, and the like (WWF 2008, Simberloff 1998). They often use a species as a 'flagship' for conserving habitat and other species in an area. Another approach emphasises direct conservation measures that aim to protect areas at high risk or with high levels of endemism or biodiversity (Crozier et al. 1999). Since the late 1980s the concept of biodiversity hotspots has also proved useful for identifying high biodiversity and high-risk habitats for conservation and management. The habitat conservation and biodiversity hotspot approach is based on the use of protected areas, which are considered a cornerstone in the protection of biodiversity (see also Protected Areas Indicator) (Nicholson et al. 2012).

A criticism of many species-specific conservation activities is that they tend to target 'charismatic species'. The human appeal of these species can attract funding, though from a global biodiversity conservation perspective, it can also contribute to the sub-optimal allocation of scarce resources (Crozier et al. 1999). However, habitat conservation has also been criticised for focusing on processes and species protection at global or national levels, often at the expense of diversity of local species populations (Simberloff 1998). This approach can reduce the genetic biodiversity within a species, putting them at greater risk from disease or inbreeding.

In developing nations (many of which are located in the Tropics) it is estimated that 20-30% of household income in rural areas is derived from 'wild' natural resources (Kaimowitz & Sheil 2007, Ceballos & Ehrlich 2006). Many of these resource rich areas are also the focus of global conservation efforts, which may overlook the significance of ecosystem services to local communities. In affected communities the loss of these ecosystem services can have a major impact on livelihoods (see Box 5.4).

Nonetheless, as the links between poverty, population growth and effective biodiversity conservation are increasingly understood, many programs now aim to address poverty and conservation issues simultaneously (Fisher 2005).

Table 5.2 Threatened species

Region	Amphibians		Birds		Mammals		Reptiles		Plants	
	# Assessed	Threatened %	# Assessed	Threatened %	# Assessed	Threatened %	# Assessed	Threatened %	# Assessed	Threatened %
Tropics	**5,356**	**43**	**9,117**	**12**	**4,243**	**26**	**2,756**	**27**	**13,225**	**67**
Central & Southern Africa	949	35	2,175	10	1,190	23	599	36	2,683	61
Northern Africa & Middle East	83	1	1,289	3	472	9	162	9	774	29
South Asia	300	57	973	7	305	30	166	22	1,204	47
South East Asia	795	30	2,540	10	1,121	31	797	21	2,897	52
Caribbean	200	74	798	7	190	17	114	47	630	72
Central America	691	62	1,424	6	521	18	533	19	960	59
South America	2,271	38	3,233	12	1,147	20	398	24	4,792	68
Oceania	391	12	1343	10	501	24	314	32	1,593	53
Rest of the World	**1,243**	**25**	**4,398**	**9**	**2,410**	**15**	**1,418**	**20**	**3,918**	**42**
World	**6,355**	**41**	**10,050**	**13**	**5,492**	**25**	**3,744**	**26**	**15,645**	**60**

Source: IUCN (2012a), State of the Tropics project.
Note: The threat assessment was undertaken using the mid-point formula set out in: IUCN (2011). Guidelines for appropriate uses of IUCN Red List Data. Incorporating the Guidelines for Reporting on Proportion Threatened and the Guidelines on Scientific Collecting of Threatened Species. Version 2. This excludes data deficient and extinct species in the threat analysis. Threatened Species = Critically Endangered + Endangered + Vulnerable.

Although there are clear links between economic prosperity and environmental impacts (Mikkelson et al. 2007), the strength of the relationship can vary substantially (Taylor & Irwin 2004, Naidoo & Adamowicz 2001, Holland et al. 2009). Economic inequality has been shown to be a significant indicator of biodiversity threat, particularly for plants and amphibians (Mikkelson et al. 2007, Holland et al. 2009), and provides a further lever for policy makers in biodiversity conservation efforts.

Globally, although biodiversity loss targets under the CBD have not been met, the program has delivered some positive outcomes (CBD 2010b). At the aggregate level, of the 21 targets that formed the 2010 biodiversity improvement goals, significant progress was made against four and some progress against fourteen, and only three have reported no progress (CBD 2010b).

Although there is an increasing extinction rate among terrestrial species, a recent review reports that without conservation efforts, the extinction rate among mammals, birds and amphibians may have been 18% higher (Hoffmann et al. 2010). In addition, conservation efforts have helped stabilise or improve population numbers for 33 critically endangered bird populations and 8% of mammals, birds and amphibians classified as threatened or near threatened by the IUCN (Hoffmann et al. 2010).

Looking forward

Global awareness of the need to preserve biodiversity is increasing, and there are indications that some global targets are being achieved. However, as programs tend to be delivered locally, an ongoing challenge to the success of conservation efforts will be the capacity to engage local communities in programs by aligning conservation goals with economic realities and socio-cultural aspirations. This 'bottom up' approach is typically more resource-intense in the short term, but tends to be more effective in delivering longer term, sustainable conservation outcomes. Although there is no consensus yet, there may be more returns from effort by focussing on habitats rather than individual species, and the IUCN has commenced developing a Red List of Ecosystems to assess their status.

Sabah, Malaysia. Image: Mark Ziembicki.

Box 5.4 Local versus global conservation

As the global footprint of human activity expands, biodiversity conservation is an important element in managing ever-increasing risks to ecosystems. While progress is being made, significant risks to conservation programs persist. One of the most pressing issues relates to how to manage the impacts on local communities and livelihoods of global and nationally-focused conservation initiatives, especially in developing nations (Kaimowitz & Sheil 2007, Vermuelen 2004). Many global and national programs use an exclusion/preservationist approach to biodiversity conservation that can be at odds with local, sustainable resource use. This can create community tension, increase poverty risk and reduce the effectiveness of conservation efforts.

Initiatives that have attempted to integrate poverty alleviation with biodiversity conservation have had mixed results. Successful programs have been able to address the underlying cause of the threat, and to also secure local ownership and participation of the program (Kaimowitz & Sheil 2007). Encouragingly, more programs are also recognising the need to integrate poverty alleviation, and to link this with local democratic support and engagement to achieve biodiversity and conservation goals.

One important reality is that effective biodiversity protection is not a 'one-size-fits-all' process. Effective management needs to recognise global, regional and local needs, and to then tailor programs which respect stakeholder needs, encourage behavioural change and maximise biodiversity benefits.

Protected areas

Protected areas are a fundamental tool in biodiversity conservation. They provide ecological refuges that link and maintain habitats and sustain key natural processes (CBD 2012b). Of equal importance, protected areas help maintain essential ecosystem services to a large proportion of the world's population. They are a primary source of drinking water for over one-third of the world's largest cities and provide livelihoods for about 1.1 billion people worldwide (CBD 2012b). Protected area functions are also recognised as being integral to addressing climate change.

A protected area is an area recognised, dedicated and managed through legal or other means to achieve long-term conservation of nature and associated ecosystem services and cultural values (Dudley 2008). There are however, different types of protected areas with different levels of protection (see Box 5.5).

Among the Millennium Development Goals (MDG) is the recognition of the need to maintain biological diversity because of the role it plays in delivering key ecosystem services. One of the MDG targets was for at least 10% of each of the world's terrestrial bioregions[14] to be protected by 2010. Although, by 2010, protected areas covered 12.7% of the world's land area, the 10% target was only achieved in half of the 821 identified bioregions. Furthermore, only 1.6% of total ocean area was protected (MDG Report 2010). The internationally recognised Strategic Plan for Biodiversity has now set protected area targets of at least 17% of terrestrial areas, and 10% of marine areas by 2020 (UNEP 2012). It also identifies the need for protected areas to be well-connected systems that are integrated into the wider environment (CBD 2010b).

Creation of protected areas to conserve special features has a long history. The protection of natural resource areas through royal decrees extends back as far as two millennia in India, while in Europe wealthy aristocracy have set aside hunting grounds for over a thousand years. In other regions, locations of religious or sacred significance have been managed for hundreds to thousands of years (Holdgate 1999, IUCN-WCPA 2010).

The modern movement for protection of significant areas of natural value began in the 19th century, though it was during the latter part of the 20th century that the extent and number of terrestrial protected areas expanded rapidly. Between 1985 and 2008 there was an increase from 3.5% of global area to 12.2% (Jenkins & Joppa 2009). However, this expansion has not been consistent across all regions and ecosystems. In particular, recognition and declaration of marine protected areas has lagged behind terrestrial areas.

The greatest proportion of biodiversity hotspots (both terrestrial and marine) are in the Tropics (Ceballos & Ehrlich 2006) (See Box 5.3, Figure 5.1). Earlier conservation efforts and protected area programs focussed on terrestrial biodiversity 'hotspots' to protect endemic and endangered species and their habitats. More recently, this effort has extended to the oceans to protect key 'hot spots' associated with coral reefs, seagrasses, mangroves and other important marine ecosystems (Roberts et al. 2002).

The extent of protected areas is increasing slightly faster in the Tropics than in the Rest of the World, at 2.2% and 2.0% per annum respectively. In 2010, 13.9% of the Tropics were protected, compared with 10.1% of the Rest of the World.

All tropical regions report an improvement in the total number and extent of protected areas, though the degree of change varied considerably (see Figure 5.2). Three of the eight tropical regions achieved the MDG goal of 10% area protected. At 26.2% South America had the highest combined proportion of marine and terrestrial protected areas in 2010, having more than doubled its protected area since 1990. Central America also more than doubled its extent of protected area in the period, from 6.5% to 16.0%. Growth in the extent of protected areas in other tropical regions was more modest. Although growth has been slow in Central & Southern Africa it did meet the MDG, with 15.5% of area protected. Much of this growth was in terrestrial protected areas given the large number of nations in the region that are landlocked.

Terrestrial protected areas

The proportion of terrestrial protected areas (TPA) in the world was 8.3% in 1990, with the Tropics accounting for 10.4% of its area under formal protection and the Rest of the World 7.2% (see Figure 5.3). Since then the area under protection in the Tropics has increased at a greater rate than in the Rest of the World, with the proportion of TPA in tropical regions increasing to 15.5% – an increase of almost 50% over 20 years.

By nation, the extent of TPA coverage in the Tropics ranges from minimal to extensive. Of the 43 nations of the world with less than 1% of their land mass protected in 1990, 24 were in the Tropics. By 2010, the number of nations worldwide with less than 1% TPA had fallen to 24, with 14 in the Tropics (MDG 2010). At the other end of the scale, nearly two-thirds of nations with more than 40% of their land area under protection in 2010 are in the Tropics, with the proportion of tropical nations in this group having increased since 1990 (IUCN & UNEP-WCMC 2012).

In the Tropics the greatest area of TPAs is in South America, which at 26.3% also had the largest proportion of its land area protected in 2010. South America also had the largest increase in TPA between 1990 and 2010, accounting for 75% of the TPA increase in the Tropics. In part this is due to significant increases in protected areas in the Amazon since 2000 (see Box 5.6). Central America has also seen a doubling of the proportion of TPA since 1990, primarily due to increases in Mexico. There has been little in the way of major changes in the extent of TPA in other tropical regions between 1990 and 2010 (see Figure 5.3).

[14] Bioregion is described under the Convention on Biological Diversity as a territory that is defined by a combination of biological, social, and geographic criteria. It is synonymous with biogeographic region.

Twin falls, Kakadu National Park. Image: Peter Forster.

Box 5.5 Types of protected areas

The International Union for the Conservation of Nature identifies seven categories of protected area. The categories vary based on the character of the protected area – which may be determined based on natural beauty, endangered species or cultural or historical significance – and the management practices employed. Categories I – IV are more restrictive in terms of allowed activities, while categories V – VI allow greater scope for exploitation (Dudley 2008). All seven categories are included in the dataset for this report.

Ia – Strict Nature Reserves are set aside for protection of biodiversity/ geological/ geomorphological features. There are strict limits on use, visitation and impact.

Ib – Wilderness Areas are large areas with little or no modification that retain their natural character and have limited temporary human habitation.

II – National Parks are large natural areas designed to protect large-scale ecological systems along with characteristic flora and fauna, but may allow environmental and cultural activities to occur.

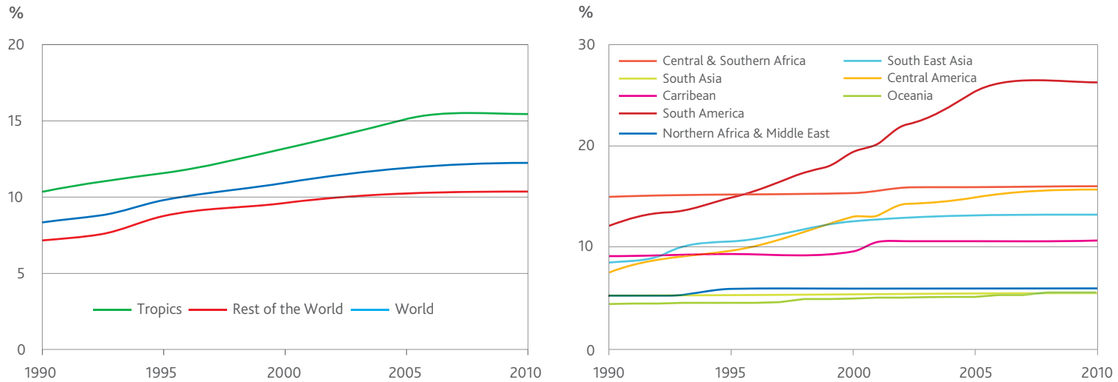
III – Natural Monuments are areas set aside to protect a specific natural feature, with a unique value because of its rarity, cultural significance or aesthetic qualities. They are generally relatively small areas and often have high visitor numbers.

IV – Habitat/ Species Management Areas are specifically designed to protect identified species or habitats, with intensive management focussed on species protection.

V – Protected Landscapes are areas that have become ecologically, biologically, culturally or scenically significant as a result of human/ environment interaction over time. These can include traditional land use patterns such as agriculture and forestry.

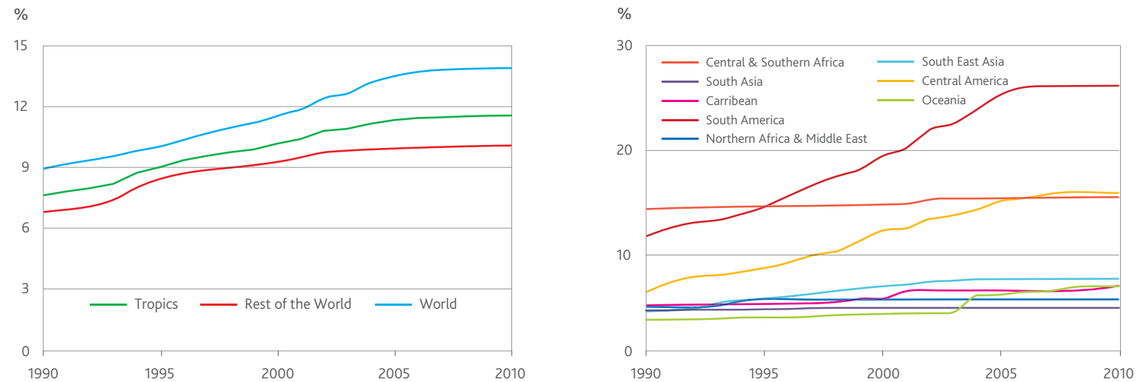
VI – Protected Area/ Sustainable Use Areas have identified cultural and/ or traditional natural resource management systems associated with them. Low-level non-industrial sustainable extraction is considered compatible with the conservation aims of these areas.

Figure 5.2 **Protected areas (% of land and territorial waters)**



Source: MDG (2010), IUCN & UNEP-WCMC (2012), State of the Tropics project.

Figure 5.3 **Area protected as a percentage of land area**



Source: MDG (2010), IUCN & UNEP-WCMC (2012) and State of the Tropics project.

Marine protected areas

The proportion of the area in a nation's territorial waters (extending 12 nautical miles) that is protected tends to be lower than the proportion of terrestrial protected areas. This reflects a general lag in recognising the need to protect marine areas and difficulties in establishing and protecting areas of marine conservation value (Chape et al. 2003). Nonetheless, this is changing, and the global proportion of protected territorial waters increased from 2.6% in 1990 to 6.8% by 2010 (see Figure 5.3). Although below the 2010 MDG target, it is approaching the goal of 10% protection by 2020 defined by the Strategic Plan for Biodiversity 2011–2020 (CBD 2010b, UNEP 2012).

The extent of marine protected areas (MPA) is much lower in tropical regions. In 1990, 39 nations with marine territorial waters had no MPA, with 28 of these in the Tropics. Between 1990 and 2010 the number of nations with no MPA decreased to 14, but 13 of these were in the Tropics (MDG 2010). However, during this period the proportion of protected territorial waters in the Tropics increased from 1.7% to 6.1%. Although still less than the 7.5% protection in the Rest of the World, the proportion of MPA in the Tropics is increasing at a faster rate.

In 1990, no nation had more than 40% of their territorial waters under formal protection. By 2010 there were seven nations, with three in the Tropics (MDG 2010).

In the Tropics, South America has the highest proportion of MPA, at 23.8% of territorial waters, up from 5.5% in 1990 (see Figure 5.4). The declaration of the internationally important Galapagos Marine Reserve in 1996 was a significant contributor to this increase. Five of the seven nations in South America had more than 15% of their territorial waters under marine protection by 2010 (MDG 2010).

Since 1990 Central America and Oceania also reported substantial increases in MPA, with respective increases of 17.1% and 9.6% of territorial waters by 2010. Five of the eight nations in Central America had more than 10% of their territorial waters under MPA by 2010, while the three largest marine protected areas (Great Barrier Reef Marine Park, North Western Hawaiian Island Coral Reef Reserve and the Phoenix Islands Protected Area) are in Oceania. All other tropical regions have less than 5% of marine territorial waters protected. South Asia had the smallest increase in MPA between 1990 and 2010 and also, of the tropical regions has the lowest overall proportion of MPA at 1.5% in 2010.

Costs and benefits of protected areas

Protected areas deliver conservation benefits through the protection of biodiversity and ecosystem services, as well as a range of economic benefits from income generation and employment opportunities for local communities (Dixon & Sherman 1991). Protected areas also deliver indirect benefits through the maintenance of aesthetic and cultural values (Dixon & Sherman 1991). In addition to biodiversity conservation, recognition of tropical rainforests as carbon sinks has prompted actions to reduce deforestation in protected areas (Andam et al. 2008, Soares-Filho et al. 2010), and also focussed attention on developing robust economic measures for environmental values (Dixon & Sherman 1991).

The potential of 'eco-tourism' in protected areas can also be an important source of economic activity. Eco-tourism in protected areas allows for the preservation of natural resources that may otherwise be exploited through non-renewable or unsustainable practices (such as logging, mining, or industrial development), and opportunities to generate foreign exchange income. In Africa a number of economic assessments suggest that income per hectare from big game tourism may be up to 50 times greater than for pastoral activity (Westem & Thresher 1973).

Similarly, a significant proportion of the revenue generated in tropical eastern Australia is from direct and indirect tourism associated with the Great Barrier Reef Marine Park (GBRMP). In 2003 around 9.3 million people visited the GBRMP, spending an estimated $4.1 billion (Bailey et al. 2003). Tourism was responsible for 9.1% of employment in the GBRMP region (Bailey et al. 2003).

Our understanding of the links between biodiversity, ecosystem services and human benefits is also increasing due to greater research attention. For example, it is now recognised that biodiversity protection can improve air and water quality, support sustainable economic development, improve food security and assist to alleviate poverty (UNEP 2012). In protecting biodiversity many nations are indirectly making progress against a broad range of other Millennium Development Goals.

Notwithstanding these benefits, the declaration of protected areas can be disenfranchising to local communities, especially if they depend heavily on resource use from the designated area. This can result in adjustment or transitional costs, particularly where a community is displaced or key income or resource use is lost. Unless these costs are recognised and addressed, resource-use conflicts can arise between conservation authorities and the local communities (Ngugi 2002). Another common issue is costs related to the conservation of top-end predators in protected areas. Successful conservation can lead to conflict when 'spillover' effects of predators from a protected area lead to issues in adjoining communities through domestic stock losses, agricultural harm or human mortality.

Similarly, many MPAs are designed to protect key habitat and recruitment areas for important fisheries species. This has often led to conflict between MPA managers and commercial, artisanal and recreational fishers over the loss of fishing rights. An increasing body of research demonstrates that the fish stock benefits of no-take zones extends beyond the MPA within

two to three years of establishment (Hodgson & Ross 2003), but this has often been difficult to demonstrate to fishing communities a priori. Without community cooperation, support and understanding, effective management of protected areas is difficult (Ngugi 2002).

Overcoming community resentment and resource-conflict in protected areas can be achieved through integration of local communities in key decision making processes and management roles. This is being increasingly recognised, with highly successful indigenous and community management programs in place in many protected areas (UNEP 2012).

Threats to protected areas

Effective management of protected areas is critical to ensure that conservation values and ecosystem services are maintained. Research into the effectiveness of terrestrial Protected Area Management (PAM) suggests the key threat to protected areas is over extraction of biological resources from activities such as hunting and logging. Other threats include agricultural and aquaculture development; human disturbance; system modification through changes in fire regimes; development of settlements; pollution; invasive species; and fragmentation due to road and utility corridors (Leverington et al. 2010). Hunting and fishing are the major threats in Africa, Asia, Latin America and Oceania, with logging also significant in Africa and Oceania. The establishment of settlements within protected areas is the second highest threat in Latin America, while human development is the most common threat in Europe (Leverington et al. 2010).

Marine biodiversity hot spots and protected areas are not necessarily contained within the national territorial waters of single nations, hence appropriate management may require effective international cooperation. Some marine bioregions such as the Great Barrier Reef and Galapagos Islands are recognised as being internationally significant, and this has helped in

Box 5.6 Protected areas in Brazil

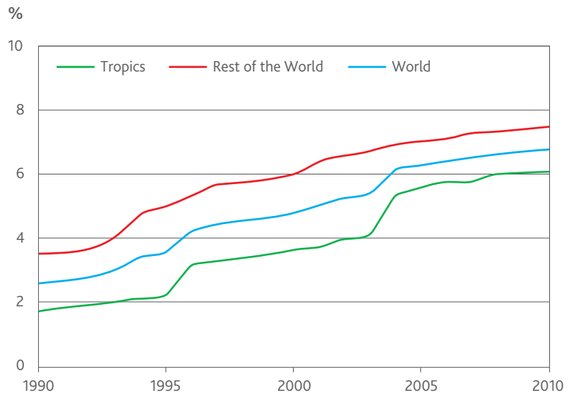
Brazil has the fourth largest system of protected areas in the world, and since 2000 has had the greatest increase in terrestrial protected areas. Part of the success in increasing TPA in Brazil is the development of the Amazon Region Protected Areas Program (ARPA), which began with a 1998 pledge to set aside 10% of Brazil's forests in protected areas (GEF 2012a).

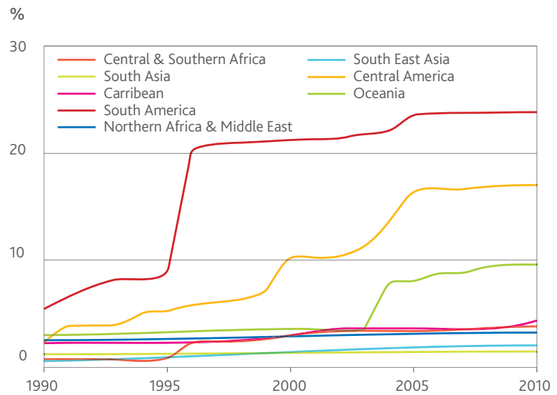
The Amazon bioregion covers almost half (49.3%) of Brazil and is considered the 'lungs' of the earth. With international aid, ARPA was successful in 2002 in establishing the Tumucumaque National Park, currently the world's largest tropical forest reserve (GEF 2012a). ARPA has also been effective in reducing the amount of deforestation in protected areas (GEF 2012a).

Over 25% of the Brazilian Amazon is now protected, but many of Brazil's other bioregions are less well protected, even though they also have high levels of biodiversity. In recognition of this, efforts are being made to extend the area of protection in other bioregions to meet MDG targets (GEF 2012b).

Image: Mark Ziembicki.

Figure 5.4 Area protected as a percentage of marine territorial waters





Source: MDG (2010), IUCN & UNEP-WCMC (2012), State of the Tropics project.

securing their protection status. While there are no official MPAs in international waters, areas like the Southern Ocean and Indian Ocean Whale Sanctuaries are recognised by many nations as being important reserves to protect migratory whale species. However, without formal recognition and enforcement as protected areas, whaling activity can and does occur in these sanctuaries.

Coral reefs are the most biologically diverse ecosystem in shallow marine waters, and are found around 12% of tropical coasts (Roberts et al. 2002). Seagrasses and mangroves are also found in tropical coastal waters. These environments provide important habitats for wildlife and are centres of biodiversity and endemism. Although such areas may be within protected areas many of the threats to these systems arise from adjacent terrestrial environments. Deforestation, urban and industrial development and poor agricultural practices contribute to the degradation of coastal marine systems through increased sedimentation and nutrient run-off. Nonetheless, in many locations efforts to protect coastal marine systems are increasing, often through community integration into management processes and controls on development activities in 'upstream' terrestrial areas (Roberts et al. 2002).

Looking forward

Increasing recognition of the importance and extent of ecological services offered by healthy ecosystems has contributed to the substantial increase in global protected areas over the past two decades. Nonetheless, the fragility of many ecosystems is becoming more apparent as they are affected by a greater range and intensity of human pressures. Ecosystem degradation is an ongoing issue, though the expansion of protected areas proposed under the Strategic Plan for Biodiversity 2011–2020 is likely to offset this process somewhat. There appears to be increasing community acceptance of the rationale and need for protected areas, and greater recognition that community involvement in the planning and management of protected areas can act to reduce transition costs – and increase benefits to both the environment and to society.

Global recognition of the importance of tropical forests has contributed to a rapid increase in the area of forest under protection and the quality of their management. However, many other significant non-forest bioregions receive less attention and are poorly protected. Looking forward, these issues will need to be addressed by local, national and international decision makers, while balancing the needs of the local, national and international communities. The broad range of stakeholders in many instances means that, while a nation may have territorial rights to a particular area, cooperation at a broad range of levels is needed to ensure that valuable ecosystems are adequately protected and maintained.

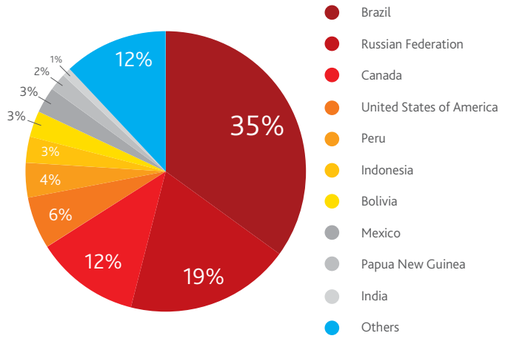
Primary forests

Forests, and especially primary forests, tend to be more biologically diverse than other terrestrial landscapes and make significant contributions to broader ecosystem functioning. Primary forests, sometimes referred to as old growth forests, are forests of native species in original condition that are largely undisturbed by human impacts and where ecological processes have not been significantly disturbed. Tropical forest ecosystems host at least two-thirds of the Earth's terrestrial species and provide significant local, regional and global benefits to humans through the provision of economic goods and ecosystem services.

The future of tropical forests is uncertain. Between 1990 and 2010 the global area of all forests decreased from 4.17 to 4.03 billion hectares, representing an average loss of 6.8 million hectares (or 0.2%) per annum. The Tropics accounted for these losses with 9.5 million hectares (-0.5%) lost per annum. In contrast, the Rest of the World reported an increase of 2.7 million hectares (0.1%) per annum, due primarily to increases in plantation forests. Few areas of the Tropics have escaped human impacts, and the combined influence of high rates of deforestation, degradation, over-harvesting, invasive species and global environmental change, threaten to make tropical forests the centre of current and future extinctions (Gardner et al. 2009). The future of tropical forests is therefore dependent on effective management of human impacts on these ecosystems.

Biodiversity values differ between forest types. In the Tropics, primary forests host the greatest biodiversity, followed by selectively logged forests, secondary forests and, finally, plantation forests (Barlow et al. 2007, Gibson et al. 2011). That is, even without complete habitat loss through deforestation, the transition from primary forest to less natural forests affects biodiversity, even though these other forest types and plantations add to the overall stock of forests. This point is important to consider when assessing changes in the type of forest cover, noting that globally, areas of plantation forests increased by 85 million hectares in the 20 years to 2010, while there was a concomitant loss of 220 million hectares of non-plantation, natural forest. Related to their biodiversity values primary forests also have many essential ecological functions that may also be affected by their natural quality, including the protection of soil and water resources, carbon sequestration and the provision of aesthetic, cultural and religious values.

Figure 5.5 **Nations with the largest areas of primary forest, 2010**



Source: FAO

Although difficult to report on a globally consistent basis (see Box 5.7), monitoring the extent of primary forests is an indicator of biodiversity risks.

The Food and Agriculture Organization (FAO) estimates that in 2010 primary forests accounted for 36% of forest area globally (FAO 2010). Seven of the ten nations with the largest area of primary forest holdings are located, or substantially located, in the Tropics (see Figure 5.5). Around 35% of the world's primary forest is located in Brazil, mainly within the Amazon Basin. It should be noted that information is missing for some large tropical nations which might otherwise be part of the top ten nations, including the Democratic Republic of the Congo, Cameroon and Venezuela (see Box 5.7).

Around 57% or 7.8 million square kilometres of primary forest is estimated to be in the Tropics in 2010. Between them the Russian Federation, Canada and the United States of America account for more than 85% of primary forest holdings in the Rest of the World.

In 2010 approximately 41% of forests in the Tropics were primary forest, compared to 27% in the Rest of the World. Of the tropical regions South America has the highest proportion of primary forest (77%) and the Caribbean (3%) the lowest.

Globally, of the 18 nations in which primary forests are more than 50% of total forest area, 16 are in the Tropics. In the Tropics 31 nations report no primary forests compared to 35 in the Rest of the World, which is unchanged over the 20 years to 2010.

Box 5.7 Data quality and limitations

Analyses of changes in forest cover are limited by the availability and quality of data. Data reported here are sourced from the Food and Agriculture Organization's Global Forest Resources Assessment 2010. These data are generally considered the most reliable cross-national estimates available over the period 1990 to 2010. They do, however, have some important limitations associated with: self-reporting by nations; inconsistencies in how and when forest cover is evaluated (Laurance 2007); and non-reporting by some nations for key variables, notably the extent of primary forests. Numerous research projects have independently assessed the extent of forests, but they typically do not report globally, report over shorter time periods or report on different variables.

Major forested nations that have not reported on their primary forests for the 2010 FAO assessment include the Democratic Republic of Congo (DRC), Cameroon and Venezuela. However, independent assessments suggest primary forests may represent 40-45% of forests in DRC (or around 650,000km2 in 2000), 65% in Venezuela (300,000km2) and 25% in Cameroon (50,000km2) (Verhegghen et al. 2012, Mongabay 2012, Potapov et al. 2008). Assuming comparable assessment methods this suggests that DRC has the fifth largest area of primary forests and Venezuela the tenth largest (see Figure 5.4). As such, the actual area of tropical primary forests reported here is understated.

As an alternative point of reference to nation-reported data, FAO 2010 has also used remote sensing technology to assess global forest change from 1990 to 2005 (FAO & JRC 2012). The advantage of this approach is that it creates a global time series dataset collected on a consistent basis. Remote sensing results indicate total global forest area of 3.8 billion hectares in 2005 (compared with 4.06 billion hectares based on FAO2010 self-reported national assessments), with an average net loss of 4.0 million hectares per annum (-0.1%) between 1990 and 2005. Net losses in tropical forests increased from 5.6 million hectares per annum in 1990-2000 to 9.1 million hectares per annum in 2000-2005. Nation-level data are not yet publicly available.

Segama River, Darnum Valley, Borneo. Image: Mark Ziembicki.

Trends

In the ten years to 2010, the FAO reports that based on country reported data, the world's area of primary forest decreased by an estimated 42 million hectares or 3.7% - a loss on average of 0.4% per annum[15] (see Table 5.3). The vast majority of the losses were in the Tropics, with almost 70% occurring in South America (see Figure 5.6). In South America the sheer vastness of primary forests combined with their accessibility are contributing to huge and ongoing losses. Although nowhere rivals South America in terms of the total area of primary forests being lost, in some other tropical regions percentage loss rates are considerably higher than in South America, and are increasing. The most notable regions in this regard are Central & Southern Africa and Oceania.

Nonetheless, driven by improvements in South America and South East Asia, the annual loss of primary forests in the Tropics has been falling, from 4.56 million hectares per annum in 1990-2000 to 4.17 million hectares in 2000-2010, a reduction of 389,000 hectares (or 8.5%) per annum. More modest improvements occurred in Central & Southern Africa and South Asia, while in Oceania annual losses of primary forests increased by 148,000 hectares.

In the Tropics, Northern Africa & Middle East reported the biggest improvement in the rate of primary forest loss, falling from -0.8% per annum in 1990-2000 to -0.1% in 2000-2010. Oceania and Central & Southern Africa were the only two tropical regions to report increases in the rate of primary forest losses.

Declining rates of nationally-reported primary forest losses are encouraging, but alternative assessments using remote sensing technology suggest that actual losses may be considerably higher in some regions (see Box 5.8). This is concerning as the remaining primary forests

[15] The Russian Federation is excluded from the analysis as the irregular trend in the area of primary forest is the result of changes in the classification system introduced in 1995.

Table 5.3 Primary forests

Region	Area of Primary Forest (1,000 ha)				Annual Change							
	1990	2000	2005	2010	1990-2000		2000-2005		2005-2010		2000-2010	
					1,000 ha/yr	%	1,000 ha/yr	%	1,000 ha/yr	%	1,000 ha/yr	%
Torrid Zone	**868,999**	**823,314**	**801,065**	**781,526**	**-4,569**	**-0.5%**	**-4,450**	**-0.5%**	**-3,908**	**-0.5%**	**-4,179**	**-0.5%**
Central & Southern Africa	51,149	45,242	42,450	39,723	-591	-1.2%	-558	-1.3%	-545	-1.3%	-552	-1.3%
Northern Africa & Middle East	8,799	7,761	7,658	7,565	-104	-1.2%	-21	-0.3%	-19	-0.2%	-20	-0.3%
South Asia	10,462	10,402	10,372	10,372	-6	-0.1%	-6	-0.1%	0	0.0%	-3	0.0%
South East Asia	70,873	67,300	65,531	65,000	-357	-0.5%	-354	-0.5%	-106	-0.2%	-230	-0.3%
Caribbean	206	205	204	206	0	0.0%	0	-0.1%	0	0.2%	0	0.0%
Central America	29,480	26,526	25,693	25,087	-295	-1.1%	-166	-0.6%	-121	-0.5%	-144	-0.6%
South America	664,500	634,182	618,644	605,191	-3,032	-0.5%	-3,108	-0.5%	-2,690	-0.4%	-2,899	-0.5%
Oceania	33,531	31,697	30,513	28,382	-183	-0.6%	-237	-0.8%	-426	-1.4%	-331	-1.1%
Rest of the World	**321,919**	**320,943**	**320,776**	**320,856**	**-98**	**0.0%**	**-33**	**0.0%**	**16**	**0.0%**	**-9**	**0.0%**
World	**1,190,918**	**1,144,257**	**1,121,841**	**1,102,382**	**-4,666**	**-0.4%**	**-4,483**	**-0.4%**	**-3,892**	**-0.3%**	**-4,188**	**-0.4%**

Source: FAO 2010, State of the Tropics project
Notes: Totals may not sum due to rounding.
The Russian Federation is excluded from time series analysis because there was a large difference in the reported change rate (from +1.6 million hectares per year in the 1990s to-0.5 million hectares per year in the period 2000–2005) related to a modification to the classification system introduced in 1995 rather than actual changes in primary forest area.

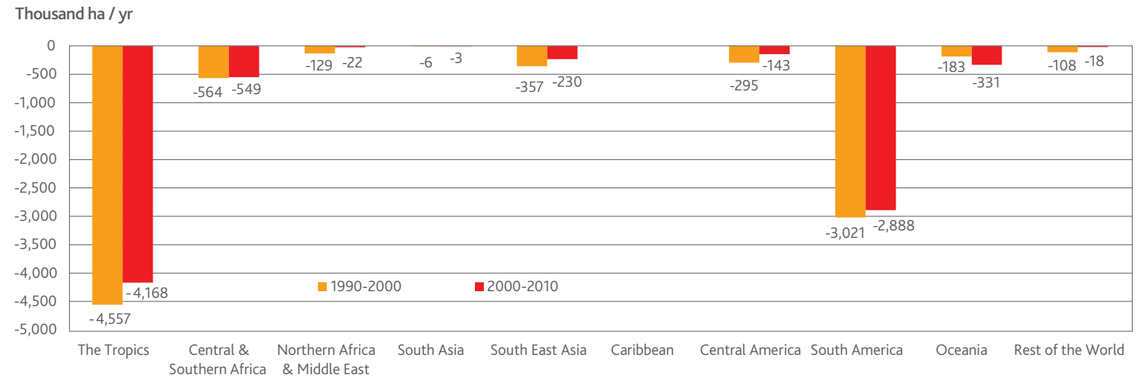
and the biodiversity they hold are especially important, as in many parts of the world forests were already significantly depleted prior to 1990 (the start of the time series here). For example, in Bangladesh it is estimated that total forest cover (that is, primary, secondary and plantation forests) around this period was only 10% of the original cover, and in India it was around 22% (Laurance 2007).

As habitat loss is a major factor contributing to extinctions there is no doubt that the loss of species-rich primary forests across the world has the potential to significantly impact biodiversity. Destruction of primary forests in Asia is well-advanced, but in other regions such as the Amazon in South America and the Congo in Central & Southern Africa there is the opportunity to protect a greater proportion of these forests and biodiversity from human threats. The biodiversity in many tropical rainforests is poorly documented, and globally it is estimated that only 14% of existing terrestrial species have been described (Mora et al. 2011). Many species risk becoming extinct before they are even described, with unknown ecological consequences. There are also potential impacts on the genetic resources available for use by humans for medicinal and other purposes. These risks are magnified in the Tropics given the region's rich biodiversity.

Forests for conservation of biodiversity

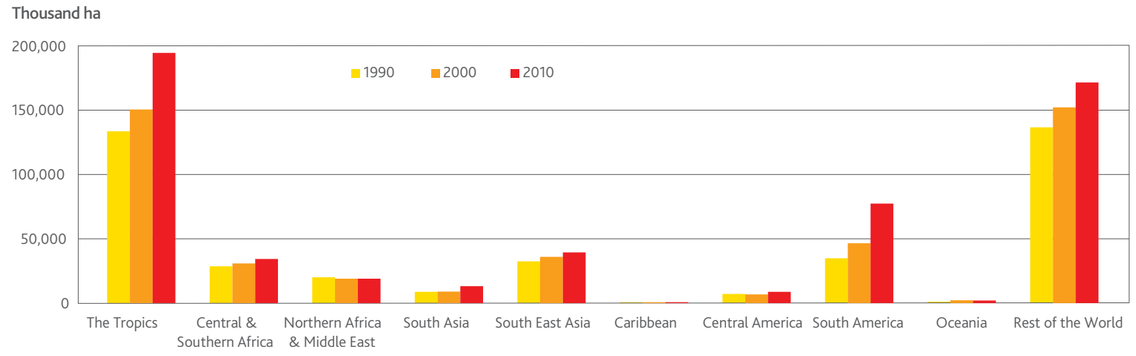
Forests deliver a wide range of ecosystem services to the environment and to humanity through provisioning (food, water, wood etc.), regulating (nutrient, water and carbon cycles, climate regulation) and cultural services. Habitat destruction through deforestation or other impacts that affect forest biodiversity may therefore not only affect species diversity, but also the performance of broader ecological systems and regulatory processes. Focusing forest conservation efforts on protecting habitats is therefore more likely to conserve both

Figure 5.6 Average annual primary forest change



Source: FAO (2010), State of the Tropics project.

Figure 5.7 Forest area primarily designated for conservation of biodiversity



Source: FAO (2010), State of the Tropics project.
Note: Estimates are for the 186 nations that submitted data for all three reference periods.

biodiversity and underlying systems (Duffy 2008).

The importance of primary forests in protecting biodiversity is increasingly acknowledged, but demand for timber products, industrial and subsistence farmland and access to resources is putting increasing pressure on primary forest stocks. Growing concerns about the ever increasing impacts of anthropogenic pressures on tropical biodiversity and natural ecosystem services have led to increases in the number and extent of protected areas across the tropics (Laurance et al. 2012). Protected areas are now a key part of global conservation efforts and an important indicator for policy makers.

Nonetheless, as with forests, not all protected areas are the same, and the performance of each will be affected by factors such as the effectiveness of management and enforcement activities, boundary demarcation and the 'health' of adjacent areas. Recent research suggests that only about half of all protected areas in the Tropics are effective, while the rest are experiencing declining biodiversity (Laurance et al. 2012).

Using information from 186 nations that provided data for all time periods in the Global Forest Resources Assessment 2010, the area of forests in the Tropics reserved for the conservation of biodiversity was 195 million hectares in 2010 (see Figure 5.7). This is a 46% increase since 1990, and represents 53% of global biodiversity reserves. The Rest of the World reported an increase of 26%.

In the Tropics the largest areas of forests reserved for conservation of biodiversity are in South America, followed by Central & Southern Africa and South East Asia. Northern Africa & Middle East is the only tropical region to report a decrease (-6.2%) in forested biodiversity reserves in the 20 years to 2010. Fourteen of the 20 nations estimated to have reduced conservation of biodiversity reserves in the past 20 years are in the Tropics.

Box 5.8 Deforestation in Indonesia

Indonesia is one of the world's most forest-rich nations. Reliable information is critical for effective forest management and policy development but is often not available.

Data reported to the Food and Agriculture Organization (FAO) by the Indonesian government suggests forest losses in the order of -0.5% per annum in the ten years to 2010. Over the same period, other datasets collected with the assistance of remote sensing technologies estimate the rate of forest loss at -1.0% per annum – double that reported by the FAO. Most of these losses occurred in Borneo and Sumatra which accounted for losses of 57% and 39% respectively (Miettinen et al. 2011).

In Sumatra, between 2000 and 2010 deforestation occurred almost exclusively in secondary forests (99%), with 10% of primary forests degraded to secondary forest status. This is an improvement on the ten years to 2000 when primary forests represented 5% of natural forest losses in Sumatra, and 30% of the primary forest stock was degraded. Over the 20 year period primary forest losses in Sumatra from deforestation and degradation averaged 2.6% per annum. Primary forest loss in Asia appears to be particularly significant given its biota appears particularly susceptible to human impacts (Gibson et al. 2011).

These independent assessments suggest recent deforestation rates in Indonesia are significantly greater than those reported to the FAO. To an extent this reflects differences in methodologies and definitions used to characterise forests, however, greater use of remote sensing technologies and consistant use of methods should reduce such discrepancies and provide a more accurate picture of the status of the world's forests.

Deforestation. Image: Mark Ziembicki.

Using FAO data for 2010, around 15% of forests in the Tropics were reserved for the conservation of biodiversity, compared with 9% in the Rest of the World. In the Tropics, South Asia has the highest proportion of forests reserved for the conservation of biodiversity (29%), followed by Central America (24%) and the Caribbean (19%).

Looking forward

The increase in forest area set aside for conservation reflects the growing understanding of the risks to human wellbeing from a loss of ecosystem services associated with biodiversity decline and, particularly, changes to ecosystem regulating services. Relative to ecosystem provisioning services, knowledge of the role and value of ecosystem regulating services is relatively poor, and extensive research is required if we are to understand these complex processes.

Looking forward, in addition to maintaining the integrity of ecosystem services, greater efforts to protect primary forests from exploitation is likely to improve biodiversity outcomes. This will be critical in the Tropics, which has 21 of the 35 global biodiversity hotspots (see Box 5.3 and Figure 5.1). Acknowledging that all forests have competing uses, any effective response to stemming biodiversity and primary forest loss will need to integrate ecological, economic and social values, while considering prospects for conservation and sustainable use (Wilcox 1995).

Image: Mark Ziembicki.

References

Andam KS, Ferraro PJ, Pfaff A, Sanchez-Azofeifa GA, Robalino JA. (2008). Measuring the effectiveness of protected area networks in reducing deforestation, in *Proceedings of National Academy of Sciences* **105**(42).

Bailey G, Riley D, Heaney L, Lubulwa M, Barry T, Salma U. (2003). *Assessment of Tourism Activity in the Great Barrier Reef Marine Park Region.* Bureau of Tourism Research, Canberra.

Barlow J, Gardner TA, Araujo IS, Ávila-Pires TC, Bonaldo AB, Costa JE, Esposito MC, Ferreira LV, Hawes J, Hernandez MIM, et al. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests, in Proceedings of the *National Academy of Sciences* **104**(47).

Birdlife International (2013). *Investing in Conservation is Essential and Affordable* http://www.birdlife.org/datazone/sowb/response/RESPO2 (accessed on 21 February 2013).

Brook BW, Sodhi NS, Bradshaw CJA. (2008). Synergies among extinction drivers under global change, in *Trends in Ecology & Evolution,* **23**(8)

Brooks TM, Mittermeier RA, da Fonseca GAB, Gerlach J, Hoffmann M, Lamoreux JF, Mittermeier CG, Pilgrim JD, Rodrigues ASL. (2006). Global biodiversity conservation priorities, in *Science* **313**(58).

Brooks TM, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Rylands AB, Konstant WR, Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylor C. (2002). Habitat loss and extinction in the hotspots of biodiversity, in *Conservation Biology* **16**(4).

Butchart SHM, Akcakaya HR, Kennedy E, Hilton-Taylor C. (2006). Biodiversity indicators based on trends in conservation status: Strengths of the IUCN Red List Index, in *Conservation Biology* **20**(2).

Canale GR, Peres CA, Guidorizzi CE, Ferreira-Gatto CA, Kierulff MCM. (2012). Pervasive defaunation of forest remnants in a tropical biodiversity hotspot, in *PLoS ONE* **7**(8).

CBD (2010a). *Global Biodiversity Outlook 3*. Secretariat of the Convention on Biological Diversity, Montréal.

CBD (2010b). *Strategic Plan for Biodiversity 2011–2020.* Secretariat of the Convention on Biological Diversity, Montreal.

CBD (2012a). *Protected Areas – an overview.* Convention on Biological Diversity http://www.cbd.int/protected/ overview/ (accessed on 26 June 2012).

CBD (2012b). *History of the Convention.* Convention on Biological Diversity http://www.cbd.int/history/ (accessed on 17 January 2012).

Ceballos G, Ehrlich PR. (2006). Global mammal distributions, biodiversity hotspots, and conservation, in *Proceedings of the National Academy of Sciences* **103**(51).

Chape S, Blyth S, Fish L, Fox P, Spalding M. (2003). *2003 United Nations List of Protected Areas.* IUCN, Gland & UNEP-WCMC, Cambridge.

Chomitz KM, Buys P, DeLuca G, Thomas TS, Wertz-Kanounnikoff S. (2007). *At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests.* The International Bank for Reconstruction and Development/ World Bank, Washington.

Christofferesen LE. (1997). *IUCN: A Bridge Builder for Conservation.* Green Globe Yearbook.

Crozier RH, Pedersen K, Agapow P-M. (1999). Phylogenetic assessment of total biodiversity, in Ponder W, Lunney D. (Eds), *The Other 99%. The Conservation and Biodiversity of Invertebrates.* Transactions of the Royal Zoological Society of New South Wales, Mosman.

Dixon JA, Sherman PB. (1991). Economics of Protected Areas, in *Ambio* **20** (2).

Dudley N. (Ed) (2008). *Guidelines for Applying Protected Area Management Categories.* Gland, Switzerland: IUCN.

Duffy JE. (2008). Why biodiversity is important to the functioning of real-world ecosystems, in *Frontiers in Ecology and the Environment* **7**(8).

Dunn RR. (2005). Modern insect extinctions, the neglected majority, in *Conservation Biology* **19**(4).

FAO (2010). *Global Forest Resources Assessment 2010.* Food and Agriculture Organization, Rome.

FAO, JRC (2012). *Global Forest Land-use Change 1990–2005*, by Lindquist EJ, D'Annunzio R, Gerrand A, MacDicken K, Achard F, Beuchle, Brink A, Eva HD, Mayaux P, San-Miguel-Ayanz J, Stibig H-J. FAO Forestry Paper No. 169. Food and Agriculture Organization and European Commission Joint Research Centre, Rome.

Fisher B. (2005). Poverty and biodiversity conservation, in *Mekong Update & Dialogue* **8**(3).

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA, Sodhi NS. (2009). Prospects for tropical forest biodiversity in a human-modified world, in *Ecology Letters* **12**(6).

GEF (2012a). *From Rio to Rio: A 20 Year Journey to Green the World's Economies.* Global Environment Facility, Washington DC.

GEF (2012b). *Consolidation of National System of Conservation Units (SNUC) and Enhanced Flora and Fauna Protection – GEF Project 4859.* Global Environment Facility http://www.thegef.org/gef/project_detail?projID=4859 (accessed on 20 June 2012).

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJA, Laurance WF, Levejoy TE, Sodhi NS. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity, in *Nature* **478.**

Hodgson G, Ross M. (2003). Using Reefcheck to stimulate community management of Gilutongan, Central Philippines, in Wilkinson C, Green A, Almany J, Dionne S. (Eds), *Monitoring Coral Reef Marine Protected Areas. A Practical Guide on How Monitoring Can Support Effective Management of MPAs.* Australian Institute of Marine Science and the IUCN Marine Program, Townsville.

Hoffmann M, Hilton-Taylor C, Angula A, Böhm M, Brooks TM, Butchart SHM, Carpenter KE, Chanson J, Collen B, Cox NA et al. (2010). The impact of conservation on the status of the world's vertebrates, in *Science* **330.**

Holdgate M. (1999). *The Green Web – A Union for World Conservation.* Earthscan, London.

Holland TG, Peterson GD, Gonzalez A. (2009). A cross-national analysis of how economic inequality predicts biodiversity loss, in *Conservation Biology* **23**(5).

Isaac J, Turton S. (2009). *Expansion of the tropics: Evidence and implications* http://www-public.jcu.edu.au/public/groups/everyone/documents/media_release/jcuprd_048832.pdf (accessed on 13th December 2012).

IUCN (2011). *Guidelines for appropriate uses of IUCN Red List Data. Incorporating the Guidelines for Reporting on Proportion Threatened and the Guidelines on Scientific Collecting of Threatened Species.* Version 2. Adopted by the IUCN Red List Committee and IUCN SSC Steering Committee.

IUCN (2012a). *The IUCN Red List of Threatened Species.* International Union for the Conservation of Nature http://www.iucnredlist.org/search/list (accessed on 6 November to 7 December 2012).

IUCN (2012b). *Summary Statistics.* International Union for the Conservation of Nature http://www.iucnredlist.org/about/summary-statistics#Tables_3_4 (accessed on 14 December 2012).

IUCN, UNEP-WCMC (2012). *The World Database on Protected Areas.* International Union for the Conservation of Nature & United Nations Environment Programme-World Conservation Monitoring Centre www.protectedplanet.net (accessed June 2012).

IUCN-WCPA (2010). *50 Years of Working for Protected Areas: A Brief History of IUCN World Commission on Protected Areas.* International Union for Conservation of Nature-World Commission on Protect Areas, Gland.

James AN, Gaston KJ, Balmford A. (1999). Balancing the earth's accounts, in *Nature* **401.**

Jenkins CN, Joppa L. (2009). Expansion of the global terrestrial protected area system, in *Biological Conservation* **142**(10).

Kaimowitz D, Sheil D. (2007). Conserving what and for whom? Why conservation should help meet basic human needs in the Tropics, in *Biotropica* **39**(5).

Klink CA, Machado RB. (2005). Conservation of the Brazilian Cerrado, in *Conservation Biology* **19**(3).

Laurance WF, Lovejoy TE, Vasconcelos HL, Bruna EM, Didham RK, Stouffer PC, Gascon C, Bierregaard RO, Laurance SG, Sampaio E. (2002). Ecosystem decay of Amazonian forest fragment: A 22-year investigation, in *Conservation Biology* 16(3).

Laurance WF. (2007). Forest destruction in tropical Asia, in *Current Science* 93(11).

Laurance WF, Goosem, M, Laurance, SGW. (2009). Impacts of roads and linear clearings on tropical forests, in *Trends in Ecology & Evolution,* 24

Laurance WF, Useche DC, Rendeiro J, Kalka M, Bradshaw CJA, Sloan SP, Laurance SG, Campbell M, Abernethy K, Alvarez P, et al. (2012). Averting biodiversity collapse in tropical forest protected areas, in *Nature* **489.**

Leverington F, Cost KL, Courrau J, Pavese H, Nolte C, Marr M, Coad L, Burgess N, Bomhard B, Hockings M. (2010). *Management Effectiveness Evaluation in Protected Areas – A Global Study.* Second Edition. University of Queensland, Brisbane.

Lunney D, Ponder W. (1999). Emergent themes from the Other 99%, in Ponder W, Lunney D. (Eds), The Other 99%. *The conservation and biodiversity of invertebrates.* Transactions of the Royal Zoological Society of New South Wales, Mosman.

MDG (2010). *Millennium Development Goals Indicators.* United Nations http://unstats.un.org/unsd/mdg/Data.aspx (accessed on 6 June 2012).

MDG Report (2010). *The Millennium Development Goals Report 2010.* United Nations, New York.

Miettinen J, Shi C, Liew SC. (2011). Deforestation rates in insular Southeast Asia between 2000 and 2010, in *Global Change Biology* **17**(7).

Mikkelson GM, Gonzalez A, Peterson GD. (2007). Economic inequality predicts biodiversity loss, in *PLoS ONE* **2**(5).

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C. (2011). Global biodiversity conservation: The critical role of hotspots, in Zachos FE, Habel JC (Eds), *Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas.* Springer Berlin Heidelberg.

Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B. (2011). How Many Species Are There on Earth and in the Ocean?, in *PLoS Biology* **9**(8).

Naidoo R, Adamowicz WL. (2001). Effects of economic prosperity on numbers of threatened species, in *Conservation Biology* **15**(4).

Ngugi I. (1999). Economic impacts of marine protected areas: a case study of the Mombasa Marine Park, in Richmond MD, Francis J. (Eds), *Marine Science Development in Tanzania and Eastern Africa.* Proceedings of the 20th Anniversary Conference on Advances in Marine Science in Tanzania.

Nicholson E, Collen B, Barausse A, Blanchard JL, Costelloe BT, Sullivan KME, Underwood FM, Burn RW, Fritz S, Jones JPG et al. (2012) Making robust policy decisions using global biodiversity indicators, in *PLoS ONE* **7**(7).

OECD (2002). *The DAC Guidelines Integrating the Rio Conventions into Development Co-operation.* Organisation for Economic Co-operation and Development, Paris.

Pimental D, McNair S, Janecka J, Wightman J, Simmonds C, O'Connell C, Wong E, Russel L, Zern J, Aquino T, Tsomondo T. (2001). Economic and environmental threats of alien plant, animal, and microbe invasions, in *Agriculture, Ecosystems and Environment* **84.**

Pounds JA, Bustamante MR, Coloma LA, Consuegra JA, Fogden MPL, Foster PN, La Marca E, Masters KL, Merino-Viteri A, Puschendorf R, Ron SR, Sanchez-Azofeifa GA, Still CJ, Young BE. (2006). Widespread amphibian extinctions from epidemic disease driven by global warming, in *Nature* **439.**

References | Continued

Roberts CM, McClean CJ, Veron JEN, Hawkins JP, Allen GR, McAllister DE, Mittermeier CG, Schueler FW, Spalding M, Wells F, Vynne C, Werner TB. (2002). Marine biodiversity hotspots and conservation priorities for tropical reefs, in *Science* **295.**

Rosenzweig ML. (1995). *Species Diversity in Space and Time.* Cambridge University Press, Cambridge.

Simberloff D. (1998). Flagships, umbrellas and keystones: is single-species management passé in the landscape era?, in *Biological Conservation* **83**(3).

Soares-Filho B, Moutinho P, Nepstad D, Anderson A, Rodrigues H, Garcia R, Dietzsch L, Merry F, Bowman M, Hissa L, Silvestrini R, Maretti C. (2010). Role of Brazilian Amazon protected areas in climate change mitigation, in *Proceedings of the National Academy of Sciences* **107**(24).

Taylor BW, Irwin RE. (2004). Linking economic activities to the distribution of exotic plants, in *Proceedings of the National Academy of Sciences* **101**(51).

Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BFN, de Siqueira MF, Grainger A, Hannah L et al. (2004). Extinction risk from climate change, in *Nature* **427.**

UNEP (2012). *Global Environment Outlook 5: Environment For The Future We Want.* United Nations Environment Programme, Valletta.

Verhegghen A, Mayaux P, de Wasseige C, Defourny P. (2012). Mapping Congo Basin forest types from 300m and 1km multi-sensor time series for carbon stocks and forest areas estimation, in *Biogeosciences Discussions* **9.**

Vermuelen S. (2004). *Biodiversity Planning: Why and How Should Local Opinions Matter?* Gatekeeper Series No. 115. International Institute for Environment and Development.

Vié JC, Hilton-Taylor C, Stuart SN. (Eds) (2009). *Wildlife in a Changing World – An Analysis of the 2008 IUCN Red List Of Threatened Species.* International Union for Conservation of Nature, Gland.

Weldon C, du Preez LH, Hyatt AD, Muller R, Speare R. (2004). Origin of the amphibian chytrid fungus, in *Emerging Infectious Diseases* **10**(12).

Western D, Thresher P. (1973). *Development Plans for Amboseli.* World Bank Office, Nairobi.

Wilcox BA. (1995). Tropical forest resources and biodiversity – the risks of forest loss and degradation, in *Silviculture* **46**(2).

Wilson EO (1992) *The Diversity of Life.* The Belknap Press of Harvard University Press, Cambridge.

Woinarski JCZ, Legge S, Fitzsimons JA, Traill BJ, Burbidge AA, Fisher A, Firth RSC, Gordon IJ, Griffiths AD, Johnson CN, McKenzie NL, Palmer C, Radford I, Rankmore B, Ritchie EG, Ward S & Ziembicki M. (2011) The disappearing mammal fauna of northern Australia: context, cause, and response, in *Conservation Letters* **4.**

WWF (2008). *A Roadmap for a Living Planet.* World Wide Fund for Nature, Gland.

Red mangroves.
Image: Mark Ziembicki.

Kiribati, Seawall.
Image: Johanna Mustelin.

Essay 2

The impacts of climate change in the Tropics

Richard T. Corlett
Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Yunnan, China

Richard Corlett obtained his first degree from the University of Cambridge in 1974, followed by a PhD in plant ecology at the Australian National University, with fieldwork in the highlands of Papua New Guinea. He has subsequently held teaching posts at the University of Chiang Mai, National University of Singapore, and University of Hong Kong. In 2012 he moved to the Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, in Yunnan, to take charge of a new Center for Integrative Conservation. His major research interests include terrestrial ecology and biodiversity conservation in tropical East Asia, plant-animal interactions, and the impacts of climate change. In addition to numerous scientific papers, he is the author of several books, including *Tropical Rain Forests: an Ecological and Biogeographical Comparison* (Wiley-Blackwell, 2011) co-authored with Richard Primack, and *The Ecology of Tropical East Asia* (Oxford University Press, 2009). He is a lead author for the 'Asia' chapter in the 2014 Report of the Intergovernmental Panel on Climate Change (IPCC) and a member of the steering committee of the IUCN Climate Change Specialist Group. He was elected President of the Association for Tropical Biology and Conservation (ATBC) in 2012.

XTBG

The impacts of climate change in the Tropics

Richard T. Corlett

The climate is changing in the Tropics, as it is in the rest of the world (IPCC, 2013). The effects of steadily rising concentrations of greenhouse gases on the climate may be less obvious to tropical residents, however, because they are overlain by considerable natural variability. Much of this variability is driven by the El Niño-Southern Oscillation (ENSO) (see Figure E2.1). The Tropics has warmed by 0.7-0.8°C over the last century—only slightly less than the global average—but a strong El Niño made 1998 the warmest year in most areas, with no significant warming since. Climate models predict a further 1-2°C warming by 2050 and 1-4°C by 2100, but the rise will certainly not be as smooth as the graphs that are produced by averaging many different climate models.

Trends in rainfall over the last century are much less clear than those in temperature. Many tropical areas are now significantly wetter or drier than they were a century ago, and others show marked fluctuations. Predictions for future rainfall vary between models in most regions, reducing confidence in their usefulness. Climate extremes are even harder to predict, but the low day-to-day variability of tropical temperatures means that a rise in mean temperatures of only a few degrees is almost certain to bring temperature extremes higher than any that occur today. There are good reasons to believe that other extremes—droughts, floods and high-intensity cyclones—will also increase in much of the Tropics, although none of these predictions are made with high confidence (IPCC, 2013).

Tropical climates have changed in the past, with the most recent major change being the several-degree warming at the end of last glacial period, between 20,000 and 10,000 years ago. Temperatures have also been higher than now, although the last period that was consistently warmer than the present in the Tropics appears to have been the early Pliocene, more than 3 million years ago. But, although climate change is nothing new, there are very good reasons for thinking that the changes predicted for the remainder of the 21st century will be a major problem for the Tropics.

First, the models suggest that the rates of change will be faster than any known from the past, leaving little time for adaptation or movement to cooler areas. Second, although the Tropics have been warmer before, most of the last 3 million years has instead been cooler, suggesting modern species will be unlikely to have retained adaptations to these higher temperatures. Finally, and perhaps most important, rapid climate change is only one of the many stresses on plants, animals and people in the 21st century. Many of these other stresses will interact with climate change in ways that increase the negative impact of both. For example, the fragmentation of most natural habitats in the Tropics by agriculture and infrastructure will make it very difficult for species to respond to climate change by moving.

The impacts of climate change: observed and predicted

High natural climatic variability, coupled with the rarity of long-term records in the Tropics, has so far made it difficult to detect the impacts of climate change on natural and human systems (IPCC, 2014). Moreover, the impacts of climate change are expected to interact with those of other, more direct, human impacts, including deforestation, population growth, increased urbanisation and pollution, making it difficult to pin down the major drivers of change in any particular case. Terrestrial impacts are clearest on high mountains, where both plants and animals have moved upslope in response to warming in several parts of the Tropics, while glaciers have shrunk on the highest peaks in the Andes, East Africa (see Figure E2.2), and New Guinea. In the sea, coral reefs across the Tropics have suffered unprecedented mass bleaching episodes as a result of rising sea-surface temperature extremes. Most other suggested impacts are less clear than these, however. It is tempting to treat recent floods, droughts and massive cyclones as manifestations of human-caused climate change, but the science is still not certain.

Predictions for the future add the uncertainties of the biological and social sciences to the already large uncertainties from the climate models. In the case of temperature, a significant increase is all but certain, but the impacts of changes in other climate variables are best stated as 'IF climate changes in a particular way, THEN the following impact is likely'. Although not strictly aspects of climate change, both sea-level rise and ocean acidification have the same ultimate causes (rising levels of atmospheric carbon dioxide), and both are certain to increase in a delayed response to atmospheric changes that have already happened.

It is simplest to consider the impacts on natural and human systems separately, but it is important to realise that these are rarely, if ever, independent. Many of the natural systems that will be impacted are important sources of ecosystem services to human communities, including fish from coral reefs and water from mountain ecosystems. Conversely, human responses to climate change impacts, such as diverting freshwater water supplies, building sea walls, or expanding agricultural land, are expected to have large, additional impacts on natural systems.

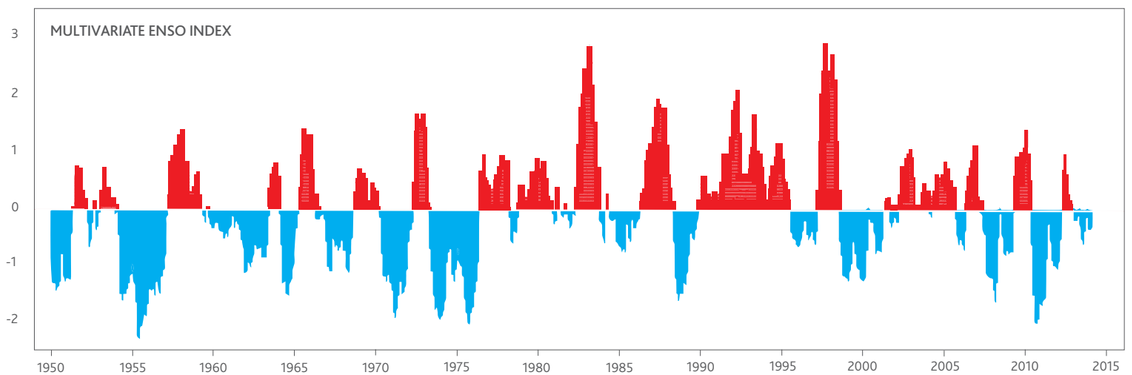
Impacts on natural systems

Outside the Tropics, it is possible to get a rough idea of future changes in natural systems by looking towards the equator, where temperatures are already warmer. London, for example, is expected to have a climate more like the present-day south of France by 2100. Even in the temperate zone, a simple poleward migration of species and ecosystems is an oversimplification, but it is a useful guide. In the tropical highlands one can look downslope to see what is coming, but in the tropical lowlands there is usually no existing analogue for the climates predicted for the second half of this century. Equatorial Singapore will not just be warmer than it is now, but warmer than anywhere on Earth with year-round rainfall.

These 'no-analogue futures' leave predictions dependent on models, but we currently lack the data needed to test whether their simulations are realistic. Scientists have warmed up insects, frogs and tree seedlings in their laboratories, and tree branches in the field, but until someone warms an entire tropical forest for several years we are unlikely to be able to say with confidence what will happen. Predictions for biodiversity in the lowland Tropics currently range from little change to a drastic 'lowland biotic attrition', as species retreat upslope or die, and are not replaced.

There are also concerns that warming, with or without changes in rainfall, could convert tropical forests, which are currently a huge net 'sink' for carbon dioxide (i.e. they absorb more than they emit), into a net source. There is currently evidence on both sides of this debate and model predictions depend strongly on what assumptions are built into them. In particular, there have been suggestions that the eastern Amazon, which is expected to get both warmer and drier over future decades, could be subject to massive forest die-back and a transition to a new, fire-adapted state, with fewer species

Figure E2.1 **The El Niño-Southern Oscillation (ENSO) has a large impact on tropical climates.**



Source: This graph shows the Multivariate ENSO Index (MEI) developed by the U.S. National Oceanic & Atmospheric Administration: positive values represent El Niño events and negative values La Niña events (http://www.esrl.noaa.gov/psd/enso/mei/).

Figure E2.2 **Shrinking glaciers on Mount Kilimanjaro in 2009. More than 80% of the ice cover on this mountain has been lost since 1912.**

Image: Muhammad Mahdi Karim (GNU Free Documentation License, Version 1.2, Wikipedia).

and less stored carbon. Most models suggest that the risk of such a transition is relatively low when only climate change is considered, but rises rapidly when the drying effects of other human impacts—particularly logging and forest fragmentation—are also factored in.

An additional factor that must be considered is the direct impact of higher levels of carbon dioxide—the major greenhouse gas—on plant growth. There are physiological reasons for believing that rising carbon dioxide levels may partly offset the adverse impacts of climate change on plants by the so-called 'carbon dioxide fertilisation effect'. Indeed, there is increasing evidence from across the Tropics that this is already happening, although not all the data supports this conclusion. Moreover, higher carbon dioxide levels are expected to favour trees over tropical grasses, and may already be contributing to observed increases in tree invasions into savannas. There is also some evidence—again debatable—for an increase in the abundance of lianas in tropical forests, which may again be driven by rising carbon dioxide levels.

In comparison with the tropical lowlands, tropical montane ecosystems have potential advantages in withstanding climate change impacts, including generally lower direct human impacts and much steeper temperature gradients, so that plants and animals will not need to move as far in order to compensate for rising temperatures. However, most mountains are basically conical in shape, meaning that the area available declines rapidly with altitude, reaching zero at the summit. If species are pushed uphill by rising temperatures they will be crowded into a smaller and smaller area, with 'mountain-top extinction' inevitable if warming continues long enough. Tropical mountains support numerous species with small geographical ranges—often confined to a single mountain—and these species may be among the most vulnerable to climate change.

The plants and animals of freshwater ecosystems—streams, rivers, lakes and wetlands—are similarly isolated from each other by inhospitable habitats and potentially vulnerable to climate change. However, any impacts so far have been difficult to disentangle from natural variability and the effects of increasing human use of freshwater resources. Future impacts from rising water temperatures and changes in water flow will continue to interact with dam construction, pollution, and land-use changes.

Coastal systems will also face threats from rising sea-surface temperatures, as well as increases in sea-level and ocean acidity, although these impacts can again be hard to distinguish from the many other effects of increasing development on tropical coastlines. Any increase in cyclone frequency and intensity would also be felt most strongly near the coast. The climate change impacts observed in recent decades largely reflect the warming sea, with many tropical species expanding their ranges towards the poles. Rising sea-levels (about 20 cm since 1900) may also be having an impact on coastal systems already, by adding to storm-surge maxima and thus increasing flooding and coastal erosion. This impact is certain to increase in the coming decades. Undisturbed coastal ecosystems can usually retreat inland in response to rising sea-levels, but on human-occupied coasts retreat is often prevented by fixed barriers intended to protect agriculture and infrastructure. The resulting 'coastal squeeze' will eliminate some coastal communities and restrict others.

The most dramatic impact of climate change observed so far across the Tropics has been the increasing frequency and scale of mass bleaching of coral reefs and, in some cases, the subsequent death of the corals (see Figure E2.3). These events correlate well with high-temperature extremes, leaving little doubt that this is a real impact of recent global warming. Ocean acidification appears to have a synergistic impact with temperature extremes on corals and other reef-building organisms, leading to plausible predictions that coral reefs as we know them will have largely disappeared by 2050. In contrast, ocean acidification is expected to enhance the growth of sea-grasses, algae and other plants through the carbon dioxide fertilisation effect.

Figure E2.3 **Coral bleaching in the Keppel Islands, Great Barrier Reef Marine Park, Australia in 2006.**

Image: Ove Hoegh-Guldberg, Global Change Institute, University of Queensland.

The impacts of warming also extend out into the tropical oceans, with shifts in the distributions of species already observed and expected to intensify in the coming decades. By mid-century there are predictions that the species richness and productivity of tropical oceans will have declined markedly as species shift polewards and are not replaced.

Natural systems have an innate capacity to adjust to climate change, by changes in the distribution and abundance of species and ecosystems, as well as by the acclimation (i.e. adjustments within the lifetime of an individual organism) and evolution (i.e. genetic changes over multiple generations) of individual species. There must be limits to this capacity, but we are currently unsure when they will be reached: another 1°C? 2°C? more? In practice, thresholds for irreversible change will certainly vary between species and may already have been exceeded in some of the more sensitive organisms.

Impacts on human societies

Compared with the impacts on natural systems, both the detection of impacts on human societies and the attribution of these impacts to climate change are considerably more difficult. Not only do human problems rarely have a single cause, but they often also come at the end of long—and sometimes tortuous—causal chains. The impacts from extreme climatic and climate-associated events—cyclones, floods, droughts, storm surges etc.— may be obvious, but such events are difficult to attribute confidently to climate change. Conversely, the gradual changes in climatic variables which we can confidently attribute to climate change have impacts that are difficult to detect against a background of rapid social and economic change arising from numerous other factors.

The most straightforward climate-change impact on human society is the effect of high temperature extremes on human health. Heat waves already kill more people than any other climatic event and their frequency and severity is almost certain to increase in the coming decades. The old and sick are most at risk of dying. Many more people are hospitalised for heat stroke and outdoor work may become impossible during the warmest months of the year. Other potential impacts on human health are less straightforward, but an increased risk of food- and water-borne diseases is likely and lowland disease vectors, such as mosquitoes, are expected to spread into tropical highlands that are currently too cool to support them. Health will also be affected indirectly by impacts on freshwater resources and the food supply.

Climate change is expected to further reduce the freshwater supply for people, agriculture and industry in presently dry areas of the Tropics and subtropics, although the generally low confidence in current rainfall predictions creates a lot of uncertainty. The continuing loss of glaciers from tropical mountains may cause a temporary increase in water flows in the streams they feed, but will also eventually reduce the availability of water downstream. Several major rivers flow towards the Tropics from the extra-tropical Himalayas and Tibetan Plateau, but glaciers and snowmelt make a significant contribution to their flow only in their upper reaches. Rising sea-levels increase the risk of saltwater intrusion into freshwater sources near the coast. The frequency and intensity of droughts is also expected to increase in some parts of the Tropics, as is the flood risk from extreme rainfall events. Floods near the coast will be exacerbated by rising sea-levels, with fixed infrastructure at particular risk. Small islands, which are effectively all coast, will be particularly vulnerable.

The potential impacts of climate change on the food supply are complex. Impacts on agricultural production will be variable, with both winners and losers depending on local circumstances. Impacts in the tropical lowlands are expected to be mostly negative as the temperature tolerance of major crops is exceeded, although, as with natural vegetation, the potential benefits of carbon dioxide fertilization are a big uncertainty. The opportunities for adapting agricultural practices to changing climates will also be important in determining future crop yields. In contrast, agriculture in tropical highlands may benefit from rising temperatures.

Several studies have predicted large declines in the fish catch in tropical oceans, as marine productivity falls, coral reefs disappear, and valuable species move polewards. Reductions in the average body size of tropical marine fishes have also been predicted. Freshwater fisheries may be threatened by warming and changed water flows, although the many other threats to freshwater ecosystems, including overfishing, water abstraction, pollution and dam construction, make the impacts of climate change hard to separate.

Urban societies face all the potential problems already discussed, plus additional threats from sea-level rise and cyclones when they are situated in low-lying coastal areas. Vulnerability is often associated with poverty, although nobody is immune to major failures in infrastructure. Many tropical cities are surrounded by vast informal settlements, often on steep land that is highly vulnerable to extreme rainfall events and their consequences. On the other hand, well-managed cities provide services, such as early warning systems, disaster relief and health care, that are often not available in rural areas, partly buffering residents from the impacts of climate extremes.

Like natural systems, human societies have an innate capacity to adjust to climate change, and the options for adjustment in the future are considered in more detail below. Some sectors of society are more vulnerable than others, either because they are more exposed to climate change or because they have a lower capacity to adjust. In general, it is the poorest people who occupy flood-prone sites and steep hillsides, and they also have least access to supporting infrastructure and government services. Indigenous people may be unusually vulnerable because of a heavy dependence on natural resources and strong cultural ties to the land, although the degree of social marginalisation is another key variable.

There is historical evidence that climate change—or, at least, a succession of 'bad' years—has triggered the collapse of civilisations in the past, and there have been suggestions that the coming decades will see increased civil unrest and violent conflict as a result of rapid climate change. Flash-points could include competition for water or food, or the impact of extreme climate events. However, the globalisation of disaster relief has made the world less vulnerable to localised disasters, and these predictions may be excessively pessimistic.

Mitigation and adaptation

Both climate and sea-level have a delayed response to rising greenhouse gases, so the Earth is already committed to some additional warming and sea-level rise, even if greenhouse gas concentrations could be stabilised at present levels. At least in theory, any additional change is under our control, and could be avoided, although the long working life of expensive energy infrastructure, such as coal-fired power stations, makes a rapid reduction in emissions extremely unlikely. Reducing the amount of future climate change by reducing greenhouse gas emissions (or increasing sinks, such as forests) is known as climate-change mitigation, and is distinguished from climate-change adaptation, which is reducing the vulnerability of human and natural systems to change.

Mitigation has been considered a task for international bodies, with the support of national governments, but the failure to reach a binding international agreement limiting future emissions suggests that this approach is not working well. Local governments and businesses have sometimes had more success in promoting low-carbon alternatives, but the real need is for a cultural change away from our current, unsustainable, dependence on fossil fuels. Cultures change from the bottom up, suggesting a key role for individuals and communities in achieving the necessary global goals. Unfortunately, the politicisation of climate change issues in many countries has made this more difficult, since attitudes to action on climate change have become packaged with unrelated issues, leading to an exaggerated polarisation of views.

Adaptation is not an alternative to mitigation, since rapid climate change will continue until we stabilise greenhouse gas concentrations and must eventually exceed even the most optimistic assessment of our capacity to adapt. However, adaptation is essential and in many cases can result in a significant reduction in adverse impacts. Uncertainties in the predictions for future climates favour 'low regrets' strategies which provide benefits under current climate conditions as well as a range of future climates. Some of these measures produce co-benefits for other development goals, making them particularly attractive.

For example, increasing trees and other greenery in urban areas would help reduce the 'urban heat island effect', which increases the threat from heat waves, but will also have co-benefits, such as improved public health. Similarly, forest restoration can contribute to mitigation by storing carbon and to adaptation by directly cooling the local climate, while also benefitting biodiversity conservation. Other potential low-regrets measures include better early-warning systems, climate-proofing of infrastructure, climate-sensitive land-use planning, and improvements to environmental education.

There are other adaptation options where the benefits depend on specific future climate scenarios. While these measures may be less easy to get implemented than those with current benefits, their potential impacts can be greater. Examples include breeding new crop varieties for tolerance of future climatic conditions, extending protected areas to include land that will be critical for conservation in the future, and the 'assisted migration' of threatened plant and animal species to locations where suitable future climates are expected. Conservationists are currently working to identify the species that will be most vulnerable to climate change so that conservation effort can be focussed where needed.

Biofuel crops were initially seen as a low-regrets mitigation option. In theory, biofuels can reduce net carbon emissions, because the carbon dioxide released by burning them is withdrawn from the atmosphere during growth, while at the same time providing economic benefits to the tropical countries that grow them. In practice, a net carbon gain has been hard to achieve with biofuel crops, because carbon-rich vegetation is often cleared for their cultivation. Moreover the economic benefits have been partly offset by negative impacts on food production and conflicts over land use. Improved land-use planning and new technologies that can utilise a wider range of plant materials may make biofuels a viable mitigation option for the Tropics, with social and environmental co-benefits, but a cautious approach is needed.

Conclusions

The global risks to natural and human systems from climate change are becoming increasingly obvious (IPCC, 2014), but most of the evidence come from outside the Tropics. In consequence, the word 'uncertainty' appears many times in this essay. Climate change impacts depend on interactions between complex physical, biological and social systems, none of which are well understood at present. The global climate models are gradually improving and now incorporate feedbacks from ecosystems, but their predictions depend heavily on the trajectory of greenhouse gas emissions over the coming decades, which in turn will be influenced by socioeconomic factors and technological change. This suggests that although the overall uncertainties in impact prediction can be reduced, they cannot be eliminated. Uncertainties are inherent in any complex system, but climate scientists have so far done a poor job of communicating this to decision-makers and the general public. This is unfortunate because the most important message from the recent IPCC reports is that our fate is in our own hands.

References

IPCC (2013) ***Climate Change 2013: The Physical Science Basis.*** Working Group 1 contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC (2014) ***Climate Change 2014: Impacts, Adaptation, and Vulnerability.*** Working Group 2 contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Trewin, B. (2014) The climates of the Tropics and how they are changing. In: ***State of the Tropics.*** James Cook University. Australia.

Flooding from Cyclone Nargis, Burma/Myanmar.
Image: Neryl Lewis RRT.

Indonesia.
Image: World Bank.

Singapore skyline.
Image: Mark Ng.

Section 3

The Human System

Chapter 6

Society

Children in Niger.
Image: Arne Hoel World Bank.

Chapter 6.1

Society | Poverty and urbanisation

Panama City.
Image: Gerardo Pesantez, World Bank

Summary of poverty and urbanisation indicators

Indicator		Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Poverty	People living in extreme poverty (1981-2008) %*	50-30	53-53	55-29	59-37	63-16	25-28	15-4	21-7	31-28	53-16	52-22
	Undernourished population 1990-2012 (million)	553-508	137-195	34-46	162-139	161-85	9-6	9-9	41-27	1-1	450-360	1002-868
Urbanisation	Urban population 1980-2010 %	31-45	22-35	22-33	24-34	24-47	50-65	57-69	65-81	36-34	44-56	39-51
	Slum population (2001) % of urban population	46	76	73	56	30	25	2	38	15	24	32

Red: Situation is deteriorating
Green: Situation is improving

*% of people living on less than $1.25 per day

Poverty and urbanisation

Poverty and urbanisation are central to any discussion about wellbeing and development. Poverty relates to and influences all aspects of society. Poverty - insufficient income, food and services - is both the cause and result of poor health, lack of education (especially for women and girls), over-exploitation of natural resources, corruption, conflict and poor governance. Worldwide, there is commitment from all nations to reduce the number of people living in extreme poverty through the Millennium Development Goals.

Although significant progress has been made, poverty remains widespread in sub-Saharan Africa and Southern Asia. Conditions that are conducive for poverty reduction include strong and stable institutions and governance; sustainable land management and agriculture; social justice and equality; economic growth; and ongoing human development. Additionally, conflict and violence have a powerful and negative influence on poverty reduction.

Ongoing urbanisation and significant declines in poverty rates have been major features of human development in the 21st century, particularly in the Tropics. More people now live in cities than in rural areas and hundreds of millions of people have moved out of extreme poverty. However, in the face of a rising population and changing climate, nations in the Tropics will need to develop innovative ways of providing food and infrastructure (especially clean water and sanitation) to continue this trend into the future.

Headline Indicator

Poverty is pronounced deprivation in wellbeing. Although a limited measure, for the purpose of this report, people living in poverty are those who do not have income or consumption above $1.25 per day. This is commonly referred to as the extreme poverty line, and reducing the proportion of the population living below this threshold is one of the United Nations' Millennium Development Goals.

Supplementary indicators

Undernourished population; urbanisation; slum population.

Links to other dimensions

Life expectancy, maternal and child mortality, education, gender equality, economic growth, land degradation, agricultural land.

Extreme and moderate poverty

Is it getting better?

The proportion of the population in developing nations of the Tropics living in extreme poverty declined from 51% in 1981 to 28% in 2010. Despite this achievement, more than two-thirds of the world's population that is living in extreme poverty lives in the Tropics. There is considerable regional variation in the prevalence of extreme poverty. Most poverty reduction in the Tropics has occurred in South East Asia and Central America. In contrast, the number of people living in extreme poverty in Central & Southern Africa has more than doubled over the past 30 years although the rate has been stable.

Consistent with the over-representation of poverty, more people experience undernourishment in the Tropics than the Rest of the World. The prevalence of undernourishment declined in the Tropics between 1990 and 2012, down from 27% to 18% of the population, and down from 13% to 9% of the population in the Rest of the World.

In the Tropics the urbanisation rate has increased considerably faster than globally from 30.5% in 1980 to 45% in 2010. Despite this, a greater proportion of people in the Rest of the World (56%) live in cities compared with the Tropics.

In 2001, there were around 925 million people living in slums globally, or 32% of the world's urban population. The proportion of the urban population living in slum conditions was higher in the Tropics at 46% compared with 24% in the Rest of the World. In absolute terms there were almost 470 million slum inhabitants in the Tropics, compared with 460 million in the Rest of the World. The proportions were highest for Central & Southern Africa (76%) and Northern Africa & Middle East (73%).

Favela in Rio. Image: Matt McG.

The concept of poverty is central to any discussion about progress, human development and wellbeing. Conditions which are both a result and cause of poverty include poor health, lack of education, depleted or spoiled environmental resources, corruption, conflict and poor governance. Outside of nations with recent, large scale conflicts, the poorest nations in the world, with the highest poverty rates, are all in the Tropics.

Poverty is pronounced deprivation in wellbeing. The conventional view links wellbeing (and therefore poverty) to money or the command over commodities, so the poor are those who do not have enough income or consumption to put them above some minimum threshold. This one-dimensional view of poverty is, however, being supplanted by a perspective that considers poverty in terms of social dimensions, and the capability of an individual to function in society (Sen 1987). Using this broad approach, poor people often lack key capabilities: they may have inadequate income or education; have poor health; feel powerless; or lack political freedoms.

With this framework, reducing poverty is more complex than just increasing income or consumption, and also requires measures which empower the poor. Most analysis of poverty still relies on income (or consumption) as the underlying measure, as information on these metrics is relatively simple to collect and easy to interpret (see Box 6.1.1). Using income as a base, there are a couple of commonly used poverty benchmarks. Extreme poverty is defined as average daily consumption of $1.25 or less, which is the mean of the national poverty lines of the poorest 15 nations in the world and, in reality, means living on the edge of subsistence (World Bank 2013).

Another common measure of poverty is average daily consumption of $2.00 or less, which is the median poverty line of developing nations, and is sometimes referred to as moderate poverty (Baur et al. 2008). The consensus view is that eliminating poverty will require a multifaceted approach which, in addition to increasing income, also empowers the poor by increasing their access to education, employment, health and other social

services (World Bank 2010). It should be noted that the 'poverty line' varies between nations, and particularly between developing and developed nations. In Australia for example one definition of the poverty line is 50% of the median income, meaning that in 2010 the poverty line for a single adult was $358 per week, and $750 for a couple with two children (ACOSS 2012).

Trends

Globally, the proportion of people in developing nations that are living in extreme poverty has fallen consistently since the early 1990s (see Figure 6.1.1 and Table 6.1.1). In 1981, 52% of the population living in developing nations was living in extreme poverty, subsequently falling to 21% in 2010[1]. In the Tropics the proportion fell from 51% to 28%, while the improvement in the Rest of the World was markedly better, decreasing from 53% to 14% of the population. Globally the number of people living in extreme poverty has also fallen significantly over this period, from 1.85 billion in 1981 to 1.12 billion in 2010.

Nonetheless, rapid population growth in the Tropics and a worsening poverty situation in some nations mean that although the prevalence of extreme poverty has declined, the number of people living in extreme poverty only fell marginally. Slower population growth in the Rest of the World combined with a larger fall in the proportion of people living in extreme poverty resulted in numbers falling from around 1.06 billion to 0.4 billion over the same period.

Globally, the reduction in extreme poverty has been driven by China, where the proportion of the population living in extreme poverty fell from 84% in 1981 to 12% in 2010 and, in numbers, from around 835 million to 155 million. If China is excluded from the analysis of extreme poverty, the prevalence in the Tropics is estimated to fall from 48% in 1981 to 30% in 2010, but the total number increases from 700 million to 760 million people living in extreme poverty. As around 90% of China's population lives outside of the Tropics, its removal from analysis has a greater impact in the Rest of the World, with the poverty rate in 1981 falling from 53% to 28%, and then declining to 15% in 2010.

Although the number of people living in extreme poverty in the Tropics has only fallen marginally since 1981 (our analysis suggests it is less than five million people), there is considerable variation at the regional level (see Table 6.1.1). South East Asia has had the most dramatic improvement, with numbers falling by almost 65% to 95 million, or almost 175 million fewer people living in extreme poverty. Central America also had a major improvement in percentage terms with a decline of almost 65%, or around 7 million fewer people living in extreme poverty.

South Asia and South America were the only other tropical regions to report a decline in the number of people living in extreme poverty. Although there has been some year-to-year volatility, since 1981 the extreme poverty rate in Central & Southern Africa has increased slightly, and the number of people living in extreme poverty has more than doubled to 360 million in 2010. In fact, all 16 nations considered to be in chronic poverty (or 'desperately deprived') are in tropical sub-Saharan Africa (Handley et al. 2009). However, over the past decade there have been signs of improvement in the percentage of people living in extreme poverty.

Despite the extreme poverty rate falling from 59% to 33% in South Asia, the decline in the number of people living in extreme poverty has been less dramatic, only falling by 30 million to around 255 million. In South Asia, while it is true that economic growth has lifted millions out of extreme poverty, wealth disparities appear to be growing, and the number of people that are extremely poor remains very high.

[1] This is based on data for 124 developing nations. High income nations are not included in the analysis. For further information see http://iresearch.worldbank.org/PovcalNet/index.htm.

Box 6.1.1 PovcalNet

Understanding and monitoring poverty is essential for its eradication, and in recent decades the understanding of national poverty lines, the coverage and quality of household consumption (or income) data, and information on prices have improved greatly (Chen & Ravallion 2010).

Assessing global poverty is complex because its definition varies across nations, and comparisons across nations requires an internationally consistent approach to estimating the purchasing power of a given income and knowledge of prices prevailing at the time of the relevant household survey (World Bank 2013).

The development of the PovcalNet tool by The World Bank has been significant in addressing these issues, and in quantifying the extent of poverty in developing nations. PovcalNet also allows users to define their own poverty line to compare across nations and regions. Despite these improvements there are concerns about the reliability of some of the surveys that inform PovcalNet. Issues relate to the comparability of results over time and across nations, as well as under-reporting and compliance. This means there is still some uncertainty around poverty estimates generated using PovcalNet (Ravallion 2013).

Children in Uganda. Image: World Bank Photo Collection.

Moderate poverty

Between 1981 and 2010 the number of people in the developing world living in extreme poverty fell by around one-third, or almost 600 million, to 1.2 billion. While this is undoubtedly a positive outcome, it has been associated with only a modest decline in the number of people living in moderate poverty, which decreased by around 6%, or 155 million, from 2.47 billion in 1981 to 2.31 billion in 2010.

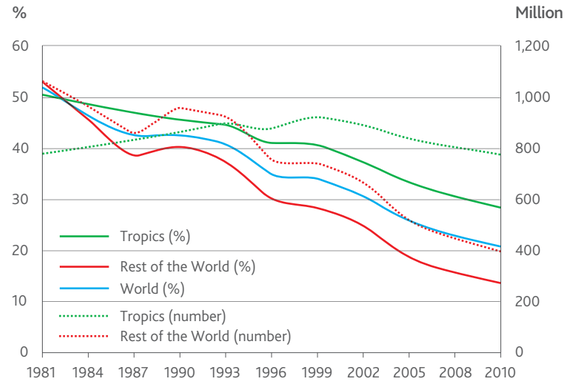
That is, the transition out of moderate poverty has been markedly slower than the transition out of extreme poverty. This has especially been the case in the Tropics, where the number of people living in moderate poverty increased by almost 300 million (27%) between 1981 and 2010.

Since 1981 the proportion of the population in the Rest of the World living in moderate poverty has more than halved, from 68% to 31% in 2010, and there are 670 million (63%) fewer people living in moderate poverty (see Table 6.1.2). In the Tropics there was a modest improvement in the proportion, from 72% to 51%, but the number of people living in moderate poverty has increased, and in 2010 almost half of the population of the Tropics was living in moderate poverty.

Moderate poverty generally refers to conditions where basic needs are met, but just barely (Sachs 2005). Currently this poverty line receives little attention by multilateral development agencies, with most focus and attention being on extreme poverty. However with more people moving into this poverty band and fewer moving higher, addressing moderate poverty is becoming an issue that will require greater attention from policy makers.

Moderate and extreme poverty trends are similar in that South East Asia has reported the greatest improvements, while Central & Southern Africa is the worst performing region.

Figure 6.1.1 **Population living on less than $1.25 per day**



Source: PovcalNet (2013), State of the Tropics project.

Poverty, growth and equality

The causes of poverty are manifold, but can be broadly grouped into socio-economic factors such as risk and vulnerability and low capabilities, and political economy factors such as the strength and integrity of political and social institutions and risks of corruption (Handley et al. 2009). Some of these factors are structural while others are cyclical, and may be associated with weather conditions and harvest or changes in prices. Health-status is another key vulnerability which can affect the poverty status of whole families, while low capabilities can limit income-generating opportunities. Where rights are not protected and services such as education and health are not provided, people will have reduced capacity to improve their lives and move out of poverty (Handley et al. 2009).

Notwithstanding this, many regions of the Tropics report quite remarkable achievements in economic growth and poverty reduction since 1981. Not surprisingly, as nations become richer, living standards improve and poverty rates generally fall. Strong growth in GDP per capita since 2000 has been reflected in the extreme poverty rate falling more rapidly than in the 20 years prior to that (see Figure 6.1.2). Similarly, according to World Bank surveys, living standards of the developing world as a whole have been growing at rates much faster than the developed world since 2000 (Ravallion 2013).

Several factors are driving rapid economic growth, including market-oriented reforms, globalisation and technological progress (ADB 2012), which are often complemented by social policy reform and public investment in health, education, social protection and legal empowerment, as well as economic infrastructure (UNDP 2013). It is these actions and innovations, complemented by strong economic growth, which have contributed to the decline of poverty (see Box 6.1.2).

Economic growth alone does not however guarantee fewer people living in poverty, especially where there is significant inequality in income distribution (Fosu 2010). Research

in Latin America suggests that up to 32% of poverty reduction in this region is due to declining inequality (Lustig et al. 2013). Although the concept of inequality is typically considered in terms of income or expenditure, it also relates to non-income dimensions of wellbeing, such as access to education, health, security and other social factors. Rapid economic growth has lifted millions out of poverty in the Tropics, but rising inequality in many nations is constraining the potential improvement.

A factor contributing to rising inequality is that many of the drivers of productivity and income growth – such as technological change, globalisation and market reforms – tend to favour the owners of capital over labour, high skilled over low skilled workers and urban and coastal areas over rural and inland communities (ADB 2012). This contributes to inequalities with respect to income and access to services, and hampers poverty reduction.

According to the Asian Development Bank, between 1990 and 2008, expenditure or income inequality increased in 11 out of 28 nations in Asia representing 82% of the population. In contrast, 14 of the 17 nations in Latin America for which data are available report increased equality since 2000, following a period of high inequality during the 1990s (Lustig et al. 2013). The decline in inequality in Central and South America is attributed to an increase in the supply of educated workers and greater wealth distribution through government transfers. Although in Asia skill levels in the labour force have also increased, this has potentially exacerbated inequality due to the number of jobs for unskilled workers declining (ADB 2012).

In sub-Saharan Africa, where poverty reduction has been the slowest, income inequality has been rising (Fosu 2009). While many factors will contribute to poverty reduction, an improved understanding of the significance of specific factors will help to expedite the process of reducing poverty. For example, in some nations (and notably poorer nations), policies which reduce inequality are likely to have the greatest impact on poverty reduction, while in richer nations sustained economic growth may have a greater impact (Fosu 2009). It is generally accepted though, that investment in infrastructure, health, education and social protection is important if poverty rates and levels are to decline (ADB 2012, Fosu 2010).

Table 6.1.1 **People living in extreme poverty**

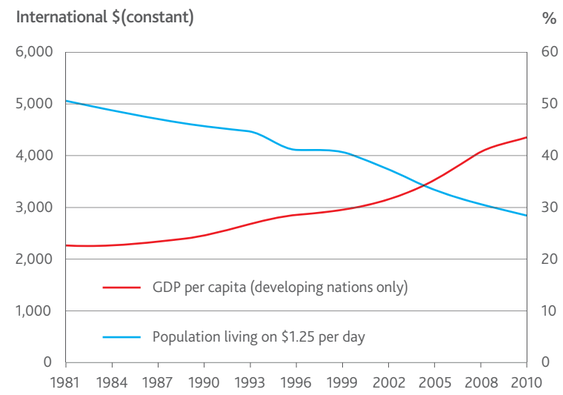
	1981		1990		1999		2010		Change 1981 to 2010		
	Million	% pop.	Million	% pop.	Million	% pop.	Million	% pop.	Million	PPT*	% pop.
Tropics	**780**	**51**	**864**	**46**	**926**	**41**	**776**	**28**	**-4**	**-22**	**-1**
Central & Southern Africa	161	53	231	58	310	61	359	54	198	1	123
Northern Africa & Middle East	30	55	40	56	42	46	37	29	7	-26	22
South Asia	284	59	300	51	308	46	253	33	-30	-26	-11
South East Asia	268	63	245	48	212	35	95	14	-173	-49	-64
Caribbean	4	25	4	25	6	27	7	28	3	4	82
Central America	11	14	11	12	11	10	4	3	-7	-11	-63
South America	22	12	31	14	35	14	18	6	-4	-6	-19
Oceania	1	31	2	42	2	34	3	35	1	4	123
Rest of the World	**1,065**	**53**	**960**	**41**	**745**	**28**	**397**	**14**	**-668**	**-39**	**-63**
World	**1,845**	**52**	**1,825**	**43**	**1,670**	**34**	**1,173**	**21**	**-672**	**-31**	**-36**

Source: PovcalNet (2013), State of the Tropics project.

Looking forward

With around 65% of people who suffer extreme poverty living in the Tropics, there is no doubt that ending poverty is an essential step to improve wellbeing in the Tropics. Although there have been significant reductions in the proportion of the world's population that is living in extreme poverty, the number remains unacceptably high. A major challenge for many tropical nations will be balancing economic growth with environmental sustainability and equality. Improvements to food production and distribution will be essential. Approaches to alleviate poverty must not only consider how the poor can benefit from economic growth, but also how they contribute to it. As more people rise out of extreme poverty, the cost of eradicating poverty will fall.

Figure 6.1.2 **Poverty and economic activity, the Tropics**



Source: PovcalNet (2013), World Bank (2012), State of the Tropics project.

Box 6.1.2 **Using technology to address poverty in India and Bolivia**

New technology is assisting people living in poverty in rural and remote regions of the Tropics to join the formal economy and rise above the poverty line. In rural India the introduction of 'smart cards' which store information such as address, income and microfinance history have enabled social programmes to better target those in need, and to reduce opportunities for corruption and fraud. Those living below the poverty line in rural India can use their smart card to access aid, government and social services, microfinance and highly subsidised food. Streamlining access to services has contributed to improvements in India's poorest areas (World Bank 2011, Mohan 2008).

A different kind of smart card has been successful in Bolivia. A microfinance organisation has overcome the problem of operating expensive mobile telecommunications by using multi-lingual smart card ATMs. Smart cards store personal details, account numbers, transaction histories and a fingerprint which allows cash dispensers to operate without the need for a permanent network connection (Prahalad & Hammond 2002). Additionally, the machines offer voice commands in Spanish and local dialects, so the services can be used by illiterate and semi-literate people.

These cards use readily accessible technologies which also allow for more efficient and detailed data collection and management. Using this information will allow policy makers and service providers to better target future programs and monitor outcomes.

Female farmers, India. Image: Bill and Melinda Gates Foundation.

Undernourished population

Nutrition is a fundamental factor underlying health and wellbeing (see Box 6.1.3). Despite progress over the past 30 years a significant number of people still do not have access to adequate food and water, which can contribute to the occurrence of preventable diseases like diarrhoea, pneumonia and measles (UNICEF 2012). Women, infants, and children are the most at risk from undernourishment, including from micronutrient deficiencies. Undernutrition is responsible for almost one-half of child deaths globally and has a substantial impact on general wellbeing and economic productivity (Black et al. 2013).

Although there have been important reductions in the proportion of undernourished people in the Tropics, a number of issues continue to cause and exacerbate undernourishment, and have increased global food insecurity in recent years. The growing population, poor governance and political instability, changes in food production and consumption and the effects of climate change are affecting food prices and the availability of food, and are adding pressure to already food insecure regions (CFS 2012). Producing and distributing enough food to satisfy growing populations will be a major challenge for all nations in the future.

Trends

Globally the undernourished population has declined steadily over the past 20 years, from around 1 billion people in 1990-92 (19% of the global population), to 870 million people in 2010-12 (15%) (see Figure 6.1.3). Over this period the undernourished population in the Tropics fell from 553 million to 508 million, a decline of 8%, while in the Rest of the World it declined by nearly 20% to 360 million (see Table 6.1.3).

Five of the eight tropical regions have reported a decline in the undernourished population since 1990-92, and all regions reported a decline in the proportion of the population that is undernourished. South East Asia had the greatest success in alleviating undernourishment, with the undernourished population almost halving, from 161 million in 1990-92 (28% of the population), to 85 million in 2010-12 (11%).

There were also significant reductions in the number of undernourished people in South Asia (where the number fell by 19 million (12%) to 139 million) and South America (where it declined by 13 million (32%) to 27 million).

Although prevalence in Central & Southern Africa has declined marginally since 1990-92, the undernourished population has increased significantly, from 137 million in 1990-92 to 195 million in 2010-12. In 2012 almost half of the nations in Central & Southern Africa had prevalence rates of 30% or more. The undernourished population in Northern Africa & Middle East has also increased, from 34 million in 1990-92 to 46 million 2010-12, despite prevalence falling by almost nine percentage points.

Box 6.1.3 Hunger, undernourishment and malnutrition

Hunger, undernourishment and malnutrition are terms used to describe a range of physical health effects caused by diets lacking in food quantity, calories, or nutritional quality. These terms are often used interchangeably to describe the causes and symptoms that result from a lack of food and nutrition, but each has a specific meaning. Hunger is defined on two levels. Firstly, as a physical signal from the body that food intake is required, and secondly as a subjective feeling of discomfort as the result of a lack of food (WFP 2013). Prolonged hunger can lead to 'chronic hunger', undernourishment and malnutrition. Women and children in developing nations are considered the most vulnerable to undernourishment.

Undernourishment occurs when a person's diet does not provide sufficient energy to perform daily tasks. Undernourishment can compromise the immune system and increase the risk of acquiring illnesses, which can diminish the body's ability to absorb food and nutrients (Burgess & Danga 2008). The physical consequences of undernourishment include body and muscle wasting, and atrophy of vital organs. Estimates of the prevalence of undernourishment are essentially a measure of food deprivation based on the calculation of three key parameters for each nation: the average amount of food available for human consumption per person, the level of inequality in access to that food and the minimum number of calories required for an average person.

Malnutrition arises from deficiencies in specific micro-nutrients and is not necessarily related to calorific intake, as it may be the result of a nutritionally poor diet. That is, malnutrition can affect people suffering from undernutrition (prolonged food and nutritional deprivation), or overnutrition (excessive food intake relative to energy requirements). Diseases like anemia, goitre and scurvy are forms of malnutrition caused by diets lacking in iron, iodine and vitamin C respectively (Shetty 2003).

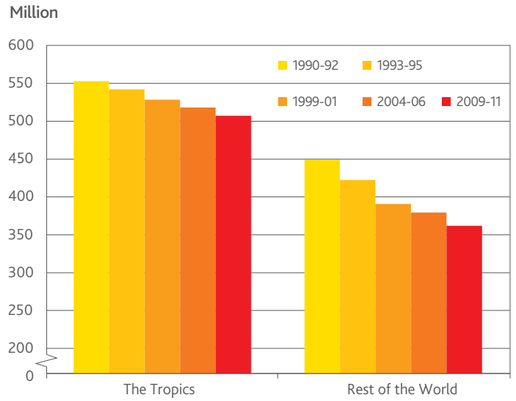
A child recovering from malnutrition in Niger. Image: Jonathan Hyams, Save the Children.

Table 6.1.2 **People living in moderate poverty**

	1981		1990		1999		2010		Change 1981 to 2010		
	Million	% pop.	Million	% pop.	Million	% pop.	Million	% pop.	Million	PPT*	% pop.
Tropics	**1,102**	**71**	**1,303**	**69**	**1,469**	**65**	**1,396**	**51**	**293**	**-20**	**27**
Central & Southern Africa	225	74	308	78	406	81	500	75	275	1	122
Northern Africa & Middle East	43	78	55	78	64	70	70	56	28	-23	65
South Asia	415	86	480	82	527	78	529	68	113	-18	27
South East Asia	345	81	374	74	374	62	240	34	-106	-47	-31
Caribbean	6	39	7	41	8	37	9	38	3	-1	56
Central America	22	28	19	20	24	21	11	9	-10	-20	-49
South America	45	25	57	26	62	24	33	11	-12	-14	-26
Oceania	2	52	3	63	3	56	4	56	2	4	111
Rest of the World	**1,065**	**68**	**960**	**61**	**745**	**51**	**397**	**31**	**-668**	**-37**	**-63**
World	**2,467**	**69**	**2,740**	**65**	**2,818**	**58**	**2,311**	**41**	**-155**	**-29**	**-6**

Source: PovcalNet (2013), State of the Tropics project.
*Percentage point

Figure 6.1.3 **Undernourished population**



Source: FAO (2013a), State of the Tropics project.

Factors contributing to undernourishment

At a global level there is enough food to feed the world's population, but undernourishment persists (FAO 2002). While the root cause of undernourishment is a lack of food, the reasons for the uneven availability of food can vary. The reality is that hunger and undernourishment are not caused by global scarcity, but by poverty, inequality and unaffordable food prices. Long term solutions need to address this, as well as issues around food storage and distribution. Women and children are particularly vulnerable to undernourishment (see Box 6.1.4).

Roughly one-third of all food produced in the world for human consumption is lost or wasted – around 1.3 billion tonnes per annum (da Silva 2012). Losses and waste occur at all stages of food production, distribution and consumption – from the farm to the market, and within the home. Food losses occur mainly in developing nations, and are associated with underinvestment in the production, harvest, storage, post-harvest and processing phases as well as in general infrastructure. On the other hand, food waste is more common in wealthier nations. Consumers waste between 95 and 115 kilograms a year per person in Europe and North America, while in sub-Saharan Africa and South and South East Asia, consumers throw away only 6 to 11 kilograms a year (da Silva 2012).

Most often the reason people are undernourished is because they cannot grow enough food for themselves, or do not have enough money to buy it. With over 70% of the world's poor living in rural areas, improving their capacity to produce food will improve wellbeing and help to secure food security (da Silva 2012).

Agricultural productivity

Improvements in agricultural productivity over the past 60 years have played a central role in reducing undernourishment rates. Strong growth in agricultural productivity has also supported the process of economic restructuring and the movement away from agriculture based economies to industrialised, knowledge based economies (OECD 2012). Economic growth has increased household incomes and, combined with increased agricultural productivity, has made food more available and affordable in many societies (FAO 2013b).

Nonetheless, many tropical nations continue to rely on agriculture for employment, subsistence, and to sustain GDP. For example, in sub-Saharan Africa most nations still have agricultural based economies, with agriculture employing on average 65% of the labour force and generating nearly one-third of GDP (World Bank 2008). Most farms in sub-Saharan Africa are relatively small in scale and, with limited access to capital, technology and markets, farmers have had limited capacity or incentive to boost productivity (Jaffee et al. 2011).

At the other end of the spectrum, agricultural productivity has increased rapidly in South America, especially in the past 30 years. Brazil is a prime example of the impact of productivity improvements, and is the first tropical 'food giant', going from a food importer 30 years ago to the world's largest exporter of beef, poultry, sugar cane and ethanol (The Economist 2010). South Asia and South East Asia have also reported strong growth in agricultural productivity, which has supported the transition from agrarian to industrial and more modern economies for many nations in these regions (Turral et al. 2011). In South East Asia however, recent years have seen stagnation in yield growth, particularly in China and Indonesia (Ray et al. 2012)

Perhaps the single most important factor separating nations that have sustained long-term agricultural productivity growth from those that have not is national agricultural research and development capacity, with nations that are able to produce a steady stream of new technologies suitable for local conditions performing better. Local research and development capacity also creates an environment that is more conducive to capturing 'technology spillovers' from research and development undertaken in other nations and regions (Fuglie & Wang 2012). Although there are conflicting assessments regarding the status of global agriculture (The Economist 2011), the reality is that population increases will require additional food production. Competing demands in the agriculture industry between food and non-food products are growing. Yields will need to be increased and waste losses decreased to balance the environmental, social and economic objectives associated with sustainability.

Food security

The world's population is expected to increase by 30% by 2050, with food demand expected to increase by 70%, and double in developing nations (Turral et al. 2011). Improving food security will be a critical development goal for many of these nations. Importantly, this will need to occur in an environment where the use and consumption of food is changing, where competition from non-food uses of agricultural production is increasing, climate change is influencing rainfall and temperature patterns, and where sustainable use of land and water resources will have greater prominence in decision making (The Royal Society 2009).

Part of the food security story relates to energy prices and affordability. Currently around 30% of global energy demand is used for the production and distribution of food, of which around 70% is associated with farming (FAO 2011). Increased demand for energy and rising oil prices are expected to raise the cost of agricultural production and contribute to higher food prices. aRising energy costs combined with policies which encourage use of less CO_2-intensive biofuels are seeing more farming area being used to produce these fuels. In 2007-08 biofuels were a significant factor contributing to higher food prices, which increased by up to 75% in some cases (The Guardian 2008). Between 2006 and 2030 biofuel use is expected to increase at an average rate of 6.8% per annum (IEA 2008).

Rising incomes, urbanisation and lifestyle are driving changes in the demand for foods, with a greater emphasis on meat, dairy products and fats. As a consequence, demand for grains and cereals to feed livestock has also increased, with up to two-thirds of cereal production in the developed world being used as animal feed (Erb et al. 2012). This has, and will continue to, put pressure on food prices and availability. Urbanisation also has the potential to affect food availability as the urban footprint expands into arable land, and as farmers move away from agriculture to pursue other opportunities.

A potentially profound impact on food security may come from climate change, and particularly its impact on water availability (Ludi 2009). In some parts of the world it is suggested that climate change could reduce yields by one-third (The Economist 2011). Although impacts will vary by location and geography, temperatures could rise by 0.3 - 4.8° Celsius by 2100, and rainfall patterns will be less predictable (IPCC 2013), with major impacts on agricultural output. Adaptation to climate change will be an important objective for water and agriculture policies.

Demand for water intensive foods such as meat, milk, fruit and vegetables is increasing, and water-use efficiency will need to improve if food demand and environmental objectives are to be met. Around 40% of the world's food is currently produced using irrigation, and as the available water per person decreases, food will need to be produced by using less water, or by applying more sustainable irrigation techniques (Turral et al. 2011). Other long term strategies could include increased trade, through market liberalisation and integration, managing price volatility of key commodities, increasing urban agriculture to supplement rural food production, and agricultural innovation.

Table 6.1.3 **Undernourished population**

	1990-92		1995-97		2000-02		2005-07		2010-12	
	Million	% pop.	Million	% pop.	Million	% pop.	Million	% pop.	Million	% pop.
Tropics	**553**	**27**	**527**	**24**	**530**	**22**	**511**	**19**	**508**	**18**
Central & Southern Africa	137	33	154	32	170	31	173	31	195	28
Northern Africa & Middle East	34	38	34	33	36	30	39	28	46	29
South Asia	162	28	153	24	147	22	147	2%	139	18
South East Asia	161	28	129	21	123	18	104	14	85	11
Caribbean	9	29	8	27	7	22	7	20	6	18
Central America	9	9	9	9	8	7	8	6	9	7
South America	41	18	39	16	37	14	32	11	27	9
Oceania	1	15	1	14	1	12	1	11	1	10
Rest of the World	**450**	**13**	**402**	**11**	**389**	**10**	**372**	**10**	**360**	**9**
World	**1,002**	**19**	**930**	**16**	**919**	**15**	**883**	**13**	**868**	**13**

Source: FAO (2013a), State of the Tropics project.

Looking forward

Globally, undernourishment is a critical human development issue. Long-term strategies to reduce undernourishment and improve food security will require working with a number of significant and, in some cases, unpredictable factors. These include changing patterns of human food consumption, adapting to the impacts of climate change (including extreme weather events), and sustainably maximising land and water resources to maintain and increase agricultural productivity (The Royal Society 2009).

Unless issues around food loss and waste are addressed, great productivity improvements will need to be made to meet the requirements of an increasingly large and affluent population. Additionally, ecological impacts of these improvements will need to be managed and minimised.

Also, unless current inequalities in access to food are resolved, undernutrition will continue to be a barrier to increased wellbeing and development, notably in the Tropics.

Box 6.1.4 Women and children

Women of maternal age and children are more susceptible than other groups to the health impacts of undernourishment and micro-nutrient deficiencies. Undernutrition was linked to 45% of child deaths in 2011 (Black et al. 2013), and 11% of the total disease burden world-wide is due to maternal and childhood undernourishment (Black et al. 2008). For women the risks of undernourishment are especially acute during pregnancy and lactation when they require up to three times more nutrition to support fetal growth, metabolic changes, tissue growth and lactation (Labuschange et al. 2012, Picciano 2003). Undernourishment at these times can also increase the chance of anemia and depression. During pregnancy undernourishment risks are not confined to the mother, and can also have major impacts on the fetus, increasing the risk of fetal death or defects and low birth weight (CORE Group 2004).

Beyond birth, the nutrition of infants and children is also critical, and undernourishment can increase the risks of neonatal disorders, and impact long-term cognitive development. Unfortunately, the extent of many of these problems is linked to the mother's nutritional status during pregnancy. Undernourishment in infants and children also increases their vulnerability to infectious diseases, including diarrhoea, measles and pneumonia (UNICEF 2012), and is linked to increased risk of becoming overweight and developing non-communicable diseases in later life (Black et al. 2013).

This suggests that some of the foundations that underpin human development potential are affected by early life nutritional status. Reflecting this, there is now a greater focus on improving nutrition during the first 1,000 days of life from conception to a child's second birthday, as it is during this period that good nutrition and healthy growth have lasting benefits throughout life (Horton & Lo 2013).

Child with symptoms of edema, a consequence of undernutrition. Image: Oxfam International.

Urban populations in the Tropics

For most of human history people have lived in rural environments. However, a transition to urban living has been underway since industrialisation commenced, and the world's urban population exceeded the rural population for the first time in 2007.

Large-scale urbanisation initially occurred as technology improvements in the agricultural sector reduced demand for labour, which was absorbed by emerging industrial activities. The process of industrialisation also encouraged urbanisation, as factories needed large, locally based labour pools. The prospect of diverse and rewarding employment and business opportunities in cities are still key factors which, coupled with greater access to services such as education and health care and social and cultural activities, encourage ongoing migration from rural to urban areas. In many regions of the world cities also offer an escape from unsustainable rural livelihoods affected by conflict, natural disasters and environmental and social change (UN-ESCAP 2011).

The process of urbanisation has supported economic development in many regions of the world, and one estimate suggests that 80% of the world's gross domestic product is generated by urban areas (UN 2011a). Nations that are more highly urbanised also tend to have higher life expectancy and literacy rates. This may relate to economy of scale advantages in the provision of infrastructure and services in urban areas and, with this, the possibility of better access to social infrastructure and improved living conditions. For example, in 2010 it is estimated that 79% of the world's urban population had access to improved sanitation facilities, compared with 47% for the rural population (WHO/ UNICEF 2012). Cities are also known as centres of culture and heritage, as well as social and political innovation.

The development and growth of cities has also had adverse environmental, social and health impacts, which tend to be exacerbated where growth is not adequately planned. For example, cities are responsible for natural habitat and biodiversity loss and the majority of global carbon emissions, while health risks in urban slums from sub-standard housing, water and sanitation facilities are significant, and air pollution can be a major health issue.

Trends

Reported urbanisation rates – the proportion of the population living in urban areas – are influenced by the definition of 'urban'. The definition can vary significantly across nations, though it is usually based on factors such as population size or density, administrative boundaries or economic organisation. All nations regard settlements of 20,000 or more as urban (consistent with the United Nations' interpretation), though many nations classify settlements ranging in size from 500 to 20,000 as urban. As such, caution should be exercised when comparing urbanisation rates across nations. The impact of these definitional variations is less significant when analysing trends at regional and global scales.

The world's urban population has grown rapidly over the past 30 years, with the urbanisation rate increasing from 39.4% in 1980 to 51.6% in 2010. Over the same period the urban population doubled from 1.8 billion to 3.6 billion, a growth rate of 2.4% per annum (see Figure 6.1.4).

In the Tropics the urbanisation rate has increased considerably faster than globally, up from 30.5% in 1980 to 45% in 2010, with the urban population increasing from 0.5 billion to 1.3 billion (or 3.3% per annum). In the Rest of the World the urbanisation rate increased from 44.3% to 56.2%, and the urban population from 1.3 billion to 2.3 billion, a growth rate of 2% per annum (see Figure 6.1.4). Though growth in the urbanisation rate has been significantly faster in the Tropics, in 2010 it is still 11.2 percentage points lower than in the Rest of the World. The higher urbanisation rate in the Rest of the World's reflects the larger proportion of its population in developed nations, which experienced major rural-to-urban transitions during earlier phases of industrialisation (UN-HABITAT 2010). With the exception of Oceania, all regions of the Tropics report increasing urbanisation rates since 1980, with the most notable increases in South East Asia (24.1% to 47.2%), South America (65% to 81.4%), and the Caribbean (50.5% to 65.7%). Nonetheless, across the Tropics urbanisation rates vary significantly, and in 2010 ranged from 33.8% in Northern Africa & Middle East to 81.4% in South America (see Table 6.1.4).

South East Asia accounted for almost one-third of growth in the urban population in the Tropics since 1980, with the number of urban dwellers increasing from 110 million to 360 million in 2010. Tropical China has been a major contributor to this growth, with its urban population increasing from around 14 million to 90 million (its urbanisation rate increased from 15.1% to 56.5%). Rural-to-urban migration accounted for around 75% of the growth in China's urban population, and is linked to economic reforms since the late 1970s, including the relaxation of restrictions on worker mobility.

Since 1980 South America has maintained its position as the most urbanised region in the Tropics, followed by Central America and the Caribbean (see Table 6.1.4). In the Tropics these are the only regions to consistently report urbanisation rates above those of the Rest of the World. Factors contributing to these relatively high rates of urbanisation have included the consolidation of land holdings away from small peasant plots, government policies favouring industrialisation and import substitution, and the influence of landowners in setting agricultural policy. Poor working conditions and low wages in rural areas combined with manufacturing-related employment opportunities in urban areas have also encouraged the transition to cities (Kay 1998).

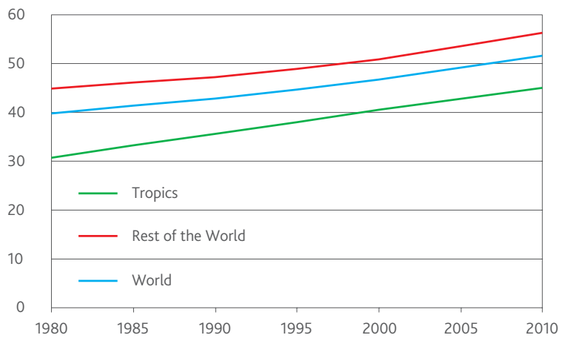
In contrast, all other regions of the Tropics remain mostly rural and, with the exception of South East Asia, each has an urbanisation rate of around 35%. In South East Asia the proportion of the population living in urban areas is almost 50%, having increased from 24% in 1980. Despite relatively low urbanisation rates, these five regions accounted for around 75% of growth in the urban population in the Tropics in the 30 years to 2010, with the

majority of this growth in South East Asia (249 million), Central & Southern Africa (175 million) and South Asia (154 million).

Low rates of urbanisation in these regions is consistent with many nations having an ongoing dependence on subsistence agriculture and being at a relatively early stage of industrial development – two factors which impact rural to-urban migration. Some governments are concerned about the capacity of infrastructure to cope with this influx. Some 77% of African nations claimed in 2009 to have implemented policies to reduce migration into urban agglomerations, up from 54% in 1996 (UN DESA 2010).

Oceania is the only region of the Tropics to report a decline in the urbanisation rate, down from 36.3% in 1980 to 34.3% in 2010. This result is skewed by Papua New Guinea which accounts for over half of Oceania's population, and which reported a decline in its urbanisation rate from 13% in 1980 to 12.4% in 2010. If Papua New Guinea is removed from the analysis the proportion of the Oceania population that is urbanised increases to 57.1% in 1980 and 62.1% in 2010 – well above rates in the Rest of the World. Low urbanisation rates in Papua New Guinea reflect cultural diversity and attitudes, and an agriculture-based economy with low rates of industrialisation (Jones 2012).

Figure 6.1.4 **Urban population**



Source: World Bank (2012), State of the Tropics project

Urban growth

Changes in the spatial distribution of a nation's population are primarily due to economic growth and technological advances, with economic and social economies of scale generated in urban areas creating a dynamic range of opportunities. Urban areas also support high-productivity and high-growth activities in ways that rural areas cannot (Spence et al. 2009). In the industrial age no nation has sustained high rates of economic growth driven primarily by agriculture (Annez & Buckley 2009). This relationship appears to hold in both developed and developing nations. Research also indicates that no nation has reached middle income status without a significant population shift to cities, and nearly all nations to have achieved middle income status have had urbanisation rates of at least 50% (Spence et al. 2009). There are some exceptions, though these are typically small, resource-rich nations. In addition to higher per capita incomes, in both more and less developed regions, nations with higher urbanisation rates tend to have more stable economies and stronger political institutions (UN DESA 2010).

Urbanisation can be a significant contributor to economic growth, but it is not sufficient in itself. Urbanisation without economic growth is uncommon though, and is largely restricted to some small African nations which have low levels of urbanisation or are failed states. In some African nations agricultural stress associated with poor soils or rainfall can also be 'push' factors for urbanisation, and this may be an influence in nations that are experiencing both slow economic growth and rapid urbanisation (Barrios 2009). Urbanisation's initial contribution to economic growth is thought to arise from the difference in productivity levels between rural and urban areas. This encourages employment shifts from lower value agricultural labour to higher value skilled jobs in manufacturing, services and finance. As cities expand they generate further efficiency gains in production and consumption, which attracts investors, creates new opportunities for entrepreneurs and contributes to further productivity gains and economic growth. São Paulo in Brazil and Bangkok in Thailand each hosts around 10% of the national population but account for more than 40% of national economic output (UN DESA 2011). It is estimated that a five percentage point increase in a nation's urbanisation rate is associated with a 10% increase in GDP per capita (Credit Suisse 2012). This suggests that, if well managed, higher rates of urbanisation can improve societal wellbeing and provide the means to promote sustainable development and reduce poverty – in both urban and rural communities.

Box 6.1.5 Urbanisation in Colombia

Colombia's urbanisation has its roots in the modernisation of the agriculture sector, and also civil unrest which saw people move to the relative safety of cities, with large migrations to urban centres in the 1950s and 1960s.

Rapid urbanisation outstripped the government's capacity to provide infrastructure and services and, in the absence of affordable housing, most low-income immigrants to cities acquired housing through land invasion or acquisition of illegal land partitions and self-settlement in the urban periphery. Despite the illegal tenure and violations of building and other regulations, local governments could not intervene because they would be violating private land property rights or their own rules (Betancur 2007). By 1990 around one-third of Colombia's urban population (seven million people) was living in informal settlements.

In the mid-1980s the national government developed policies to eliminate absolute poverty. The government introduced laws that made it mandatory for local governments to integrate informal settlements into formal city planning and to initiate development plans to improve quality of life, environmental conditions and community participation in urban life. Colombia's 1991 Constitution essentially recognised housing as a human right (Everett 1999) and provided the basis for further legislation to develop urban plans and programs to address the slums issue.

In Medellin the Integrated Slum Upgrading Program of Medellin (PRIMED) and Integral Urban Project (IUP) were implemented in the early 1990s as part of the reforms. These projects have focused on the granting of land title to informal settlers and improving the provision of infrastructure and other government services. PRIMED has benefited around 110,000 (Betancur 2007) people, and IUP around 170,000 (Arcila 2008).

In Bogota the Programme of 'Demarginalisation' benefited 620,000 of the city's poorest residents by improving living conditions and infrastructure in illegal settlements. MetroVivienda has been established as a land banking agency to ensure the supply of urban land on the city's periphery for Integrated Affordable Housing (IAH) projects (Rueda-Garcia 2003). Since 1990 Colombia's urban population has increased by more than 50%, to be 35 million in 2010. Nonetheless, reforms have contributed to the slum population decreasing by 2 million, or 15% of the urban population. The government has also committed to reducing the proportion of the urban population living in slums to 4% by 2020 (UN-HABITAT 2008).

Bogota, Columbia. Wolfgang Steneck.

In reality, rapid urbanisation also places an enormous strain on governments and planning resources. As urban populations increase so too does demand for land, housing, infrastructure and services. Rapid urbanisation can precede the planning and resources necessary to ensure orderly urban development. This can lead to inadequate provisioning of social and economic infrastructure (e.g. water, sanitation and roads) and sharp increases in land prices as demand outstrips supply, with housing often beyond the reach of the poor (Spence et al. 2009). Additionally, land is often acquired for development without due compensation (Ghatak & Mookherjee 2013).

One of the most visible consequences of rapid and unplanned urbanisation is slums, which emerge when low income segments of the population are unable to afford conventional housing. Slums are characterised by poor quality housing, overcrowding, unsafe drinking water, a lack of basic sanitation and limited access to education and health services. These factors have health consequences, particularly for children (IHC 2009). Slums also make the maintenance of law and order difficult which, when coupled with unemployment and poverty, provide a fertile environment for social unrest, violence and crime (UN 2011b). It is estimated that in 2007 around 1 billion urban dwellers (almost 30% of the urban population) were living in slums (Satterthwaite 2007).

Slums are largely an issue in developing nations, with 33% of the urban population (830 million) in developing regions estimated to be living in slum conditions in 2010, with the rate as high as 62% (200 million) in sub Saharan Africa (UN-HABITAT 2010). Globally this is an improvement in the proportion (down from 46%), but the number of slum dwellers has increased by 170 million since 1990, and is expected to increase by more than 60 million by 2020 (UN-HABITAT 2010). Urbanisation rates in Central & Southern Africa, South Asia and South East Asia will increase rapidly in the period to 2050 (these three regions represent almost half of the United Nations' projected 2.7 billion increase in the urban population globally). Thus, adequate planning and resourcing will be required to curb the expansion of slum populations (see Box 6.1.5).

Environmental issues

Urbanisation contributes to economic development, but without adequate planning it can also have adverse impacts on the natural environment and the health of people living in and around cities (commonly referred to as environmental health). These issues exist in both developed and developing nations, but tend to be more pronounced in developing nations which are urbanising rapidly, where there are limited resources to manage the planning and investment needed for sustainable urban growth.

For the natural environment the process of urbanisation results in changes in land cover and land use, hydrological systems, biogeochemistry, climate and biodiversity and, worldwide, is a primary driver of habitat loss and species extinction (Seto et al. 2011). In addition to the impacts of land use change necessary to build cities, the resources needed to support the demands of the urban population also drive other types of environmental change (Grimm et al. 2008). These impacts can be felt locally, regionally or globally for factors such as for urban waste discharge (which can affect global biogeochemical cycles) and climate (see Figure 6.1.5).

To put this in context, rapid growth in the urban population has occurred on less than 3% of the global land surface – but the impacts have truly been global. Cities are estimated to account for 78% of global carbon emissions, 60% of residential water use, and 76% of wood used for industrial purposes (Brown 2001). Cities, and especially those in the developing nations, can expose people to a range of environmental health risks related to a lack of safe drinking water, poor sanitation and waste management and air pollution (UN-HABITAT 2008). For urban dwellers the risk of being exposed to many of these environmental health issues is influenced by household wealth (WHO/UNICEF 2012) with risks greatest for people living in slums.

Inadequate planning, investment and limited use of public transport combined with a reliance on fossil fuels are the main factors contributing to high rates of urban air pollution and greenhouse gas emissions. Recent trends indicate that high growth developing nations such as China and India are suffering outdoor air pollution levels significantly higher than the global average (See Chapter 2). It is estimated that 1 billion people in Asia are exposed to outdoor air pollutants that exceed World Health Organisation guidelines, causing half a million premature deaths annually (UN-HABITAT 2008).

One strategy to decrease emissions is to improve transport infrastructure and public transport systems. It is encouraging that many developing nations recognise the social and economic costs of urban air pollution and are looking to reduce emissions through legislative and policy frameworks (see Box 6.1.6).

A lack of planning for rapid urban growth can also affect access to safe drinking water and sanitation facilities, leading to significant health risks from infectious diarrhoea and diseases such as cholera. Notwithstanding that the majority of people without access to safe drinking water and sanitation live in rural areas, of the urban population, the majority of people without access to these human rights[2] live in the Tropics, and primarily in Africa (see Figure 6.1.6 & Figure 6.1.7).

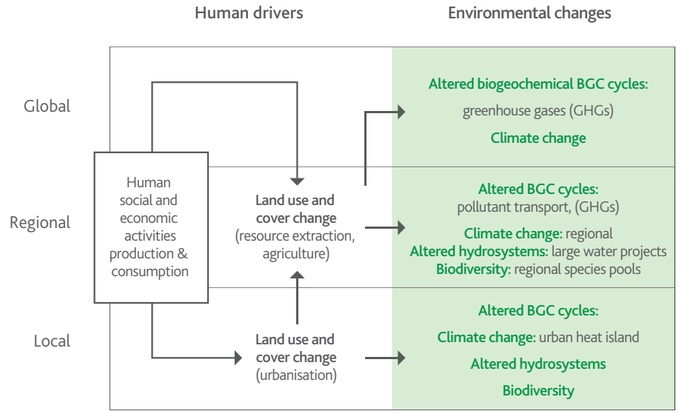
As most of the negative impacts of urban growth – such as air, water and noise pollution, congestion, risk of disease etc – are unpriced, without intervention to manage growth, cities tend to develop beyond optimal levels.

Table 6.1.4 **Urbanised population**

	1981		1990		1999		2010		1980 to 2010		
	Million	% pop.	Million	% pop.	Million	% pop.	Million	% pop.	PPT* change	Million	Av. An. Growth (pop)
Tropics	**485**	**31**	**708**	**36**	**980**	**41**	**1,285**	**45**	**14.5**	**800**	**3.3**
Central & Southern Africa	67	22	107	26	163	31	242	35	13.3	175	4.4
Northern Africa & Middle East	15	23	25	29	36	31	52	34	11.3	37	4.2
South Asia	116	25	161	28	208	31	270	35	10.1	154	2.8
South East Asia	110	24	177	32	269	40	359	47	23.1	249	4.0
Caribbean	14	51	18	55	22	60	26	66	15.1	12	2.0
Central America	45	58	59	62	75	66	90	69	11.2	45	2.4
South America	114	6	158	72	203	78	242	81	16.4	127	2.5
Oceania	2	3	3	37	4	35	4	35	-1.8	2	1.8
Rest of the World	**1,267**	**44**	**1,571**	**47**	**1,876**	**51**	**2,271**	**56**	**12.0**	**1,004**	**2.0**
World	**1,752**	**39**	**2,279**	**43**	**2,856**	**47**	**3,556**	**51**	**12.2**	**1,804**	**2.4**

Source: World Bank (2012), State of the Tropics project
*Percentage Point

Figure 6.1.5 **Framework of environmental impacts of urbanisation**



Source: Adapted from Grimm et al (2008).

Looking forward

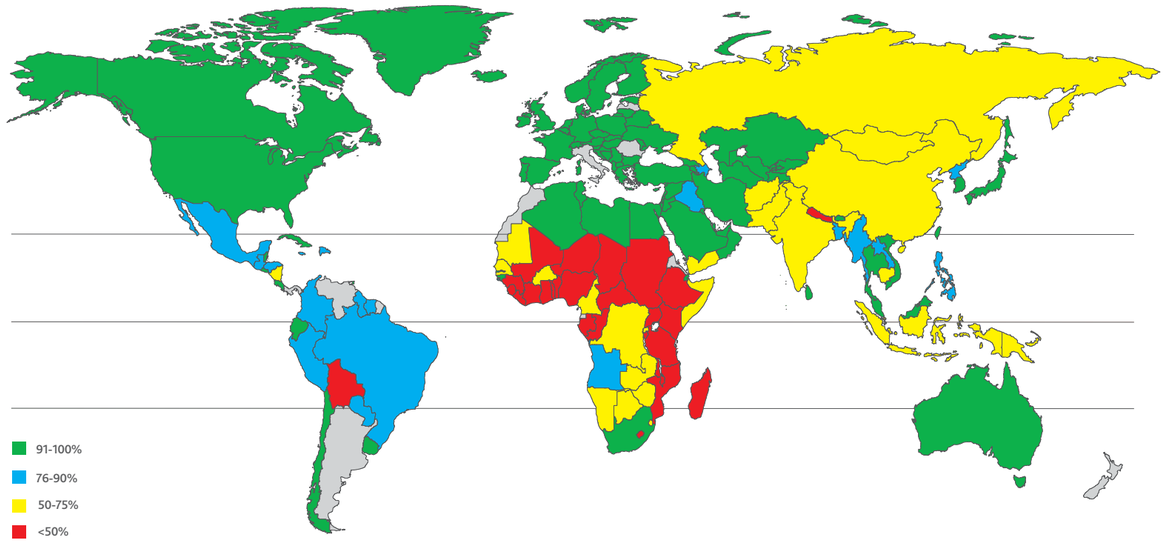
In the 40 years to between 2010 and 2050 global urban population is estimated to increase from 3.6 billion to 6.3 billion. Almost 95% of this growth will be in the developing world, and around 1.6 billion of the increase (or 60%) in developing nations in the Tropics. Additionally, urban land expansion is growing faster in low elevation coastal zones than in other areas, and without adequate planning, this is likely to put millions of people at risk from climate change impacts such as storm surge and rising sea levels (Seto et al. 2011).

A fundamental issue to sustainable urbanisation will be planning. To date attention has focused on the immediate problems arising from rapid urbanisation such as how to accommodate the poor and generate employment (Obaid 2007). The scale of the projected increase suggests more comprehensive approaches are needed to deal with the long term and globally significant consequences of urban growth (Grant 2010). In addition to planning authorities, this will require input from other disciplines, including agencies responsible for environmental, transport, energy and economic and social development policy.

The manner in which the world's urban centres are managed in the coming decades will influence patterns of economic growth, settlement and the social and political stability of many developing nations. How cities grow will also influence the extent of environmental impacts and health outcomes for urban residents. For example, future patterns of greenhouse gas emissions and consequent climate change will be driven substantially by activities in urban areas; similarly, the ways in which climate change impacts the lives and livelihoods of more than half the world's population will be mediated through actions that are taken – or not taken – in towns and cities (Dodman 2009).

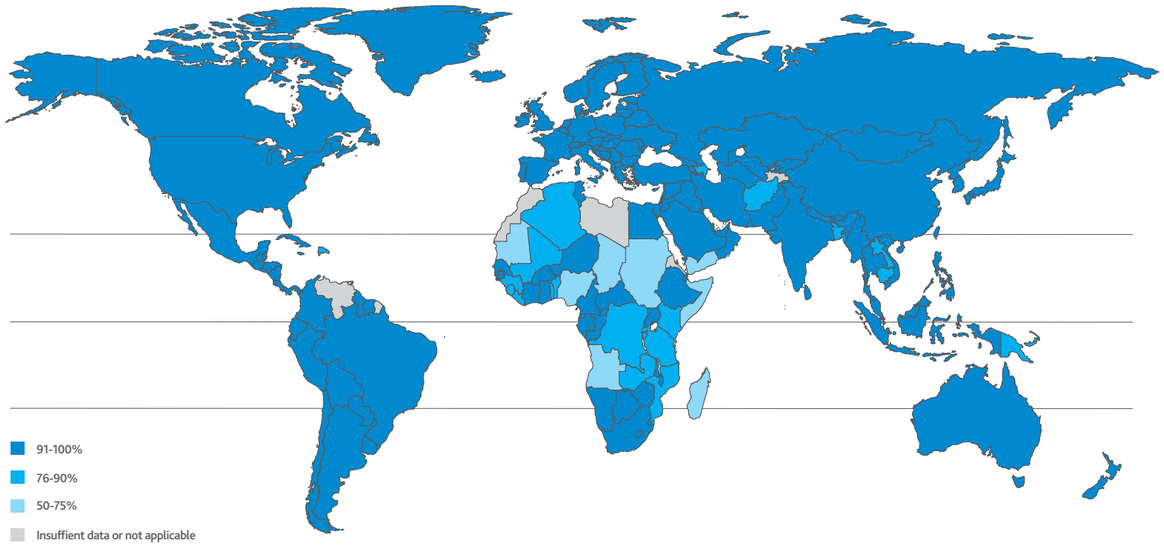
[2] In 2010 the UN General Assembly recognised that safe, clean drinking water and sanitation are human rights derived from the right to an adequate standard of living. Fundamental to the human rights framework is the concept of progressive realisation: Governments cannot solve the drinking water and sanitation situation overnight, but they must make tangible progress towards the realisation of this right.

Figure 6.1.6 **Sanitation coverage in urban areas, 2010**



Source: Source: WHO/ UNICEF (2012).

Figure 6.1.7 **Drinking water coverage in urban areas, 2010**



Source: WHO/ UNICEF (2012).

Box 6.1.6 Improving air quality in Bangkok

Since the 1960s Bangkok has undergone rapid urbanisation. Its population is estimated at around 8.2 million people, though seasonal inflows can see this almost double with the internal migration of non-residents during the dry season. Rapid growth with little urban planning or regulation has resulted in inadequate transport infrastructure and an over reliance on private transport. Motor vehicle numbers increased from 600,000 in 1980 to 7.4 million in 2012 – almost 8% per annum – and Bangkok has a high number of vehicles per capita compared with many other large Asian cities. Transport is the greatest source of air pollutants in Bangkok, and creates some of the most severe traffic congestion in the world.

Beginning in the early 1990s a number of initiatives were introduced to mitigate Bangkok's air pollution, including progressive introduction of cleaner fuels and stricter emissions standards, roadside vehicle inspections, upgrading public transport and improving air quality monitoring and traffic management. The taxation system was also used to encourage behavioural change. The Pollution Control Department was established in 1992 to monitor and reduce pollution.

Early attempts to reduce traffic congestion by developing road and expressway infrastructure were ineffective as car numbers increased rapidly. Subsequent initiatives have included investment in public transport infrastructure including the above ground Skytrain and the MRT subway. Skytrain passenger numbers have increased from around 200,000 passengers per day when it commenced operations in 1999 to 600,000 per day in 2012. The MRT commenced operations in 2004 and currently serves around 240,000 passengers per day. Each 1,000 passengers per journey on public transport is estimated to take around 800 vehicles off Bangkok's roads. These mass transport systems have helped contain fuel emissions, but their impact has been constrained by limited route coverage, although there are ongoing extensions.

Even as the number of motor vehicles on Bangkok's roads continues to increase, the impact of anti-air pollution initiatives has seen average levels of pollution fall. For example, levels of PM_{10} – a dangerous type of air pollution which consists of small dust particles that can embed themselves in the lungs — fell between 1997 and 2010, from 81 to 38 micrograms/m^3 (53%) in general areas, and from 90 to 55 (39%) for roadside areas (PCD 2010, PCD 2012). These impressive improvements now see Bangkok in line with the national standard of 50 micrograms/m^3, but exceeding the World Health Organisation's air quality guideline of 20 micrograms/m^3.

Bangkok traffic jam. Image: Dreaming Yakker.

Slum population

Slums have been a dimension of the urban landscape since the 19th century, and the basic features of slum life have changed little over time. The difference today is one of scale, and the extent of the 'concentrated disadvantage' (Vlahov et al. 2007). Slum dwellers of the new millennium are no longer limited to a few thousand residents confined to a few cities undergoing rapid industrialisation. Even though the proportion of slum dwellers has reduced, today's slums are unprecedented in their magnitude. In recent decades growth in the slum population has been most notable in developing nations where 863 million people were living in slum conditions in 2012, up from 650 million in 1990 (UN 2012). The significant increase in urban populations during this period has been a major contributor to the increase in the slum population, which has been exacerbated by a lack of planning and rapid increases in inequality in many developing nations.

Slums are characterised by inadequate access to safe water, sanitation and other infrastructure, poor structural quality of housing, insecure residential status and overcrowding (UN-HABITAT 2006). Dwellings in these settlements are diverse and can vary from traditional inner city houses which have been left in a state of decline, subdivided and rented out to lower income groups as original owners relocate to better areas, to poorly built and maintained housing projects and the self-constructed squatter settlements and illegal subdivisions which evolve at the periphery of cities.

In contrast to the beneficial consequences normally associated with urban social organisation, urban slum dwellers live in conditions akin to poverty in the majority of cases. In fact large sections of the urban population in developing nations suffer from extreme levels of deprivation that are often more debilitating than those experienced by the rural poor. Lacking a legal address they are often unable to access most of the formal institutions of society, with the result that they exhibit poorer health outcomes, lower life expectancies, lower levels of education and diminished employment, social and economic opportunities relative to non-slum urban populations (Jorgenson & Rice 2012). Slum conditions are made worse by economic decline, inequality, loss of formal-sector jobs, rapid immigration, poor governance and exclusionary actions (UN-HABITAT 2003). Although urbanisation generally has positive effects on wellbeing and economic growth, rapid, unplanned growth which results in slum expansion can be a negative side effect.

Trends

Slums encompass a broad range of living situations and populations with correspondingly disparate origins and identities, making them very difficult to survey. As a result, very little data about slum populations has been collected to date, with a lack of an agreed definition a major impediment (see Box 6.1.6). Consequently, slum populations are yet to be incorporated in mainstream monitoring instruments such as national population censuses, demographic and health surveys and global surveys.

Most slum population data sets have their origins with UN-HABITAT, the agency tasked to measure and monitor MDG slum targets. These data sets are characterised by a short time series with many missing data points and nations. The data sets also focus on the slum populations of developing nations (where the majority of the urban poor reside), and exclude slum numbers from developed regions. These issues make trend analysis difficult.

The UN-HABITAT's Global Urban Observatory in collaboration with the African Population and Health Research Centre produced a comprehensive global data set of slum populations in 2001 which included numbers for both developed and developing nations. This data set has been used in our analysis because it offers broader national coverage than in more recently published data sets.

In 2001, there were reportedly 924 million people residing in slums globally, or 32% of the world's urban population at the time (see Figure 6.1.8). The proportion of urban population living in slum conditions was higher in the Tropics at 46% compared with 24% in the Rest of the World. In absolute terms there were 467 million slum inhabitants in the Tropics, compared with 457 million in the Rest of the World.

In the Tropics there was considerable variation in regional slum populations. In Central & Southern Africa 76% of the urban population resided in slums in 2001, followed by Northern Africa & Middle East at 73%, and South Asia at 56%. Oceania reported the lowest rate at 15%, making it the only tropical region with slum population rates lower than the Rest of the World.

Central & Southern Africa also has the largest slum population in the Tropics, estimated at 132 million in 2001. Political instability and conflict in Central & Southern Africa can affect basic service provision and shelter conditions, while large numbers of refugees can affect slum numbers (UN-HABITAT 2010).

At 30 million, the slum population of Northern Africa & the Middle East was one-quarter that of Central & Southern Africa. South Asia's slum population was the second highest in the Tropics at 115 million, with India accounting for 91% of this figure. Regional patterns of slum prevalence also reflect the degree of access to basic services such as water and sanitation, as well as the nature of urban development policies. Those regions with the least ability to provide a proportional increase in basic urban infrastructure in response to rapid urban growth appear to be the most affected.

Looking at a less comprehensive data set for 2005 (UN 2011a), despite a number of missing data points the spread of slum populations within the Tropics broadly reflects the 2001 data, though Northern Africa & the Middle East replaces Central & Southern Africa as the region with the highest slum rate. South Asia again reports the third highest slum rate, though it is considerably lower than in the 2001 dataset. South America and Central America were the only tropical regions to achieve slum rates below 30% (see Figure 6.1.9).

In terms of numbers the tropical region with the largest slum population was still Central & Southern Africa in 2005, with 132 million people living in substandard housing conditions, followed by South East Asia with 105 million.

Slums

Slum dwellers frequently live in difficult social and economic conditions that manifest different forms of material, physical, social and political deprivation. That said, not all slum dwellers suffer the same magnitude of deprivation, nor are all slums the same – some provide better living conditions than others. Rather the degree of deprivation experienced by slum dwellers is thought to be dependent upon how many of the five indicators used to measure slums, otherwise known as shelter deprivations (see Box 6.1.7) are experienced by a particular slum household (UN-HABITAT 2008).

One of the shortcomings of current data sets is that they do not identify the number of deprivations experienced by slum populations. This information would be useful to policymakers to assess the severity of living conditions and to identify priority areas for improvement. For example, where inhabitants suffer from one or two deprivations, improvements in these areas will have a significant impact in reducing slum populations. Programs that promote access to improved sanitation tend to be less costly and complex to implement than those aimed at reducing in overcrowding. This suggests that a better understanding of the shelter deprivations suffered by slum dwellers would make it possible to design interventions that better target the most vulnerable urban populations.

Tropical Africa is not only home to the largest slum population, but its slum dwellers are also the most deprived. Almost 85% of slum households in tropical Africa experienced one or two shelter deprivations in 2005, 50% suffered from at least two shelter deprivations and, it had the largest percentage of slum dwellers lacking three or more basic shelter needs at 17% (UN-HABITAT 2010). One of the major reasons for slum households having multiple deprivations is because local authorities do not or cannot extend their services to slum settlements. Many of these authorities do not have the capacity to keep step with the rate of urban growth, or to spatially direct urban growth (Voigtlander et al. 2008).

Throughout Asia most slums are the consequence of only one shelter deprivation, reflecting fewer problems with infrastructure and housing policy than in sub-Saharan Africa. Nonetheless, in South Asia it is still quite common for slum dwellers to suffer similar levels of deprivation as in sub-Saharan Africa, with a lack of sanitation and overcrowding the two most common deprivations. In Latin American cities neither the magnitude of slums nor the degree of severity is as daunting as in many other developing nations. However, the proportion of slum households that suffer from at least one shelter deprivation is quite high at 66% (UN-HABITAT 2010).

Health in tropical slums

Improved health is possibly one of the greatest success stories of the second half of the 20th century, with life expectancy increasing by up to 40% in the least developed nations, and major declines in infant mortality rates. In fact the World Health Organisation reported fairly similar death rates for both developed and developing nations as recently as 2000. The major causes of death between the two groups vary considerably however, and people living in the developing world continue to die at a much younger age. What is of greatest concern is that the majority of deaths in developing nations could be prevented if living conditions were less dangerous and if better health care was available (UN-HABITAT 2003a).

Recent studies of the links between housing conditions and rates of illness and child mortality suggest that good-quality housing conditions are essential to ensuring a healthy, productive population (UN-HABITAT 2008). Urban slums in particular comprise a social cluster that engenders a distinct set of health problems (Riley et al. 2007). Inadequate shelter and poor living conditions in slums are related to a host of health risks that reduce the life span of slum dwellers, including exposure to infectious diseases and indoor air pollution (UN-HABITAT 2006). The number of shelter deprivations experienced by slum dwellers has a direct impact on human development, including health, child mortality, education and employment (UN-HABITAT 2006). Multiple housing deprivations can lead to a 25% greater risk of disability or severe ill health across an individual's life, with the risk increasing if the exposure to substandard housing is during childhood (UN-HABITAT 2004) A large proportion of households in the developing world reside in dwellings that lack two or more basic shelter amenities, threatening the health, safety and wellbeing of their residents, with many of these located in the Tropics (UN-HABITAT 2010).

A significant share of ill health experienced by slum dwellers stems from a lack of access to clean drinking water and poor sanitation. Contaminated water sources in slum areas are associated with an increased prevalence of diarrhoea and life threatening infectious diseases such as typhoid, cholera and hepatitis (Unger & Riley 2007). Inadequate infrastructure in the form of open sewers and an absence of waste collection bring an array of environmental hazards to slum areas which also contributes to the incidence of these diseases and many others. In cities featuring a large number of households suffering from four shelter deprivations the prevalence of diarrhoea rises three fold compared to the non-slum areas of the same city (UN-HABITAT 2010). Almost half the city dwellers in Africa, Asia and Latin America suffer from at least one disease caused by a lack of safe water and sanitation. In sub-Saharan Africa poor households spend at least one-third of their incomes on treatment of waterborne and water related diseases such as malaria, diarrhoea and parasitic infections (WHO/ UN-HABITAT 2010).

Box 6.1.7 Slum indicators

Slums are a multidimensional concept which have housing quality and tenure, overcrowding and access to services dimensions. Estimates of slum populations are typically based on data for a set of these dimensions.

In the UN-HABITAT Global Urban Observatory a slum household is defined as a group of individuals living under the same roof lacking one or more of the following five amenities, otherwise known as shelter deprivations:

a) Access to improved water of a sufficient amount (20 litres/person/day), at an affordable price (less than 10% of total household income) and obtainable without extreme effort (less than one hour per day to source the minimum quantity);

b) Access to improved sanitation facilities either in the form of a private toilet or a public toilet shared with a reasonable number of people;

c) Sufficient-living area, not overcrowded, with fewer than three persons per habitable room (minimum of four square metres);

d) Durable dwellings of a sound structural quality adequate enough to protect its inhabitants from extreme climatic conditions, in non-hazardous locations; and

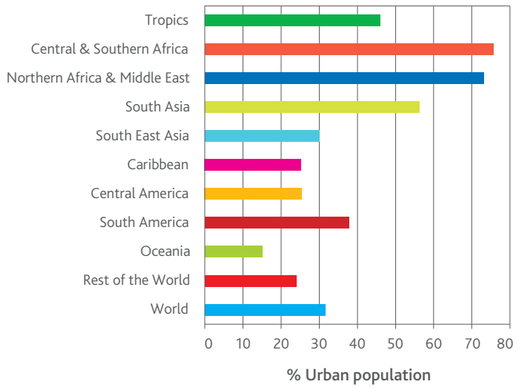
e) Security of tenure, otherwise known as protection by government from unlawful eviction (UN-HABITAT 2003).

More recent datasets published by the UN-HABITAT and MDG exclude the secure tenure dimension because of the difficulty in acquiring this data, and its lack of comparability across nations when it is available.

National Household Surveys are a primary source of data used to estimate slum populations, often supplemented with Demographic and Health Surveys and Multiple Cluster Survey data. Where data are limited, the Human Development Index has also been used to estimate slum populations (UN-HABITAT 2003).

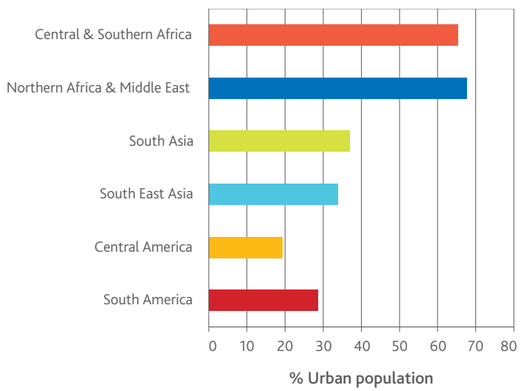
Papua New Guinea Image: Mark Ziembicki.

Figure 6.1.8 **Slum population, 2001**



Source: UN-HABITAT (2010), State of the Tropics project.

Figure 6.1.9 **Slum population, 2005**



Source: UN (2011a), State of the Tropics project

Note: Oceania and the Caribbean are excluded due to limited data availability. Nations for which data are not available include: Botswana, Cape Verde, Liberia, Mauritius, Sao Tome & Principe and Seychelles in Central & Southern Africa; Djibouti, Eritrea and Mauritania in Northern Africa & Middle East; Maldives and Sri Lanka in South Asia; and China, Hong Kong, Macao, Malaysia and Timor-Leste in South East Asia.

Box 6.1.8 Ahmedabad, India

Ahmedabad's Slum Networking Program (SNP) was initiated in 1995 to provide basic infrastructure services at the household and slum level in an affordable and sustainable way. At the time Ahmedabad had a population of approximately 3 million people, with 41% living in slums. Most slum dwellers had limited or no access to basic infrastructure services, were exposed to a high level of public health risk and lived under the constant threat of eviction. The focus of the SNP was to upgrade the city's slums with a set of interventions which focused on basic infrastructure at the household level: connections to a water supply, toilets and underground sewage for individual households; storm water drainage; stone paving of internal and approach roads; solid waste management and street lighting.

The program is funded by a combination of government, community, private sector and beneficiary investment. Local government financed the development of the basic infrastructure services to the entrance of the slums (80% of the project), and the other stakeholders covered the remaining 20% of costs necessary for service provision within the slum. Households were required to pay for access to the improved infrastructure, which was set at $US40. This cost was seen as being affordable, and loans were also offered to households to encourage connection. The government also provided a written assurance that residents would not be evicted for 10 years, providing at least some tenure security (Butala et al. 2010).

By 2008, 45 slum communities covering 10,400 households and approximately 39,000 people had benefitted from the project, though this represents only 3% of the city's slum population. Progress has been slow, but the slum communities that have benefited from the program have experienced improvements in health and wellbeing, and 82% of households report a decrease in health-related expenditure (Anand 2008). A lack of data has made it difficult to assess the impact of the SNP on general health outcomes, but a study evaluating the causal impact of slum upgrades by assessing micro-health insurance claims as a proxy for illness episodes indicates the SNP contributed to a statistically significant decrease in waterborne illness claims from 32% to 14% between 2001 and 2008 (Butala et al. 2010).

Ahmedabad India. Image: Emmanual Dyan.

Overcrowding is also a major contributor to poor health outcomes in slums. The risk of infectious disease transmission and respiratory illness is much greater in highly concentrated populations of low-income households typical in slums, owing to a lack of ventilation and hygiene and exposure to environmental contaminants. Epidemic prone infections tend to cluster in areas of urban poverty, and overcrowding has the potential to fuel both traditional illnesses such as tuberculosis and emerging diseases such as the SARS virus in 2003 (Riley et al. 2007). The prevalence of overcrowding in inadequate dwellings has also been linked to increases in negative social behaviours such as substance abuse and domestic violence. The highest proportions of urban residents without sufficient living space are in Africa and Asia, the regions where the largest slum populations are concentrated (WHO/ UN-HABITAT 2010).

Given that the majority of slum dwellings are constructed outside of formal building codes they also tend to suffer from a range of structural deficiencies. Many are made of flimsy materials that are prone to ignite, frequently collapse or offer scant protection against the elements. This can leave their residents vulnerable to injury, illness, violence and death. High mortality rates are further compounded by the fact that millions of slum dwellings are located on hazardous sites that are more prone to the effects of natural disasters such as floods and earthquakes, or are located in toxic areas such as garbage dumps, quarries or factories.

Children bear a disproportionate burden of disease in slums. The ratio of child deaths in slum areas compared to non-slum areas is consistently high in all developing nations, even in nations that have made significant progress in reducing overall child mortality. Studies undertaken of urban slum populations in 80 developing nations between 1990 and 2005 determined a positive relationship between the population living in urban slum conditions and child mortality (Jorgenson & Rice 2012). Households living under conditions of severe shelter deprivation experience child mortality rates three times higher than families that have access to safe water, improved sanitation, durable housing and decent living conditions. Children under the age of five are the most vulnerable.

Higher morbidity and mortality among urban slum children is not simply the consequence of household level deficiencies (e.g. infrastructural problems, lack of access to basic amenities) but also because of health issues arising in the context of the broader slum settlement (Jorgenson & Rice 2012). Children are particularly at risk as a result of exposure to hazards and toxins, as they tend to have greater contact with soil and contaminated water than adults, and spend a greater portion of their time in overcrowded, poorly ventilated dwellings. By virtue of their low body weight children are also more quickly and adversely harmed by any toxins they are exposed to. Exposure to parasite–borne infectious illnesses can also create a cycle where children are constantly malnourished as a consequence of unhealthy living conditions further increasing their susceptibility to disease (UN-HABITAT 2010).

Despite the tremendous need, health care services are generally difficult to access in slums, and this inequality exacerbates the health issues of slum dwellers (Riley et al. 2007). Even where health care is available it does not automatically lead to reduced mortality rates in slums. Where medical services are not freely available, high access costs in the context of other competing household expenditures often results in the deferral of healthcare until the onset of late stage complications especially for preventable chronic diseases (Riley et al. 2007). Preventative measures that eliminate shelter deprivations which contribute to illness and disease prevalence could assist in improving health outcomes for slum dwellers (Butala et al. 2010).

Over the past 15 years a consistent commitment to the large-scale upgrading of services to the urban poor has enabled tropical nations such as Colombia, Dominican Republic and India to reduce or stabilise their slum populations (UN-HABITAT 2010). The health benefits of upgrades to water and sanitation systems for slum households are yet to be rigorously evaluated, though studies undertaken in Ahmedabad in India are encouraging (see Box 6.1.8).

Looking Forward

Reducing slum populations is complex and costly, and experience suggests that to be successful, programs require a consistent political commitment to improve living conditions. Affordable access to key infrastructure and services and improved security of tenure are typical examples of improved living conditions. Nonetheless, despite significant investment in basic services, housing, health and education over many years, the number of slum dwellers in developing nations is increasing, and is predicted to reach 889 million by 2020, 26 million more than in 2012 (UN-HABITAT 2010).

In 2005 the cost to upgrade the housing of 100 million slum dwellers was estimated at $74 billion (UN Millennium Project 2005). This suggests the complicated and costly nature of future slum upgrading efforts will require innovative collaborations involving the public and private sectors, non-governmental organisations as well as the slum dwellers themselves to be effective.(Riley et al. 2007). The prevalence of overcrowding in inadequate dwellings has also been linked to increases in negative social behaviours such as substance abuse and domestic violence. The highest proportions of urban residents without sufficient living space are in Africa and Asia, the regions where the largest slum populations are concentrated (WHO/ UN-HABITAT 2010).

References

ACOSS (2012). *Poverty in Australia.* ACOSS Paper 194. Australian Council of Social Service, Sydney.

ADB (2012). *Asian Development Outlook 2012, Confronting Rising Inequality in Asia.* Asian Development Bank, Manila.

Anand S. (2008). *Best Practices in Slum Improvement: The Case of Ahmedabad. India.* Centre for Development Finance, Institute for Financial Management and Research, Chennai.

Annez P, Buckley R. (2009). Urbanization and Growth: Setting the Context, in: Spence M, Annez P, Buckley R. (eds), *Urbanization and Growth.* The International Bank for Reconstruction and Development/ The World Bank, Washington DC.

Arcila C. (2008). *Learning from Slum Upgrading and Participation.* KTH, Department of Urban Planning and Environment. Division of Environmental Strategies Research, Stockholm.

Barrios S, Bertinelli L, Strobl E. (2009). Climate Change and Rural–Urban Migration: The Case of Sub-Saharan Africa, in *Journal of Urban Economics* **60**(3).

Baur A, Hasan R, Magsombol R, Wan G. (2008). *The World Bank's New Poverty Data: Implications for the Asian Development Bank.* Sustainable Development Working Paper No. 2. Asian Development Bank, Manilla.

Betancur J. (2007). Approaches to the Regularization of Informal Settlements: The Case of PRIMED in Medellin, Colombia, in *Global Urban Development* **3**(1).

Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, Mathers C, Rivera J for the Maternal and Child Undernutrition Study Group (2008). Maternal and child undernutrition: global and regional exposures and health consequences, in *The Lancet* **371**(9608).

Black RE, Victora CG, Walker SP, et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries, in *The Lancet* **382**(9890).

Brown LR. (2001). *Eco-Economy: Building an Economy for the Earth.* Norton, New York.

Burgess A, Danga L. (2008). Undernutrition in Adults and Children: causes, consequences, and what we can do, in *Southern Sudan Medical Bulletin* **1**(2).

Butala N, Van Rooyen M, Patel R. (2010). Improved health outcomes in urban slums through infrastructure upgrading, in *Social Science & Medicine Journal* **71**.

CFS (2012). *Global Strategic Framework for Food Security and Nutrition, First Version.* Thirty-ninth Session. Committee on World Food Security, Rome.

Chen S, Ravallion M, (2010) The developing world is poorer than we thought, but no less successful in the fight against poverty in: *The Quarterly Journal of Economics* **125**(4).

CORE Group. (2004). *Dietary Guide: Maternal Nutrition during Pregnancy and Lactation.* LINKAGES, USA.

Credit Suisse (2012). *Opportunities in an Urbanizing World.* Credit Suisse Research Institute, Zurich.

da Silva HG. (2012). Feeding the World Sustainably, in *UN Chronicle* **XLIX**(1 & 2).

Dodman D. (2009). *Urban Density and Climate Change.* Paper for UNFPA Analytical Review of the Interaction between Urban Growth Trends and Environmental Change. United Nations Population Fund. New York.

The Economist (2010). *Brazilian Agriculture: The Miracle of the Cerado.* The Economist http://www.economist.com (accessed on 17 June 2013).

The Economist (2011). How much is enough?, in *The Economist,* 24 February 2011.

Erb K-H, Mayer A, Kastner T, Sallet K-E, Haberl H. (2012). *The Impact of Industrial Grain Fed Livestock Production on Food Security: an extended literature review.* Commissioned by Compassion in World Farming, the Tubney Charitable Trust & the World Society for the Protection of Animals. United Kingdom & Austria.

Everett M. (1999). Human Rights and Eviction of the Urban Poor in Colombia, in *Land Lines* **11**(6).

FAO (2002). *Reducing Poverty and Hunger: The Critical Role of Financing for Food, Agriculture and Rural Development.* Food and Agriculture Organization, Rome.

FAO (2011) *Energy-smart food for people and climate – Issue* Paper Food and Agriculture Organisation of the United Nations, Rome.

FAO (2013a). *Food Security Indicators.* Food and Agriculture Organization http://www.fao.org/economic/ess/ess-fs/fs-data/en/ (accessed on 8 May 2013).

FAO (2013b). *Committee of World Food Security: The Global Strategic Framework for Food Security and Nutrition.* Food and Agriculture Organization http://www.fao.org/cfs/cfs-home/global-strategic-framework/en/ (accessed 10 May 2013).

Fosu AK. (2009). Inequality and the Impact of Growth on Poverty: Comparative Evidence for Sub-Saharan Africa, in *The Journal of Development Studies* **45**(5).

Fosu AK. (2010) *Growth, Inequality and Povety Reduction in Developing Countries: Recent Global Evidence Background Paper* for the Global Development Outlook 2010, Shifting Wealth: Implications for Development. OECD Development Centre, Paris.

Fuglie K, Wang SL. (2012). *New Evidence Points to Robust but Uneven Productivity Growth in Global Agriculture.* United States Department of Agriculture Economic Research Service.

Ghatak M, Mookherjee D. (2013) Land acquisition for industrialization and compensation of displaced farmers, in *Journal of Development Economics* (in press).

Grant U. (2010). *Spatial inequality and urban poverty traps.* ODI Working Paper 326. Overseas Development Institute, London.

Grimm N, Faeth S, Golubiewski N, Redman C, Wu J, Bai X, Briggs J. (2008). Global Change and the Ecology of Cities, in *Science* **319**.

The Guardian (2008). *Secret report: biofuels cause food crisis.* The Guardian http://www.theguardian.com (accessed on 3 July 2013).

Handley G, Higgins K, Sharma B, Bird K, Cammack D. (2009). *Poverty and Poverty Reduction in sub-Saharan Africa:* An Overview of the Issues. ODI Working Paper 299. Overseas Development Institute, London.

Horton R, Lo S. (2013). Nutrition: a quintessential sustainable development goal, in *The Lancet* 382(9890).

IEA (2008). *World Energy Outlook 2008.* International Energy Agency, Paris.

IHC (2009). *The Challenge of an Urban World.* International Housing Commission, New York.

IPCC (2013). Climate Change 2013: *The Physical Science Basis* Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change, Geneva.

Jaffee S, Henson S, Rios LD. (2011). *Making the Grade: Smallholder Farmers, Emerging Standards, and Development Assistance Programs in Africa. A Research Program Synthesis.* The World Bank, Washington DC.

Jones P. (2012). *Managing Urbanisation in Papua New Guinea: Planning for Planning's Sake.* Alfred Deakin Research Institute, Geelong.

Jorgenson A, Rice J. (2012). Urban Slums and Children's Health in Less Developed Countries, in *American Sociological Association* **18**(1).

Kay C. (1998). *The Complex Legacy of Latin America's Agrarian Reform.* Institute of Social Studies, The Hague.

Labuschagne IL, Ackerberg TS, Lombard MJ. (2012). Optimal nutrition during pregnancy and lactation, in *Professional Nursing Today* **16**(1).

Ludi E. (2009). *Climate change, water and food security.* ODI Background Note. Overseas Development Institute, London.

Lustig N, Lopez-Calva LF, Ortiz-Juarez E. (2013) *Deconstructing the Decline in Inequality in Latin America.* Tulane Economics Working Paper 1314. Tulane University, New Orleans.

Mohan K. (2008) Andhra villagers now have pension on the their fingertips – Smart Cards Part II. In: *Business Standard* http://www.business-standard.com/article/economy-policy/andhra-villagers-now-have-pension-on-their-fingertips-108090201001_1.html (accessed 18 September 2013).

Obaid T. (2007). *UNFPA State of the world population 2007. Unleashing the Potential of Urban Growth.* United Nations Population Fund, New York.

OECD (2012). *Agricultural Policies for Poverty Reduction: A Synthesis.* Organisation for Economic Co-operation and Development Publishing.

PCD (2010). *Thailand State of Pollution Report 2008.* PCD No. 06-33. Pollution Control Department, Ministry of Natural Resources and Environment, Bangkok.

PCD (2012). *Thailand State of Pollution Report 2010.* PCD No. 06-37. Pollution Control Department, Ministry of Natural Resources and Environment, Bangkok.

PovcalNet (2013) PovcalNet: an online poverty analysis tool. The World Bank http://iresearch.worldbank.org/PovcalNet/index.htm (last accessed September 2013).

Prahald CK, Hammond A. (2002) Serving the World's Poor, Profitably, in *Harvard Business Review* September 2002.

Ravallion M. (2013) *How Long Will it Take to Lift One Billion People out of Poverty?* Policy Research Working Paper 6325. The World Bank, Washington DC.

Ray DK, Ramankutty N, Mueller ND, West PC, Foley JA. (2012) Recent patterns of crop yield growth and stagnation. *Nature Communications* **3**.

Riley L, Ko A, Unger A, Ries M. (2007). *Slum Health: Diseases of neglected populations.* BMC International Health and Human Rights(2).

The Royal Society (2009). *Reaping the Benefits: Science and the sustainable intensification of global agriculture.* The Royal Society, London.

Rueda-Garcia N. (2003). *Urban Slums Report: The Case of Bogota DC Colombia.* http://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/Bogota.pdf (accessed on 4 December 2012).

Sachs J. (2005) *The end of poverty, how we can make it happen in our lifetime.* Penguin, UK.

Satterthwaite D. (2007). *The transition to a predominantly urban world and its underpinnings.* International Institute for Environment and Development, London.

Sen A. (1987). Commodities and Capabilities. Oxford University Press, New Delhi.

References | Continued

Seto KC, Fragkias M, Güneralp B, Reilly MK. (2011). A Meta-Analysis of Global Urban Land Expansion, in *PLoS ONE* **6**(8).

Shetty P. (2003). *Malnutrition and Undernutrition.* The Medicine Publishing Company Ltd.

Spence M, Annez P, Buckley R. (2009). *Urbanization and Growth.* The International Bank for Reconstruction and Development/ The World Bank. Washington DC.

Turral H, Burke J, Faurès J-M. (2011). *Climate Change, Water and Food Security.* FAO Water Report No. 36. Food and Agriculture Organization, Rome.

UN (2011a). *World Urbanization Prospects.* The 2011 Revision. United Nations, New York.

UN (2011b). *Population Distribution, Urbanization, Internal Migration and Development:* An International Perspective. United Nations, New York.

UN (2012). *Millennium Development Goals Report 2012.* United Nations, New York.

UN DESA (2010). *World Population Policies 2009.* United Nations Department of Economics and Social Affairs, New York.

UN DESA (2011). *Population Distribution, Urbanization, Internal Migration and Development: An International Perspective.* United Nations Department of Economic and Social Affairs, New York.

UN Millennium Project (2005). *Improving the lives of slum dwellers. A home in the city.* United Nations Development Programme, London.

UNDP (2013). *Human Development Report 2013. The Rise of the South: Human Progress in a Diverse World.* United Nations Development Programme, New York.

UN-ESCAP (2011). *Statistical Yearbook for Asia and the Pacific 2011.* United Nations Economic and Social Commission for Asia and the Pacific, Bangkok.

Unger A, Riley L. (2007). Slum Health: From Understanding to Action, in *PLOS Medicine* **4**(10).

UN-HABITAT (2003). *Slums of the World: The face of urban poverty in the new millennium?* United Nations Human Settlements Programme, Nairobi.

UN-HABITAT (2003a). *The Challenge of Slums.* Global Report on Human Settlements 2003. United Nations Human Settlements Programme, Nairobi.

UN-HABITAT (2004). *Partners for Urban Health.* United Nations Human Settlements Programme http://www.unhabitat.org (accessed on 17 September 2013).

UN-HABITAT (2006). *State of the World's Cities. 2006/2007.* United Nations Human Settlements Programme, Nairobi.

UN-HABITAT (2008). *State of the World's Cities 2008/2009.* Harmonious Cities. United Nations Human Settlements Programme, Nairobi.

UN-HABITAT (2010). *State of the World's Cities 2010/11.* Bridging the Urban Divide. United Nations Human Settlements Programme. Nairobi.

UNICEF (2012). *The State of the World's Children 2012: Children in the Urban World.* United Nations Children Fund, New York.

UNICEF (2013). *Millennium Development Goals: 5. Improve Maternal Health.* United Nations Children Fund http://www.unicef.org/mdg/maternal.html (accessed on 28 June 2013).

Vlahov D, Freudenberg N, Proietti F, Ompad D, Quinn A, Nandi V, Galea S. (2007). Urban as a Determinant of Health, in *Journal of Urban Health: Bulletin of the New York Academy of Medicine* **84**(1).

Voigtlander S, Breckenkamp J, Razum O. (2008). Urbanization in Developing Countries. Trends, health consequences and challenges, in *Journal of Health & Development* **4**(14).

WHO/ UN-HABITAT (2010). *Hidden Cities. Unmasking and Overcoming Health Inequities in Urban Settings.* United Nations Human Settlements Programme, Nairobi.

WHO/ UNICEF (2012). *Progress on Drinking Water and Sanitation, 2012 Update.* WHO/ UNICEF Joint Monitoring Programme for Water Supply and Sanitation, New York.

WFP (2013). *Hunger: What is Hunger?* World Food Programme http://www.wfp.org/hunger/what-is (accessed on 14 June 2013).

World Bank (2008). *World Development Report 2008: Agriculture for Development.* The World Bank, Washington DC.

World Bank (2010). 2010 World Development Indicators. The World Bank, Washington DC.

World Bank (2011). *Andhra Pradesh Rural Poverty Reduction.* http://www.worldbank.org/ (accessed on 16 September 2013).

World Bank (2012). *World Bank World Development Indicators.* http://data.worldbank.org/data-catalog/world-development-indicators (accessed on 20 September 2012).

World Bank (2013). An Introduction to PovcalNet. http://iresearch.worldbank.org/PovcalNet/index.htm?0,1 (accessed on 16 September 2013).

Kibera slum.
Image: University of Denver.

Chapter 6.2

Society | Health

'Progress in health is central to human development and poverty reduction'

World Health Organisation

Rapid Testing for Malaria, Cambodia.
Image: Bill and Melinda Gates Foundation.

Summary of health indicators

Indicator		Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Life expectancy (years) 1950-55 – 2005-10		**41 – 65**	36 – 54	34 – 59	37 – 65	45 – 71	53 – 72	49 – 75	50 – 73	49 – 67	**53 – 73**	**47 – 69**
Maternal and child mortality	Maternal mortality ratio* 1990-2010	**574 – 308**	865 – 482	863 – 564	603 – 204	370 – 133	277 – 196	116 – 69	149 – 78	281 – 178	**238 – 104**	**395 – 211**
	Under-five mortality rate** 1950-55 to 2005-10	**263 – 80**	313 - 126	351 – 120	285 – 63	227 – 32	188 – 44	207 – 25	198 – 30	186 – 52	**186 – 35**	**214 – 59**
Obesity and non-communicable diseases	Obesity prevalence (%) 2002-2010[Ω]	**4 – 6.8**	2 – 3	5 – 6	0.9 – 2	2 – 3	15 – 23	23 – 32	14 – 21	14 – 18	**10 – 13**	**8 – 11**
HIV and AIDS	HIV prevalence (%) 1990-2010[#]	**0.7 – 1**	3 – 4	0.4 – 0.7	0.1 – 0.3	0.2 – 0.3	0.8 – 0.9	0.2 – 0.4	0.2 – 0.4	0.2 – 0.5	**0.1 – 0.4**	**0.3 – 0.7**
	AIDS mortality rate 1990-2010[##]	**15 – 39**	68 – 131	6 – 13	1 – 13	1 – 9	16 – 28	3 - 6	3 – 8	2 - 11	**1 – 11**	**6 – 23**
Tuberculosis	Incidence 1990-2010[+]	**204 – 172**	262 - 237	171 – 115	214 – 189	225 – 182	98 – 79	69 – 29	109 – 51	193 – 214	**110 – 95**	**145 – 127**
	Mortality rate 1990-2010[++]	**35 – 21**	43 – 26	20 – 10	40 - 27	46 – 23	10 – 9	8 – 2	10 – 4	46 – 31	**16 – 10**	**24 – 15**
Malaria Prevalence 2010[ß]		**7,402**	23,181	15,431	2,448	999	488	28	279	10,802	**203**	**3,182**
Dengue and other neglected tropical diseases	Incidence of dengue 2010[£]	**2,303**	1,803	719	2,714	2,792	3,264	2,008	2,742	1,429	**652**	**1,381**

Red: Situation is deteriorating
Green: Situation is improving

*Deaths per 100,000 live births. **Deaths per 1,000 live births. [Ω]Percentage of population aged 15+. [#]Cases as % of population aged 15-49 years.
[##]Deaths per 100,000 population aged 15-49 years. [+]New cases per 100,000 population. [++]Deaths per 100,000 population. [ß]Cases per 100,000 population. [£]New infections per 100,000.

Health

The World Health Organisation defines health as a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity. The biological, psychological and social determinants of wellbeing impact on an individual's life expectancy and disease burden, which are measurable and provide a degree of insight into health at national and regional levels.

The term 'tropical health' is used to describe the unique range of health issues that are primarily prevalent in the Tropics and sub-tropics. Climate is a factor in the increased prevalence of some infectious diseases in the Tropics (for example, malaria and dengue), while the relatively poor performance of many tropical nations across a range of social and environmental factors – broadly referred to as the social determinants of health – also contributes to the higher prevalence of many diseases in the Tropics. Many infectious and non-communicable diseases are closely linked with conditions of poverty, and consequently have a higher burden in the Tropics. Undernutrition, overcrowding and limited access to health care are key factors, and a characteristic of health in the Tropics is its correlation with broader development inequities.

As a fundamental human right, health reflects the hope of people to live a long life that is free from illness, pain and disability. Health reflects individual, family and community wellbeing as well as the numerous social, economic and environmental factors that underlie it.

Headline indicator

Life expectancy is comparable across populations, and is one of the most commonly used indicators of a population's health.

Supplementary indicators

Maternal and child mortality; obesity and non-communicable diseases; HIV and AIDS; tuberculosis; malaria; dengue and neglected tropical diseases.

Links to other dimensions

Poverty, education, economic output, work, urbanisation, human security, infrastructure, crime and corruption, gender equality, science and technology, international trade and investment, atmosphere, land and inland water, oceans, biodiversity.

Is it getting better?

Outcomes are improving rapidly for the majority of health indicators and for the majority of regions in the Tropics. Despite these improvements the Tropics tends to bear a disproportionate share of the global burden of many communicable and preventable diseases.

- **Life expectancy** increased across all regions of the Tropics in the past 60 years, and the gap between the Tropics and the Rest of the World has narrowed considerably. Nonetheless, in 2010 life expectancy in the Tropics was 7.7 years lower than in the Rest of the World.
- All regions in the Tropics have experienced significant decreases in **maternal mortality ratios** and **child mortality rates.** Nonetheless, the Tropics represent the vast majority of these deaths, accounting for 76% of maternal deaths and 72% of under-five deaths in 2010.
- The adult **obesity** rate in the Tropics is lower than in the Rest of the World, but is increasing at a faster rate. **Non-communicable diseases** are a growing cause of illness, disability and death in both the Tropics and the Rest of the World.
- **HIV prevalence** among people aged between 15 and 49 years is higher than in 1990 but has stabilised or declined in most regions of the Tropics after peaking in the mid to late 1990s, and the **AIDS mortality rate** has been declining in all regions since 2005. Compared with the Rest of the World prevalence and mortality rates were higher in the Tropics in 2010.
- Except in Oceania, **tuberculosis** incidence decreased in all regions of the Tropics between 1990 and 2010. The Tropics represented 56% of new cases globally in 2010.
- There are no time series data for **malaria,** but in 2010 the Tropics represented 96% of cases and 99% of deaths from malaria, with the greatest burden in Central and Southern Africa
- There are no time series data for **dengue,** but in 2010 72% of infections occurred in the Tropics, with South Asia and South East Asia having the highest number of cases, and the Caribbean the highest incidence rate. Other **neglected tropical diseases** such as soil transmitted helminthiases, schistosomiasis and lymphatic filariasis cause significant disability, disfigurement and death, ecially in impoverished communities in the Tropics.

Nurses at Vaiola Hospital, Tonga. Image: Tom Perry, World Bank.

Life expectancy

Life expectancy at birth is the average number of years a person can expect to live given existing mortality patterns, and considers a fundamental health question: "How long can I expect to live?" As a measure of health, life expectancy is readily comparable across nations and regions and is one of the most commonly used indicators of a population's general health status.[3]

Globally, health and life expectancy outcomes have improved substantially over the past 60 years. A major factor contributing to increased life expectancy has been significant reductions in infant and child mortality rates, as well as improvements in many of the social determinants of health. The social determinants of health are the conditions in which people are born, grow, live, work and age, and include aspects such as nutrition, sanitation, water supply and living conditions as well as the health system (WHO 2008b). These factors are shaped by the distribution of power and resources at global, national, local and household levels, which are themselves influenced by policy choices. Advances in medical technology and infectious disease control have also been important in improving health outcomes.

Globally, deaths are increasingly concentrated at older ages, and a shift is occurring from communicable to non-communicable diseases (Wang et al. 2012). While infectious disease rates have declined substantially, the burden remains higher in the Tropics than in the Rest of the World, and particularly in sub-Saharan Africa. A range of factors is influencing this, including vector control challenges and slower improvements in nutrition and other social determinants of health (see Box 6.2.1). Most low and middle-income nations, many of which are located in the Tropics, are burdened with both a high prevalence of infectious diseases and rising rates of non-communicable diseases, and this is presenting new public health challenges.

Trends

Life expectancy in the Tropics increased by from 41.3 to 65.2 years in the 60 years to 2010, and from 53.4 to 72.9 years in the Rest of the World, increases of 23.9 years (58%) and 19.5 years (36%) respectively (see Figure 6.2.1). Over this period, the life expectancy gap between the Tropics and the Rest of the World decreased from 12.1 years to 7.7 years – representing a significant improvement in health outcomes in the Tropics. The relatively larger increase in life expectancy in the Tropics reflects greater access to vaccines and major improvements in many of the social determinants of health, including increased access to potable water and sanitation facilities, and enhanced public health infrastructure. Nonetheless, the gap of 7.7 years is an indicator of the substantial health deficit in the Tropics when compared with the Rest of the World.

Life expectancy varies significantly across the regions of the Tropics and the gap has generally been increasing over time (see Figure 6.2.2). In 1950-55 life expectancy was highest in the Caribbean at 53.3 years and lowest in Northern Africa & Middle East at 34.1 years – a gap of 19.2 years. By contrast, in 2005-2010 life expectancy was highest in Central America at 75.1 years and lowest in Central & Southern Africa at 53.5 years – a gap of 21.6 years.

In 1950-1955 life expectancy in three regions in the Tropics was less than 40 years: 34.1 years in Northern Africa & Middle East, 36.3 years in Central & Southern Africa, and 37.2 years in South Asia. Life expectancy in these regions increased significantly to 2010, particularly in South Asia where it increased by 28.2 years to 65.4 years. Nonetheless, in 2005-2010 these three regions still had the lowest life expectancy in the Tropics, and Central & Southern Africa and Northern Africa & Middle East are the only regions in the Tropics where life expectancy is less than 60 years.

AIDS is a contributing factor to lower life expectancy in these regions, particularly Central & Southern Africa which comprises 17 of the 21 nations for which AIDS accounted for more than 10% of deaths in 2008 (WHO 2011a). In 2002 AIDS accounted for more than 60% of deaths in the worst affected nations in Central & Southern Africa (WHO 2004) and contributed to life expectancy at birth falling by more than 15 years between 1990 and 2005 in some nations.

Over the 60 years to 2010 South Asia experienced the greatest increase in life expectancy of 28.2 years, followed by 26.4 years in South East Asia, 26.0 years in Central America and 24.8 years in Northern Africa & Middle East. These four regions represent around two-thirds of the population in the Tropics, and are major contributors to the overall improvement in life expectancy in the region.

Infant mortality

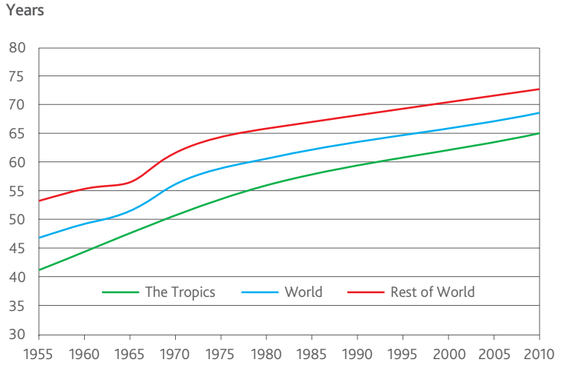
Lower life expectancy in developing nations, many of which are located in the Tropics, reflects higher mortality rates at younger ages, and especially in infancy. Across the world infant mortality rates (the number of deaths of infants under one year old per 1,000 live births) have fallen significantly over the past 60 years, but are still considerably higher in the Tropics than in the Rest of the World. In the Tropics the infant mortality rate fell from 160 in 1950-55 to 54 in 2005-10, a fall of 106 or 66% (see Table 6.2.1). In the Rest of the World the rate fell from 119 deaths per 1,000 live births to 29 over the same period, a fall of 90 or 76%.

Many factors are contributing to lower infant mortality rates, though they can be broadly grouped into factors associated with economic growth, poverty reduction and expanded social services, including improved access to education and health care. Household income and a mother's education level are key factors determining infant and child mortality rates. Increased immunisation rates are also an important factor, especially for measles, as are improvements in nutrition, hygiene and public health infrastructure (UN 2010b).

Although the decline in the infant mortality rate has been greater in the Tropics than in the Rest of the World, to some extent this reflects its considerably higher starting point. In in percentage terms the Rest of the World has actually experienced a faster rate of improvement. In the 60 years to 2010 the infant

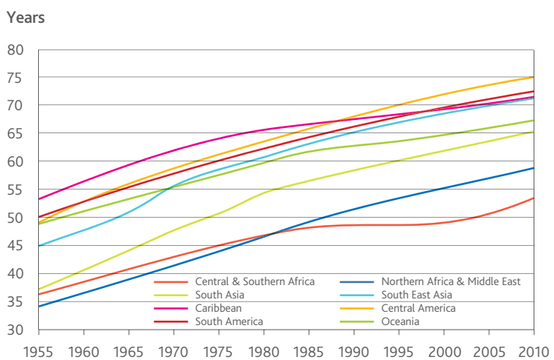
[3] An important limitation of life expectancy is that it measures length of life rather than quality of life, as it does not account for the burden of illness and disability. Alternative measures of disease burden such as 'disability-adjusted life years' and 'healthy life expectancy' quantify disability from diseases, although time series data by nation are as yet unavailable.

Figure 6.2.1 **Life expectancy at birth**



Source: UN (2013a), State of the Tropics project.

Figure 6.2.2 **Life expectancy at birth – the Tropics**

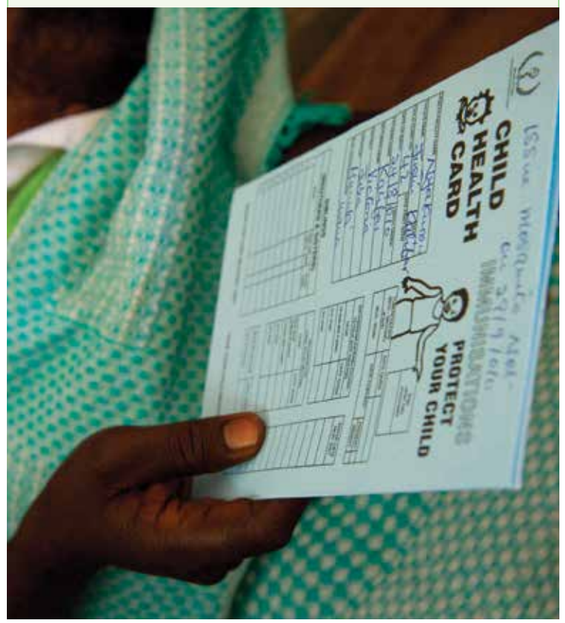


Source: UN (2013a), State of the Tropics project.

Box 6.2.1 Burden of disease impacts

Health outcomes are a complex mix of ecological, economic, social, historical and genetic characteristics of the population. In the Tropics the burden of disease is considerably higher, with health outcomes significantly better in the temperate zones, even after controlling for the level of GDP per capita (Sachs 2000).

The Tropics experience a higher burden of infectious disease for many interacting reasons: a physical ecology that supports a high level of disease transmission; poor nutrition resulting from the low productivity of food production; and multiple feedbacks through poverty (for example, illiteracy, lack of access to medical care and poor sanitation). Poorer health outcomes directly and indirectly impair economic performance: directly through reduced labour productivity due to lost workdays and reduced physical and cognitive capacities; and also indirectly through the effect of diseases on fertility rates, population age structure, and overall population growth rates (Sachs 2000).



Child health in South Sudan. Image: Arne Hoel, World Bank Photo Collection.

mortality rate in the Rest of the World decreased at an average rate of 2.5% per annum, compared with 1.9% per annum in the Tropics. That is, a significant gap persists, and there is considerable scope for infant mortality rates to decrease in the Tropics. The correlation between infant mortality and life expectancy is shown in Table 6.2.2. Regions that experience large falls in the absolute infant mortality rate tend to also experience large increases in life expectancy. The exception is Central & Southern Africa, where, although infant mortality rates have fallen significantly, high mortality rates in the non-infant population – largely attributable to HIV/ AIDS – have constrained overall improvements in life expectancy.

Adult mortality

As infant and child mortality rates have fallen, a larger proportion of global deaths now occur in adults. Also, as people tend to live longer the proportion of deaths at older ages is increasing. Globally, 54% of deaths in 2005-10 were of people aged 60 or over, compared with 26% in 1950-1955 (UN 2010b). As life expectancy has increased, so too has the burden of chronic, degenerative non-communicable diseases such as heart disease, cancer and diabetes that are associated with the ageing process (Wang et al. 2012).

Between 1950-1955 and 2005-2010 the death rate for the population aged 15 to 59 years (the adult mortality rate) has decreased. In 2005-2010 the adult mortality rate in the Tropics was 232 per 1,000 people aged between 15 and 59, higher than the rate of 148 per 1,000 in the Rest of the World (see Table 6.2.2). The gap between the Tropics and Rest of the World has decreased marginally over time, from 92 in 1995-2000 to 86 in 2005-2010. Unlike child and maternal mortality rates, the spread in adult mortality rates across the best and worst performing nations has been increasing over time (Rajaratnam et al. 2010).

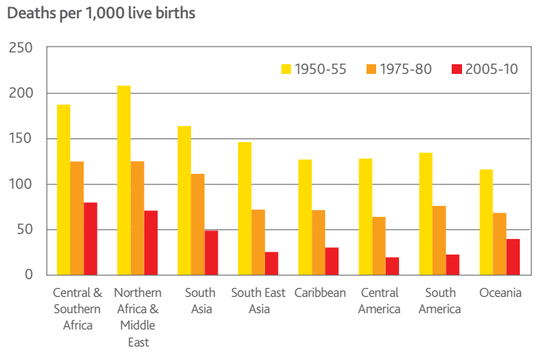
Despite declines in adult mortality across all regions of the Tropics, there are substantial differences between them. Adult mortality rates are highest in Central & Southern Africa (367 in 2005-2010), followed by Northern Africa & Middle East (270), Oceania (232) and South Asia (209). Factors such as disaster, famine, the level of socioeconomic development and the prevalence of disease risk factors will influence mortality rates. For example, armed conflict, malaria and HIV are significant contributors to higher rates of adult mortality in Central & Southern Africa, while in Oceania cardiovascular disease is a major factor. The adult mortality rate in Central America is the lowest in the Tropics, and is lower than in the Rest of the World.

Table 6.2.1 **Life expectancy and infant mortality rate, 1950-55 and 2005-10**

	Life expectancy (years)			Infant mortality rate*		
	1950-55	2005-10	Change	1950-55	2005-10	Change
Tropics	**41**	**65**	**24**	**160**	**54**	**-106**
Central & Southern Africa	36	53	17	188	80	-107
Northern Africa & Middle East	34	59	25	209	71	-137
South Asia	37	65	28	164	49	-115
South East Asia	45	71	26	146	26	-121
Caribbean	53	72	18	127	30	-97
Central America	49	75	26	128	20	-108
South America	50	73	23	135	23	-112
Oceania	50	67	19	116	40	-76
Rest of the World	**53**	**73**	**20**	**119**	**29**	**-90**
World	**47**	**69**	**22**	**135**	**42**	**-92**

Source: UN (2013a), State of the Tropics project.
* The number of deaths of infants under one year old per 1,000 live births.

Figure 6.2.3 **Infant mortality rate – the Tropics**



Source: UN (2013a), State of the Tropics project.

Looking forward

Life expectancy has increased globally over the past 60 years, reflecting significant global investment in infectious disease control, public health infrastructure and medical technology. Life expectancy remains lower in the Tropics than in the Rest of the World, and mortality patterns vary substantially between the different regions and nations. Continuing increases in life expectancy will both reflect and influence development across the Tropics.

As life expectancy continues to increase, new public health challenges are emerging, such as the growing burden of non-communicable diseases. This represents a particular challenge for many nations in the Tropics where infectious diseases and undernutrition are still significant public health concerns.

Table 6.2.2 **Adult mortality rate***

	1950-55	1955-60	1965-70	1975-80	1985-90	1995-00	2005-10	Change 1950-55 to 2005-10
Tropics	**472**	**434**	**351**	**290**	**260**	**257**	**232**	**-240**
Central & Southern Africa	495	471	422	378	363	410	367	-128
Northern Africa & Middle East	521	495	443	379	321	296	270	-250
South Asia	551	503	393	292	262	239	209	-342
South East Asia	430	395	302	259	211	188	158	-272
Caribbean	312	276	228	205	195	203	181	-131
Central America	362	319	269	238	195	153	133	-230
South America	352	320	268	233	214	192	165	-187
Oceania	499	463	388	326	302	271	232	-267
Rest of the World	**349**	**321**	**237**	**198**	**176**	**169**	**148**	**-201**
World	**386**	**352**	**270**	**226**	**201**	**193**	**170**	**-215**

Source: UN (2013a), State of the Tropics project
* Deaths under age 60 per 1,000 alive at age 15

Maternal and child mortality

The health of women and children is strongly linked, and is an important key to progress across all human development goals (UN 2010a). Despite this recognition, millions of women continue to die in pregnancy and childbirth; millions of children also die in childbirth and during the first five years of their lives from preventable causes. Maternal and child mortality are closely associated with development challenges such as poverty, gender inequality and human rights violations (IFRC 2011), and are thus important indicators of a society's health, and of a nation's level of social and economic development.

Maternal mortality – which is when a woman dies while pregnant or within 42 days of the end of pregnancy, from any cause related to or aggravated by pregnancy or its management (WHO 2012b) – is the leading cause of death among females aged 15-49 years old globally (Asamoah et al. 2011). Major causes of maternal death and disability include haemorrhage, infection, high blood pressure, unsafe abortion, and obstructed labour (WHO 2013c). Globally the number of maternal deaths is decreasing, but there were still 288,000 maternal deaths in 2010. Under-five mortality (which incorporates infant mortality) is also decreasing, although 8 million children under five died every year in the five years to 2010.

The poorest nations and poorer populations within nations experience the highest maternal and child mortality rates. It is estimated that 99% of maternal deaths occur in developing nations, with sub-Saharan Africa alone accounting for 56% of maternal deaths worldwide (WHO 2012b). Similarly, less than 1% of under-five deaths occur in high-income nations (Rajaratnam et al. 2010), with a child from a low income nation 18 times more likely to die before the age of five than a child from a high income nation (WHO 2013g). Within developing nations, children born to the poorest 20% of households are around twice as likely to die before the age of five as those from the wealthiest 20% (IFRC 2011). The link with poverty shows that the vast majority of maternal and child deaths can be prevented by implementing interventions that are commonly available in the developed world.

Trends

Reported data on maternal and child mortality are limited as only one-third of nations have a complete civil registration system with good attribution of cause of death (WHO 2012b). Estimates are produced using a combination of civil registration and census data, and household surveys.

Maternal mortality

Number of deaths

Globally there were 288,000 maternal deaths in 2010, a 47% decline from 546,000 in 1990. In the Tropics the number of maternal deaths declined by 41% over this period to 220,000 in 2010, while in the Rest of the World the number of deaths fell by 61% to 68,000. The different rates of decline are reflected in the increasing proportion of global maternal deaths occurring in the Tropics, from 68% in 1990 to 76% in 2010. A contributing factor to the slower rate of decline in maternal deaths in the Tropics is the increasing proportion of global births occurring in this region. Within the Tropics, the three regions with the highest fertility rates (Central & Southern Africa, Northern Africa & Middle East and Oceania) have had the slowest rates of decline in the number of maternal deaths (see Figure 6.2.4). The slower decline in maternal deaths in Central & Southern Africa increased the region's proportion of maternal deaths in the Tropics from 43% in 1990 to almost 60% in 2010. Relative to other regions in the Tropics, large falls in fertility rates in South Asia and South East Asia have contributed to the greater decline in the number of maternal deaths in these regions.

A large proportion of maternal deaths in sub-Saharan Africa and the Caribbean are attributable to HIV – 10% and 6% respectively (WHO 2012b). In the 18 nations most affected by HIV (most of which are in tropical Africa), between 20% and 67% of maternal deaths are attributed to HIV (WHO 2012b). The number of maternal deaths among women with HIV is expected to decrease in these nations as access to antiretroviral therapy continues to expand.

Maternal mortality ratio

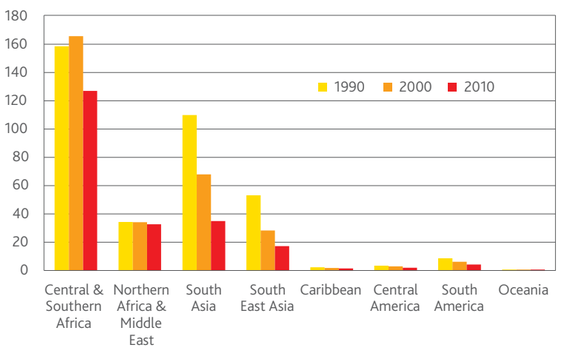
The maternal mortality ratio (MMR) is the number of maternal deaths per 100,000 live births, and it reflects the risk of maternal death from a single live birth (and is therefore independent of fertility trends). Millennium Development Goal 5 (MDG 5) aims for the MMR in 2015 to be three-quarters (75%) lower than in 1990. The World Health Organisation considers an MMR greater than 300 to be 'high' (WHO 2012b).

Globally, the MMR nearly halved between 1990 and 2010, from 395 deaths per 100,000 live births to just over 211 (see Table 6.2.4). The Tropics experienced a 46% decline from 574 in 1990 to 308 in 2010, compared with a 56% decline in the Rest of the World, from 238 to 104. In 2010 the MMR in the Tropics is almost three times higher than in the Rest of the World. Nonetheless, the number of tropical regions with a 'high' MMR has fallen from four in 1990, to two in 2010.

The MMR has been declining in all regions of the Tropics, although at different rates (see Table 6.2.3). Since 1990 the rate of decline has been slowest in the Caribbean, Northern Africa & Middle East and Oceania, at 29%, 35% and 37% respectively. Despite consistent MMR declines since 1990, Central & Southern Africa and Northern Africa & Middle East are the only two tropical regions where the MMR remains 'high' at 482 and 564 respectively in 2010. Central America and South America have consistently had the lowest MMRs in the Tropics (69 and 78 respectively in 2010), below that in the Rest of the World (104 in 2010). In South Asia and South East Asia declines of around 65% over the two decades to 2010 have reduced the MMR from 603 and 370 respectively in 1990, to 204 and 133. In these regions Lao People's Democratic Republic, Cambodia, Maldives, Bangladesh, Vietnam and Timor-Leste each had declines of 70% or more.

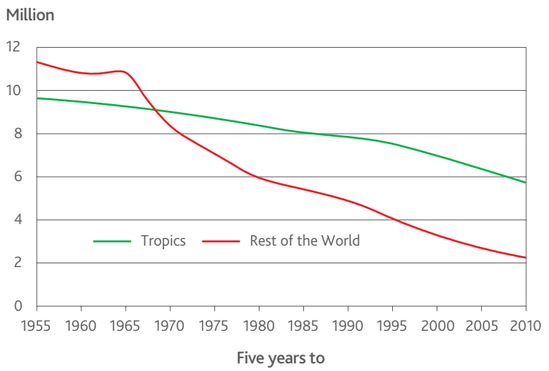
MMR declines across the two decades can be attributed to improved access to skilled health personnel and socioeconomic factors outside of the health sector (WHO 2012b). Across all developing regions, access to family planning and contraception, antenatal care and skilled health personnel attendance at deliveries has increased since 1990, though at different rates in different regions (UN 2010a). In general, nations that have the lowest access to health services have the highest maternal mortality rates (UN 2010a). Notwithstanding significant global progress since 1990, MDG 5 is unlikely to be achieved, largely due to the ongoing limitations of antenatal and obstetric services and facilities in developing nations (Karlsen et al. 2011). As the scope for MMR reduction is much greater in these nations, investing in maternal health in the developing world will be critical to making global progress towards the target.

Figure 6.2.4 **Maternal deaths, the Tropics**



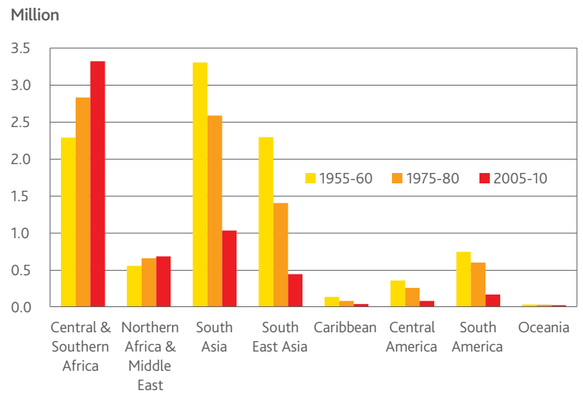
Source: Maternal Mortality Estimate Inter-Agency Group (2013), State of the Tropics project.

Figure 6.2.5 **Deaths per year of children under five years**



Source: UN (2013a), State of the Tropics project.

Figure 6.2.6 **Deaths of children under five years – the Tropics**



Source: UN (2013a), State of the Tropics project.

Child mortality

Young children are more susceptible to infectious diseases than adults and are especially vulnerable to environmental threats that are more common in poor communities, such as contaminated water. Under-five mortality relates directly to child survival, reflecting the social, economic and environmental conditions in which children live.

Number of deaths

Globally, the number of deaths of children under the age of five has declined by 62% since 1950-55, from 21.0 million per year in the five years to 1955, to 8.0 million per year in the five years to 2010 (see Figure 6.2.5). Even though the Tropics represented 50% of the global population of children under the age of five in 2010, it accounted for 72% of under-five death – 5.7 million per year in the five years to 2010, compared with 2.2 million in the Rest of the World.

In the period between 1950 and 1965, however, under-five mortality was higher in the Rest of the World than in the Tropics at around 11 million deaths per year, before falling dramatically, to 5.9 million per annum, by 1975-80. The rapid decline in the Rest of the World over this period can be attributed to a combination of factors, including sharp declines in the impact of some infectious diseases, public health measures and better nutrition (Hill 1990), with improvements in China having a major impact on global outcomes. Under-five mortality has continued to decline in the Rest of the World at a faster rate than the Tropics.

In the Tropics only Central & Southern Africa and Northern Africa & Middle East experienced an increase in the number of under-five deaths between 1950-55 and 2005-10 (see Figure 6.2.6). These are the only two regions where fertility rates are still above five births per woman, and since the mid-1970s Central & Southern Africa has consistently had the highest number of under-five deaths in the Tropics, recording 3.3 million deaths per annum in 2005-10. In 2005-10, under-five deaths in tropical India and Nigeria combined accounted for almost one-quarter of under-five deaths worldwide.

Table 6.2.3 **Maternal mortality ratio***

	1990	1995	2000	2005	2010	% Change 1990-2010
Tropics	**574**	**516**	**454**	**381**	**308**	**-46**
Central & Southern Africa	865	842	742	627	482	-44
Northern Africa & Middle East	863	794	715	644	564	-35
South Asia	603	479	386	278	204	-66
South East Asia	370	263	211	163	133	-64
Caribbean	277	259	214	208	196	-29
Central America	116	107	98	74	69	-40
South America	149	124	106	88	78	-48
Oceania	281	240	231	206	178	-37
Rest of the World	**238**	**204**	**172**	**134**	**104**	**-56**
World	**395**	**356**	**315**	**262**	**211**	**-47**

Source: Maternal Mortality Estimate Inter-Agency Group (2013), State of the Tropics project
*Maternal deaths per 100,000 live births).

Under-five mortality rate

The under-five mortality rate is the probability of a child born in a specific year dying before reaching the age of five, and is expressed as deaths per 1,000 live births. An under-five mortality rate of 40 or more is considered 'high' (UNICEF 2012a). Globally the under-five mortality rate decreased by 72% between 1950-55 and 2005-10, from 214 deaths per 1,000 live births to 59 (see Figure 6.2.5). In the Tropics the under-five mortality rate fell by 69% to 80, while in the Rest of the World it fell by 81% to 35. In 2005-10 the under-five mortality rate in the Tropics was more than double that in the Rest of the World. Although mortality rates have declined significantly, the Millennium Development Goal to reduce 1990 levels of under-five mortality by two-thirds by 2015 is unlikely to be met at the current rate of improvement (WHO 2013g).

In all regions of the Tropics the under-five mortality rate has declined steadily over the past 60 years (see Table 6.2.5 and Figure 6.2.7). Central America, South America and South East Asia each recorded reductions in the under-five mortality rate of over 80% between 1950-55 and 2005-10, while progress has been slowest in Central & Southern Africa and Northern Africa & Middle East, with declines of 60% and 66% respectively. By a long margin, these two regions had the highest under-five mortality rates in the Tropics in 2005-10, at 126 and 120 respectively. This largely reflects the high child mortality burden in sub-Saharan Africa, where one in nine children dies before the age of five (UNICEF 2012a). Sub-Saharan Africa also bears an increasing share of global under-five deaths, as mortality rates are falling more slowly than in other regions (UN 2012a).

Child mortality declines worldwide can be attributed largely to expanded efforts to reduce infectious diseases which cause the majority of under-five deaths (see Box 6.2.2) (UNICEF 2012b). In some nations, decentralised nutrition programmes and policies that promote free and universal health care access for pregnant women and children have also accelerated the rate of improvement (Amouzou 2012).

Infant Mortality

The risk of death among children under the age of five is highest closest to birth, and then decreases steadily (WHO 2013g). In 2010 an estimated 71% of all under-five deaths occurred in the first year of life, and 40% within the neonatal period (from birth to one month old) (WHO 2013g). While infectious diseases cause the majority of deaths of children under five, they are responsible for a smaller proportion of neonatal deaths, where 73% of deaths are from preterm birth complications, birth asphyxia, congenital abnormalities and sepsis (Black et al. 2010).

As with under-five mortality, the number of neonatal deaths is decreasing worldwide, but the global proportion of these deaths among all under-five deaths is increasing (UN 2012a). Neonatal deaths are declining more slowly because different interventions are needed to improve neonatal versus under-five health outcomes (UNICEF 2012a). The proportion of neonatal deaths among under-five deaths also varies widely across different regions of the world, ranging from 29% in Africa to 54% in parts of Asia (Black et al. 2010). Preventive interventions such as early postnatal home visits that target both mothers and babies have been shown to be highly effective (UNICEF 2012a), and targeting resources to these types of interventions is recognised as necessary to accelerate the under-five mortality rate decline, especially in nations that are highly burdened with neonatal deaths (UN 2012a).

Health care and education

Access to health care is a critical factor influencing both maternal and child mortality. Key health services and interventions that are still limited in many low income populations include family planning information, antenatal, newborn and postnatal care, emergency obstetrics, vaccination and immunisation services and access to nutritional and rehydration supplements (UN 2010a). Appropriate resourcing and management is essential for these services to reach populations most in need, and despite global funding for maternal, newborn and child health increasing from US$2.5 billion in 2003 to around US$6.5 billion in 2010, the rate of funding increases has now slowed (Hsu et al. 2012).

The expansion of maternal and child health care services and interventions has contributed to substantial health gains. In Sri Lanka for example the maternal mortality rate has been reduced by 87% since the 1970s, largely as a result of efforts to ensure that 99% of pregnant women receive four antenatal visits and give birth in a health facility (UN 2010a). In developing nations investments in maternal health care have led to the proportion of births attended by skilled health personnel rising from 55% in 1990 to 65% in 2010, and the proportion of women attended at least once by skilled health personnel during pregnancy increasing from 63% to 80% (UN 2012a).

However, even within nations, coverage of maternal and child health interventions can vary significantly. In Guatemala the national coverage of key maternal and child interventions is 59%, but for those in the poorest quintile coverage is only 38% (Bhutta et al. 2010).

Family planning interventions can have a substantial impact on maternal health by reducing lifetime exposure to the risks of pregnancy and birth, lowering the risk of having an unsafe abortion, delaying first pregnancy in young women and reducing the health risks associated with closely spaced pregnancies. Child survival is also enhanced by lengthened birth intervals.

Contraceptive use is estimated to have averted 44% of global maternal deaths in 2008 (Ahmed et al. 2012), although the unmet need for family planning (that is, the proportion of partnered women reporting the desire to delay or avoid pregnancy but who are not using contraception) remains high in 2010 at around 13% across all developing nations, though this is a modest improvement on the 16% reported in 1990 (UN 2012a). If the unmet need for contraception were satisfied it is estimated that maternal deaths could have been reduced by a further 29% in 2008 (Ahmed et al. 2012).

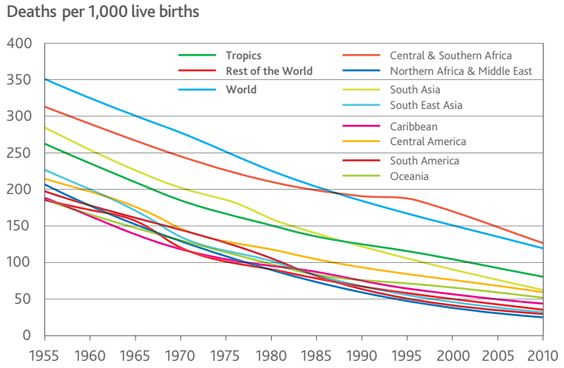
A mother's access to formal education is also a key survival factor for women and children under five. Children whose mothers have been educated for at least five years are 40% more likely to live beyond the age of five (UN 2010), and the chances of survival increase with the mother's level of education. A child whose mother has no education is 2.7 times more likely to die before the age of five than a child whose mother has secondary education or higher, and a child whose mother has only primary school education is 1.5 times more likely to die (UN 2012a).

Lower levels of maternal education are also associated with higher maternal mortality, even among women with access to postnatal care (Karlsen et al. 2011). Compared with women with more than 12 years of education, women with no education are 2.7 times more at risk of maternal death, and for those with between one and six years of education the risk is double (Karlsen et al. 2011). Globally, in 2011, women accounted for 61% of young people (aged between 15 and 24) who lacked basic reading and writing skills. (UN 2013c).

Looking forward

There is a growing awareness that investments in maternal and child health can reduce poverty in families and stimulate economic productivity and growth (UN 2010a). Nonetheless, of the eight Millennium Development Goals relating to health goals maternal and child health are the furthest from being achieved (WHO 2013g), and there are still significant disparities both between and within nations. In response to slow progress against MDGs 4 and 5 the United Nations launched the Global Strategy for Women's and Children's Health in 2010, which has been successful in securing increased commitments to achieve these goals (Lozano et al. 2011). Defining the post-2015 development agenda, including maternal and child health targets, is also a key priority of the United Nations at present (UN 2013b).

Figure 6.2.7 Under-five mortality rate



Source: UN (2013a), State of the Tropics project.

Table 6.2.4 Under-five mortality rate*

	1950-55	1955-60	1965-70	1975-80	1985-90	1995-00	2005-10	% Change 1950-55 to 2005-10
Tropics	**263**	**235**	**184**	**151**	**123**	**105**	**80**	**-182**
Central & Southern Africa	313	290	246	210	191	171	126	-186
Northern Africa & Middle East	351	324	278	226	185	153	120	-231
South Asia	285	253	201	159	122	91	63	-222
South East Asia	227	199	133	103	65	46	32	-195
Caribbean	188	165	118	95	74	56	44	-144
Central America	207	176	133	90	59	37	25	-182
South America	198	176	142	106	66	43	30	-168
Oceania	186	165	128	98	79	66	52	-134
Rest of the World	**186**	**172**	**118**	**91**	**65**	**52**	**35**	**-150**
World	**214**	**197**	**145**	**119**	**91**	**79**	**59**	**-155**

Source: UN (2013a), State of the Tropics project.
*Number of deaths per 1,000 live births.

Box 6.2.2 Impact of infectious diseases

Infectious diseases disproportionately affect poor people who lack access to basic prevention and treatment services (UNICEF 2012b). As such, the proportion of deaths due to infectious diseases is a marker of health equity. Although the civil registration systems in many nations are insufficient to accurately attribute cause of death, in developing nations infectious diseases are estimated to be responsible for a substantial proportion of child deaths.

Infectious diseases are preventable and can most often be treated effectively, yet are estimated to be responsible for around two-thirds of under-five deaths worldwide (UNICEF 2012b). The most important infectious causes of death in children under five are pneumonia (responsible for 18% of deaths), diarrhoeal diseases (11%) and malaria (7%).

More than half of the global under-five deaths caused by pneumonia or diarrhoea occur in just four nations – India, Nigeria, the Democratic Republic of the Congo and Pakistan (UNICEF 2012b). Africa is disproportionately affected by some infectious diseases, and bears 92% of child deaths due to malaria and 90% of child deaths due to AIDS in 2008 (Black et al. 2010). Undernutrition increases susceptibility and risk of death from infectious diseases and, while rarely recorded as a cause of death, is estimated to be a contributing factor in one-third of all under five deaths (Black et al. 2010).

In the decade to 2010 greater efforts against infectious diseases contributed to substantial declines in child deaths from a number of infectious diseases. For example, since 2000, increased measles immunisation coverage contributed to a 74% decline in child deaths from the disease to 2010 (UN 2012a). While progress is being made, millions more young children's lives can be saved through appropriate nutrition combined with programs to prevent and manage diarrhoea, pneumonia, malaria and HIV infection (WHO 2013g).

While many maternal deaths have direct obstetric causes (such as haemorrhage or abortion), infectious diseases are an important indirect cause of maternal death in developing nations, with studies suggesting they are often under-diagnosed in relation to maternal mortalities (Ordi et al. 2009). In Mozambique for example, infectious diseases were found to account for a higher proportion of maternal deaths than direct obstetric causes, with HIV-related complications and malaria being key contributors (Menendez et al. 2008).

Acknowledging the impact of infectious diseases on women's and children's health the United Nations Global Strategy for Women's and Children's Health stresses the need to strengthen linkages between disease-specific programs (such as for HIV, malaria and tuberculosis), and maternal and child health interventions.

Immunising children in Cambodia. Image: Chhor Sokuntha, World Bank Photo Collection.

Mothers in Mali at a breastfeeding clinic.
Image: Dominic Chavez, World Bank Photo Collection.

Obesity and non-communicable diseases

Non-communicable diseases (NCDs) include heart disease, stroke, cancer, chronic respiratory diseases and diabetes. Unlike infectious diseases, NCDs are not passed from person to person, and are also known as chronic diseases as they are of long duration and generally progress slowly. As the global burden of infectious diseases, malnutrition and maternal and child illness has decreased over the past two decades, the burden of NCDs has increased. NCDs are now the major cause of disability and premature death, responsible for 54% of global disability adjusted life years (DALYs)[4] in 2010, up from 43% in 1990 (Murray et al. 2012). In addition to human costs, the economic costs of NCDs entrench poverty in low income families and reduce national income. The magnitude of the epidemic was highlighted at the United Nations (UN) General Assembly High-Level Meeting on the prevention and control of NCDs held in September 2011, which was only the second time that a high-level UN meeting has been dedicated to a health topic after the meeting on HIV/AIDS in 2001.

The epidemic of NCDs is being driven by demographic ageing, rapid urbanisation and the global spread of unhealthy lifestyles, including increasingly energy-dense diets and low levels of physical activity (WHO 2010c). Obesity[5] is a major risk factor for a number of NCDs such as type 2 diabetes, many cancers and cardiovascular diseases, and is generally detrimental to longevity, disability-free life years, quality of life and productivity (Wang et al. 2011). Obesity has increased rapidly since the 1970s and now affects more than 500 million people worldwide, and is responsible for at least 2.8 million deaths annually (WHO 2013j). Obesity is also becoming more prevalent in children, with implications for the future health and development of nations (de Onis et al. 2010). In some regions obesity has overtaken tobacco as the largest preventable cause of disease burden (Swinburn et al. 2011).

Although obesity as a public health problem has historically been limited to high income nations it has now reached epidemic proportions in many developing nations, and is a major factor in the rapid increase in NCDs across all segments of society worldwide (WHO 2013j). Significantly for the Tropics, low- and middle-income nations now bear 80% of the global NCD burden (WHO 2010c).

Trends

Almost 530 million adults across the world were obese in 2010, up from 350 million in 2002, as the obesity rate increased from 7.9% to 10.5% (see Table 6.2.5). In the Tropics the adult obesity rate increased from 4.4% to 6.8%, while in the Rest of the World it increased from 10% to 12.8%. The obesity rate in the Tropics is around half that in than the Rest of the World, but is increasing at a faster rate.

Obesity rates increased in all regions of the Tropics in the eight years to 2010, with the greatest increases in Central America (23.1% to 31.6%), the Caribbean (14.7% to 22.9%) and South America (13.9% to 21.4%). Since 2002 these three regions have consistently reported the highest obesity rates, and in 2010 South America had the largest number of obese adults in the Tropics, at 46 million. Within regions however there is considerable variation across nations, particularly in the Caribbean where obesity rates range from 11% in Haiti to 37% in Trinidad & Tobago. In Central America obesity rates range from 12% in Honduras to 36% in Mexico.

In Oceania, Micronesia, Tonga and Samoa had obesity rates of 72%, 71% and 51% respectively in 2010 – the highest national rates in the world. A shift towards more calorie-dense diets and less physical activity is driving the obesity epidemic in the region (see Box 6.2.3). By contrast, Papua New Guinea and the Solomon Islands, which are also in Oceania, had obesity rates of 5% and 12% respectively, and are a major influence on the regional obesity rate of 18%. If these two nations are removed from Oceania, the obesity rate doubles to be 36% in 2010 – the highest rate among the tropical regions. In both Papua New Guinea and the Solomon Islands, relatively low national obesity rates mask significant variation within each nation, with undernutrition coexisting with an increasing prevalence of overweight and obesity, especially in urban areas (Andersen et al. 2013, Sakaue 2003).

'Non-communicable diseases are a major barrier to economic growth and social development. Their prevention and control must, therefore, be integrated into national and global development agendas.'

Mwai Kibaki,
President of Kenya (2011)

At 1.7%, South Asia had the lowest obesity rate in 2010, though this equates to more than 9 million obese adults. Other tropical regions where obesity rates are relatively low are South East Asia, Central & Southern Africa and Northern Africa & Middle East.

Determinants and prevention

A defining feature of NCDs is that the major risk factors – such as obesity, high blood pressure and high cholesterol – can be prevented or lessened by modifying underlying behaviours such as tobacco use, physical inactivity, unhealthy diet and harmful use of alcohol. It is estimated that up to 80% of heart disease, stroke and type 2 diabetes, and over one-third of cancers could be prevented through healthy diet, regular physical activity and avoidance of tobacco use (WHO 2008a).

Historically, obesity was predominantly associated with individual behaviour, but as the obesity epidemic has spread over the past decades there has been an increasing focus on the external determinants of energy imbalances (Caballero 2007). Economic growth (see Box 6.2.4), greater food availability and more effective marketing of energy-dense foods are the major factors contributing to higher obesity rates, but a range of other factors are also important. These include social and cultural norms, environmental impacts such as the degree of urbanisation, psychological motivations for physical activity (Gortmaker et al. 2011) and income inequality (Swinburn et al. 2011). Complex genetic and epigenetic mechanisms are also a factor, with adult obesity and risk of chronic disease increasingly linked with maternal obesity and undernutrition in early life (Barker 2012, Drake & Reynolds 2010), and the risk of chronic disease increasing at a lower BMI in some Asian and Latin American populations than in other populations (James 2008).

Obesity is the only major cause of preventable death that public health measures are yet to reverse in any population (Swinburn et al. 2011). Initiatives to address obesity have largely focused on influencing consumer decision making through information dissemination, health promotion and marketing strategies. Nonetheless, there is little consensus on the most effective approach, due partly to the range and complexity of obesity determinants (Gortmaker et al. 2011). What is clear though is that as the health, social and economic impacts of obesity mount there is greater awareness of the need for effective solutions, and recognition that collaboration between industry, government and the community will be necessary to strike a balance between commercial and public policy objectives. Strategies may include changes in food production and marketing, as well as new approaches to urban planning and transportation (Caballero 2007).

The double burden of disease

Most low- and middle-income nations now face a 'double burden' of disease where the prevalence of NCDs is increasing rapidly while infectious diseases and under-nutrition remain major public health issues (Remais et al. 2013). Low- and middle-income nations bear 80% of the global burden of NCDs, and comprise 29 million (around 80%) of the 36 million deaths from NCDs each year (WHO 2013d). Over 80% of global cardiovascular and diabetes deaths, almost 90% of deaths from chronic obstructive pulmonary disease and more than two-thirds of all cancer deaths occur in these nations (WHO 2010c). NCD-related mortality also occurs at an earlier age in developing nations – of the 9 million annual NCD deaths of people aged less than 60 years, more than 90% are in low- and middle-income nations (WHO 2013d). Different levels of access to adequate chronic health care services between developing and developed nations contribute to the higher mortality rates and premature deaths. The high NCD burden in low- and middle-income nations is driven by an increasing prevalence of risk factors, including obesity. Globally, 44% of the diabetes burden, 23% of the ischaemic heart disease[6] burden and between 7% and 41% of certain cancer burdens are attributable to excessive weight (WHO 2013j). At the same time as around 2 billion adults worldwide are overweight and obese, a further 1 billion people are undernourished. Undernutrition and obesity now co-exist in many developing nations, even within households (WHO 2013j). While obesity in lower income nations has traditionally been associated with wealthier and urban populations, there is evidence that this is changing, and that obesity rates in many low income and rural populations are increasing rapidly (Popkin et al. 2012).

Increasing rates of obesity and NCDs among lower income nations present considerable challenges for both families and nations. Economic estimates suggest that the cumulative output loss of cardiovascular disease, chronic respiratory

Table 6.2.5 **Adult obesity rates^**

	2002	2005	2010	PPT* change 2002-10	Average Annual Growth
Tropics	**4.4**	**5.2**	**6.8**	**2.3**	**5.5**
Central & Southern Africa	2.2	2.6	3.3	1.2	5.5
Northern Africa & Middle East	4.7	5.4	6.2	1.5	3.6
South Asia	0.9	1.1	1.7	0.8	8.0
South East Asia	1.9	2.3	3.4	1.5	7.7
Caribbean	14.7	17.9	22.9	8.1	5.6
Central America	23.1	26.0	31.6	8.5	4.0
South America	13.9	16.3	21.4	7.5	5.6
Oceania	14.3	15.7	18.2	3.9	3.1
Rest of the World	**10.0**	**10.9**	**12.8**	**2.8**	**3.1**
World	**7.9**	**8.8**	**10.5**	**2.6**	**3.6**

Source: WHO (2012a), State of the Tropics project
^Percent of population *Percentage point

[4] DALYs are a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

[5] The World Health Organisation defines obesity as a body mass index (BMI) greater than or equal to 30, and overweight as a BMI of 25 or more. BMI is calculated as a person's weight in kilograms divided by the square of their height in metres.

[6] Ischemic heart disease (IHD) is characterised by reduced blood supply to the heart muscle, usually due to coronary artery disease. The risk of IHD increases with age, smoking, high cholesterol levels, diabetes, and high blood pressure. It is more common in men, and people who have close relatives with ischaemic heart disease.

disease, cancer, diabetes and mental health will be US$47 trillion over the next 20 years (Bloom et al. 2011). This loss, divided by the 20-year period, is equivalent to about 5% of global GDP in 2010. Developing nations are predicted to assume an increasing share of this economic burden as their economies and populations grow. A further challenge stems from the structure of health systems in many developing nations, which are historically shaped around acute care rather than chronic care. In these nations NCDs are often detected at a late stage when treatment costs are typically higher (WHO 2010c). As access to these interventions is costly, families can struggle to afford them, further entrenching poverty by reducing the resources available for food, shelter and education (WHO 2010c). As NCDs affect people over long periods of time a key challenge for developing nations will be to develop health promotion and primary care capacity to address risk factors, detect NCDs early, reverse disease progression and prevent complications (WHO 2010c).

If current trends persist the prevalence of NCDs globally is predicted to increase by 15% between 2010 and 2020 (WHO 2008a). The greatest increases are anticipated in Africa (27%), the Middle East (25%) and in Asia and the Pacific (21%). NCDs therefore represent a significant challenge for the Tropics, with implications for other development challenges in the region such as poverty reduction (WEF 2010).

Diabetes

Obesity is responsible for 44% of the global diabetes burden (WHO 2013j). Around 90% of people with diabetes have type 2 diabetes, which is caused by a combination of genetic and lifestyle factors, including excess body weight, high blood pressure, physical inactivity and a diet high in fat and sugar. There is no cure for type 2 diabetes, but it can generally be prevented through moderate diet and lifestyle changes and, once acquired, it can be managed through a combination of lifestyle modifications and medication to control blood glucose levels. If unmanaged, the disease can lead to serious damage of nerves and blood vessels, and premature death. Until recently type 2 diabetes was only a disease in adults, but it is now increasingly diagnosed in children (Walley et al 2006).

Diabetes affects 6.4% of adults worldwide, or 285 million adults in 2010, with the number doubling since 1980 due to a combination of population ageing and rising obesity rates. By 2030 diabetes is predicted to affect 7.7% of the world's adult population, with a 69% increase in the number of adults with diabetes in developing nations, and a 20% increase in developed nations (Shaw et al. 2009). This highlights the particular relevance of the disease to low- and middle-income nations which already shoulder more than 80% of global diabetes deaths (WHO 2013n). In addition, diabetes in these nations presents a unique public health threat as it increases the risk of developing tuberculosis – which is still highly prevalent in many impoverished communities – by a factor of three (Baker et al. 2011). With diabetes accounting for 11% of global health care expenditure in 2011(World Bank 2012), diabetes also presents a significant financial challenge for developing nations.

Looking Forward

Obesity is contributing to the growing global prevalence of NCDs and is emerging as one of the greatest global public health challenges. International recognition of the burden of NCDs and key risk factors such as obesity is increasing, with a number of resolutions, targets and action plans being developed and implemented.

NCDs present a particular challenge for low income nations that also face a significant burden from communicable diseases and undernutrition. NCDs are presenting significant human, social, economic and health system challenges in these nations, and growing rates of obesity have major implications for global development and unquestionable significance for the Tropics, which is home to 75% of the world's low-income population.

Box 6.2.3 Obesity in Pacific Island nations

Many tropical Pacific Island nations are suffering an obesity crisis, with the highest adult obesity rates in the world. Compared with a global rate of 10% in 2010, obesity rates in Tonga and the Federated States of Micronesia were over 70%, and over 50% in Samoa.

A unique array of factors contributes to these high and growing obesity rates. In many of these island nations Western influences have increased since World War II, and traditional diets of fresh fish, meat, and local fruits and vegetables have been replaced by imported products such as rice, sugar, flour, canned meats, canned fruits and vegetables, soft drinks and beer (Curtis 2004). At the same time urbanisation and the increasing use of motor vehicles have decreased physical activity, and a cultural preference for a large physical size has amplified the epidemic in some nations (Curtis 2004). Research suggests that Pacific Islanders may also have a genetic predisposition to obesity (Walley et al. 2006).

Obesity in Pacific Island nations is resulting in increases in NCDs such as diabetes, stroke and heart disease. NCDs are now the leading cause of death in many of these nations, frequently accounting for 70% of all deaths (World Bank 2012). Rates of adult diabetes are among the highest in the world, and the average age at which Pacific Islanders develop diabetes and cardiovascular disease is getting lower (WHO 2010d). NCDs present a particular threat to future health in these nations as obesity is occurring at an early age – for example, nearly one in four boys and one in five girls in Tonga is obese (World Bank 2012).

The growing burden of NCDs in these nations also presents significant financial and health system challenges, with many still experiencing a high burden of communicable, maternal, neonatal and nutritional conditions.

Exercise program to combat obesity in Nauru. Image: Lorrie Graham, DFAT.

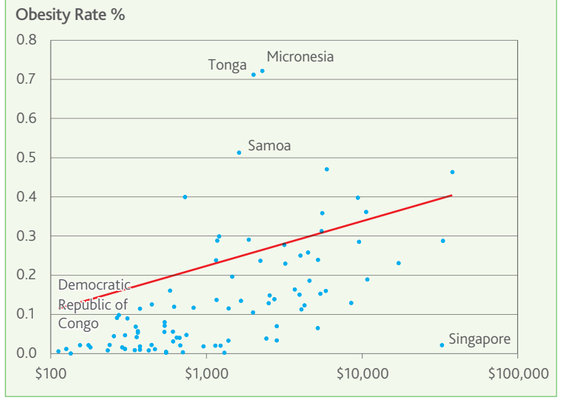
Box 6.2.4 Obesity and economic growth

A range of demographic, epidemiological and technological transitions are linked with obesity, and many are also associated with economic growth and rising wealth. For example, urbanisation tends to occur as economies modernise, contributing to changes in nutritional intake and activity levels, and a shift from infectious to non-communicable diseases (Swinburn et al. 2011).

Gross domestic product (GDP) per capita is an indicator of economic prosperity and, as such, obesity risk. In the Tropics, the general relationship between GDP per capita and obesity rates (see chart below) indicates that obesity and the risk of developing NCDs is likely to increase for millions of people as low- and middle-income nations develop.

However, a high level of prosperity is not required for obesity to become a public health issue, as there are also many other factors that influence obesity risk – as reflected in the considerable variation in obesity rates between nations that have similar GDP per capita. For example, the Pacific Island nations of Tonga, the Federated States of Micronesia and Samoa have the highest obesity rates in the world yet are lower-middle income nations with GDP per capita of around US$2,000. Conversely, Singapore is one of the wealthiest nations in the world, yet has an obesity rate of 2.1%.

Figure 6.2.8 **Obesity and GDP per capita in the Tropics, 2010**



Source: WHO (2012a), World Bank (2013), State of the Tropics project

HIV and AIDS

Acquired Immune Deficiency Syndrome (AIDS) was first recognised in the early 1980s and has since become a significant public health problem in almost every country. AIDS is caused by the human immunodeficiency virus (HIV) which damages the body's immune system until it can no longer protect itself from infection and disease (WHO 2013b). There is no preventive vaccine for HIV, but antiretroviral therapy suppresses the replication of HIV in the body and significantly increases the life expectancy of people with HIV. Globally, access to antiretroviral treatments has increased since the mid-1990s, transforming HIV from a death sentence to a chronic, manageable disease in many nations.

Transmission of HIV occurs through three routes. Sexual transmission accounts for the vast majority of people who are newly infected. It is also spread through blood (via infected blood or blood products, or the use of non-sterile injecting equipment), and from infected mothers to their babies before birth, during delivery or through breastfeeding. In most regions the HIV epidemic is concentrated among key high-risk populations, while in the most affected regions the epidemic is 'generalised' – that is, more than 1% of the general population is living with HIV (UNAIDS 2009). Misconceptions about HIV transmission (notably that it can be transmitted through day-to-day contact) and the marginalisation of high risk populations contribute to ongoing and widespread HIV-related stigma and discrimination.

The global impact of AIDS is undeniable, and the epidemic has been described as 'an unprecedented human catastrophe' (UN 2011a). Since the 1980s AIDS has significantly affected human and economic development in many nations, claimed over 30 million lives, orphaned more than 16 million children (UN 2011a) and, in the most affected nations, erased decades of progress in reducing mortality (UN 2009). Co-infection with other diseases is also a significant issue (see Box 6.2.5). As HIV primarily affects working age populations it has also had a substantial impact on labour supply, productivity and economic output (Dixon et al. 2002), and has severely undermined agricultural systems and food security in many nations (FAO 2003).

While 2.5 million people acquired HIV in 2011, the number of new infections globally has been declining since the mid-1990s. Nonetheless, in some parts of the world and within some populations the number of new infections is rising. Globally it is estimated that less than half of the people living with HIV are aware of their infection (UN 2011a). As a reflection of the continuing impact of the epidemic, 87% of governments across the world view HIV/AIDS as a major population and demographic concern, and it is a key factor limiting increases in life expectancy in the most affected nations (UN 2009).

Trends

The extent and impact of the HIV epidemic can be measured in terms of incidence (new cases), prevalence (all cases) and AIDS mortality (deaths). The number of new HIV cases provides the clearest indication of the impact of prevention strategies, but available time-series data on this indicator are limited. More comprehensive data are available for HIV prevalence and AIDS mortality, which are useful for understanding the occurrence of HIV and the impact of HIV treatment programs.

Number of People Living with HIV

The number of people between the ages of 15 and 49 living with HIV in the Tropics is higher than in the Rest of the World. In 2010 there were 16.9 million 15 to 49 year olds in the Tropics living with HIV, compared with 9.6 million in the Rest of the World (see Table 6.2.6). That is, the Tropics accounts for around 64% of people in this age group living with HIV, despite representing only 41% of its global population. While the number of new HIV infections is estimated to have peaked globally in 1996 (UN 2009), the number of 15-49 year olds living with HIV continues to increase, including in the Tropics.

In the Tropics Central & Southern Africa is the region most affected by the epidemic, with nearly 13 million 15 to 49 year olds living with HIV in 2010. This is 76% of all 15 to 49 year olds living with HIV in the Tropics, and almost 50% of global infections in this age group.

'We live in a completely interdependent world, which simply means we cannot escape each other. How we respond to AIDS depends, in part, on whether we understand this interdependence. It is not someone else's problem. This is everybody's problem.'

Bill Clinton

Prevalence

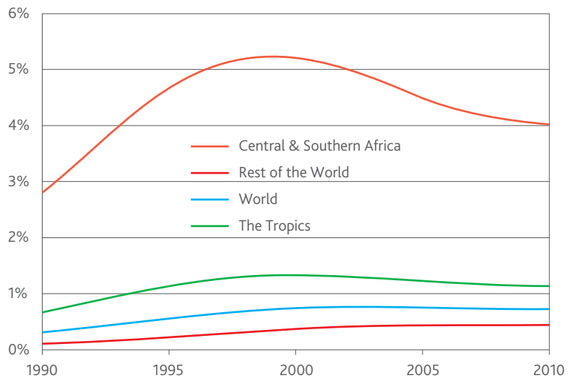
HIV prevalence is the proportion of a population living with the disease. While a useful indicator, HIV prevalence can be challenging to interpret as it is a function of both HIV incidence and AIDS mortality.

HIV prevalence among people aged 15 to 49 years is higher in the Tropics than in the Rest of the World (see Figure 6.2.9). Prevalence increased rapidly in the Tropics in the 1990s, peaking at 1.3% in 2000 before trending down to 1.1% in 2010. In the Rest of the World HIV prevalence in this age group also increased in the 1990s and early 2000s, but unlike the downward trend in the Tropics, has remained relatively steady at just above 0.5% since 2003.

In the Tropics HIV prevalence is highest in Central & Southern Africa where 4% of the population aged 15-49 years were living with the disease in 2010. This is almost four times higher than prevalence in the Tropics as a whole, and reflects the disproportionate burden of HIV in sub-Saharan Africa, where nearly 1 in 20 adults is living with HIV (UNAIDS 2012). After rising sharply through the 1990s, HIV prevalence in Central & Southern Africa has been falling steadily from the peak of 5.2% in 1999. The Caribbean has consistently reported the second highest prevalence in the Tropics.

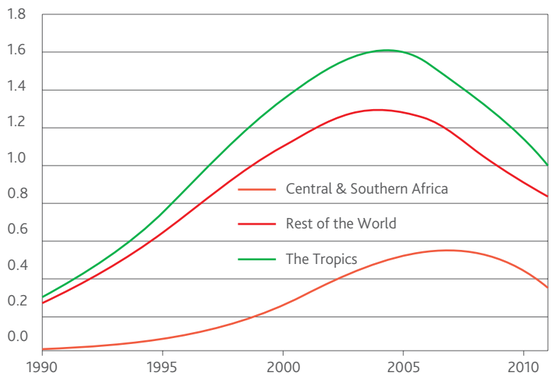
Prevalence in most tropical regions peaked in the 1990s and has since stabilised or declined. Declining prevalence may reflect a combination of fewer new cases of HIV and/or increasing AIDS mortality rates. Looking forward, even if incidence is declining, improved access to antiretroviral therapy in low- and middle-income nations is likely to result in HIV prevalence increasing as people with the disease live longer, as has been occurring in many high-income nations over the past 15 years (WHO 2012f).

Figure 6.2.9 **HIV prevalence (% of population aged 15-49 years)**



Source: World Bank (2013a), WHO (2013b), State of the Tropics project.
Note: Calculations exclude China and a number of smaller nations.

Figure 6.2.10 **Deaths from AIDS**



Source: World Bank (2013b), WHO (2013p), State of the Tropics project.
Note: Mortality rates are not age-standardised. Calculations exclude a number of nations[9].

Mortality

In 2011 around 1 million people in the Tropics died from AIDS, down from a peak of over 1.6 million people in 2004 (see Figure 6.2.10). AIDS mortality in the Tropics peaked at 62 deaths per 100,000 people in 2003, declining to 40 per 100,000 people in 2010 (see Table 6.2.7). AIDS mortality is also declining in the Rest of the World, down from a peak of 14 deaths per 100,000 people in 2006 to 11 in 2010.

The sharp decline in the AIDS mortality rate in the Tropics since 2003 reflects greater access to antiretroviral therapy in highly affected parts of Africa. In sub-Saharan Africa 30% fewer people are estimated to have died from AIDS in 2010 than in 2004 despite an increase in the number of adults living with HIV (WHO 2013i). Globally however, improvements have not however been universal, and in some parts of Eastern Europe AIDS mortality rates have been increasing since 2000.

The AIDS mortality rate in Central & Southern Africa has consistently been considerably higher than in other regions of the Tropics. For example, in 2010 the mortality rate in Central & Southern Africa was almost five times higher than in the Caribbean, the region with the next highest mortality rate. In both Central & Southern Africa and the Caribbean the AIDS mortality rate has been declining since the early 2000s, largely attributable to initiatives that have expanded access to antiretroviral therapy. By 2010 the AIDS mortality rate had decreased to 131 deaths per 100,000 people in Central & Southern Africa and to 28 per 100,000 people in the Caribbean. All regions of the Tropics have experienced declining AIDS mortality rates since 2005.

Children and young people

Around 3.4 million children aged between 0 and 14 years were living with HIV in 2011 (WHO 2013r), of which 330,000 were newly infected (UNAIDS 2012). Over 90% of new infections are in sub-Saharan Africa, and most of these children acquire HIV from their mother (WHO 2013r). Transmission of HIV to children can be reduced significantly if pregnant women living with HIV have access to antiretroviral therapy (UNAIDS 2011a). In 2011, 57% of pregnant women with HIV in low- and middle-income nations received

[9] Based on nations for which the World Bank or WHO report data. By population, China is the largest nation for which data are unavailable. The following exclusions are made in the Tropics (expressed as a percentage of the 2010 regional population): 15% of Oceania (11 nations); 11% of Caribbean (6 nations); 22% of South East Asia (3 nations; less than 1% if China is not included); 13% of Northern Africa & Middle East (2 nations); and 9% of Central & Southern Africa (2 nations). Nations in the Rest of the World for which data were unavailable represent 40% of the population, with China, Russian Federation, Algeria, Uzbekistan, Iraq and Argentina accounted for the greatest proportion.

antiretroviral therapy – an increase from previous years (WHO 2010b). Increased maternal access to treatment combined with fewer newer infections among adults and infant feeding programs resulted in a 43% decrease in the global number of new infections among children in 2011 compared with 2003 (UNAIDS 2012).

Young people between the ages of 15 and 24 years are also significantly affected by HIV, with 10.3 million living with HIV in 2011 (UN 2011a). It is estimated that 50% of global HIV transmission takes place among young people, and factors contributing to this vulnerability include risky sexual behaviour, substance use and a lack of knowledge about HIV and its prevention (Ross et al. 2006).

In the 38 nations with generalised HIV epidemics – of which 35 are in the Tropics, and all but two are in Africa – the number of deaths from AIDS among children under the age of five peaked at over 210,000 in 2003, and has since declined to around 100,000 in 2011. The declining deaths among children are attributable to reduced mother to child transmission rates and, to a lesser extent, the expansion of treatment access for children. While the number of children receiving antiretroviral therapy worldwide has increased from 71,500 in 2005 to 456,000 in 2010, treatment coverage is still less than one quarter of what is required (Zaidi et al. 2013).

High risk populations

The impact of AIDS varies between and within nations. Generalised epidemic conditions exist in the most affected nations and regions, while in less affected areas the epidemic is concentrated in sub-populations engaging in high-risk behaviours (Zaidi et al. 2013). In most parts of the world HIV disproportionately affects men who have sex with men, injecting drug users and sex workers (UNAIDS 2011b). These highly marginalised sub-populations can often face additional stigma if they contract HIV, and the additional risk of HIV-related verbal and physical abuse can impact their willingness to access treatment services (UNAIDS 2012). In some nations migrants, military personnel, prison populations and truck drivers are also at higher risk of HIV infection (UNAIDS 2009).

Men who have sex with men are at higher risk of HIV infection across all nations and ethnicities (Johnson et al. 2008), with HIV prevalence in capital cities for this group being 13 times higher on average than in national populations (UNAIDS 2012). Similarly, female sex workers have been found to be 13.5 times more likely to be living with HIV than other women. For people who inject drugs, HIV prevalence is 22 times higher than in the general population, though this varies significantly across nations. In the Tropics for example, the prevalence of HIV among people in this group ranged from below 5% in Australia to in excess of 50% in Mauritius.

Despite the variation, drug-related transmission is believed to be driving the expansion of the HIV epidemic in many nations (UNAIDS 2012).

Gender

Globally AIDS is the leading cause of death among women of reproductive age, and women bear a disproportionate share of the HIV care-giving burden (UN 2011a). While the share of women among all persons living with HIV varies significantly between different regions of the world (from 34% in Asia to 58% in sub-Saharan Africa in 2010) (UNAIDS 2012), young women aged between 15 and 24 years account for 66% of the young people living with HIV worldwide (UNAIDS 2010). In many of the highly affected nations major socioeconomic and political inequalities persist between males and females. The lower status of women in these societies limits their decision-making power and increases their vulnerability to violence and HIV infection. Initiatives that aim to tackle gender inequality – such as combating gender-based violence and fostering economic empowerment of women – are considered critical elements of an effective HIV response (UNAIDS 2012).

The vulnerability of men to HIV infection is an area of increasing focus. Even where there is widespread knowledge of HIV, heightened risk taking among young men can increase their exposure to HIV though risky sexual practices such as multiple partners and not using condoms (Nzewi 2009,

Box 6.2.5 Linked epidemics of HIV and tuberculosis

The HIV epidemic is a major factor driving the global resurgence of tuberculosis (TB), particularly in sub-Saharan Africa (Suther et al. 2012). Infection with HIV has become the strongest risk factor for developing TB. Around one-third of the 34 million people living with HIV worldwide are also infected with TB, and 1.1 million new cases of TB occurred among people living with HIV in 2010 (WHO 2012h). In sub-Saharan Africa almost 900,000 people living with HIV acquired TB in 2011 (UNAIDS 2012). Globally, TB is now the leading cause of death among people living with HIV (UN 2011a).

Combined, TB and HIV are far more damaging to human health than either disease alone, with each disease accentuating the progression of the other. People living with HIV are 21-34 times more likely to become sick with TB than people without HIV (WHO 2012h). Similarly, TB acts to increase the rate at which the HIV virus replicates in a co-infected person, worsening the course of their HIV infection (Sharma et al. 2005). This co-infection pattern is destabilising global TB control efforts and represents a worldwide public health crisis (Rodwell et al. 2010).

Treatment for both HIV and TB are necessary for the effective management of people co-infected with these diseases. Antiretroviral therapy can reduce the risk of becoming sick with TB among HIV patients by 65%, and significantly reduces the risk of dying from TB (UNAIDS 2012). Initiatives to integrate HIV and TB services are increasing and are estimated to have saved 1.3 million lives between 2005 and 2011 (WHO 2012k). Screening for both TB and HIV is increasing among affected populations, although less than half of all people living with TB and HIV worldwide received antiretroviral therapy in 2011 (UNAIDS 2012).

Preventing the spread of HIV and TB. Image: Trinn Suwannapha, World Bank Photo Collection.

Table 6.2.6 **Number of 15-49 year olds living with HIV***

	1990	1995	2000	2005	2010	% of Tropics
Tropics	**6,502**	**13,073**	**16,564**	**16,641**	**16,945**	
Central & Southern Africa	5,009	9,883	12,597	12,462	12,881	76.0
Northern Africa & Middle East	156	314	413	447	491	2.9
South Asia	288	896	1,307	1,422	1,152	6.8
South East Asia	543	1,068	1,205	1,228	1,337	7.9
Caribbean	125	195	205	192	183	1.1
Central America	113	165	194	204	278	1.6
South America	260	536	615	656	594	3.5
Oceania	8	16	26	29	31	0.2
Rest of the World	**1,866**	**3,575**	**7,294**	**9,163**	**9,600**	
World	**8,368**	**16,649**	**23,859**	**25,804**	**26,545**	

Source: World Bank (2013a), WHO (2013b), State of the Tropics project *Thousands ('000s)
Note: Calculations exclude China[7] and a number of smaller nations[8].

[7] No data are available for China, but its government estimates that HIV prevalence is high (above 1%) in certain regions and in high risk populations, with a substantial proportion of infected people yet to be diagnosed (Ministry of Health 2012).

[8] Based on nations for which the World Bank or WHO report data. By population China is the largest nation for which data are unavailable. Due to lack of data the following exclusions are made in the Tropics (expressed as a percentage of the 2010 regional population aged 15-49 years): 14% of Oceania (11 nations); 10% of the Caribbean (6 nations); 23% of South East Asia (3 nations; less than 1% if China is not included); 14% of Northern Africa & Middle East (2 nations). Nations in the Rest of the World for which data were unavailable represented 37% of the population of 15-49 year olds.

Plummer 2009). In many societies HIV is also linked to the male taboo of homosexuality, and the stigma associated with having HIV is very real for many men (Plummer 2009). This stigma can discourage men with HIV from admitting ill health, seeking medical advice and accessing antiretroviral therapy, and contributes to higher AIDS mortality rates among men (UNAIDS 2012). These behaviours can also act to amplify the epidemic across the community (Plummer 2009). These issues highlight the need to consider social context, and in particular gender norms and inequalities, in the development and implementation of effective HIV prevention initiatives.

Looking forward

The devastating global impact of AIDS continues to mobilise significant resources, and dramatic progress has been made in combatting the disease over the past two decades (UNAIDS 2012). The number of people receiving antiretroviral therapy worldwide is increasing, new infection rates are falling in many of the most highly affected nations and new, bold targets are being set (see Box 6.2.6). In fact, the goal of eliminating HIV and AIDS is now seen as feasible (UN 2011a), with global efforts being targeted towards the vision of 'a world with zero new HIV infections, zero discrimination, and zero AIDS-related deaths' (UNAIDS 2011c).

Despite the numerous gains, significant challenges need to be overcome if HIV is to be eliminated. These include improving the targeting of strategies and programs to match country-specific needs, better understanding the factors that contribute to HIV vulnerability and that impede service access and identifying the most efficient and effective use of limited AIDS resources. As the region most highly affected by the AIDS epidemic, the Tropics has a lot to gain from global HIV elimination initiatives.

Table 6.2.7 **AIDS mortality rate***

	1990	1995	2000	2005	2010
Tropics	**15**	**34**	**56**	**60**	**40**
Central & Southern Africa	68	139	208	213	131
Northern Africa & Middle East	11	22	34	35	24
South Asia	1	2	10	16	13
South East Asia	1	5	12	12	9
Caribbean	16	38	55	52	28
Central America	3	7	11	9	6
South America	3	6	10	9	8
Oceania	2	12	15	20	11
Rest of the World	**1**	**2**	**7**	**14**	**11**
World	**6**	**15**	**26**	**33**	**23**

Source: World Bank (2013b), WHO (2013p), State of the Tropics project.
*Deaths per 100,000 population
Note: Mortality rates are not age-standardised.

Box 6.2.6 HIV and health systems

The role of the health system in combating the HIV/AIDS epidemic has changed over time. Prior to the introduction of antiretroviral therapy health systems delivered short-term acute care for AIDS patients, but as more people across the world are living longer with HIV, health systems are now also required to deliver integrated, long-term HIV care and treatment services (Atun 2011). Many nations – and especially low- and middle-income nations – are facing significant challenges in making this transition.

HIV is a communicable disease, yet it now shares common health system requirements with non-communicable diseases. These requirements include long-term diagnostic and monitoring capacity, regular medication and adherence support, and patient education capability (Rabkin et al. 2012).

For people living with HIV, co-morbidities (e.g. HIV and TB), opportunistic infections and much longer life expectancies now mean that effective treatment requires long-term, individualised care (Atun 2011). Care for people living with HIV is becoming more complex, requiring greater resourcing and better integration of services.

Policy makers and service providers face a number of planning challenges to ensure that health systems adequately meet patient needs, particularly in developing nations. An adequate health workforce, new competencies to manage increasingly complex care and integrating HIV and mainstream health services are necessary to optimise patient outcomes (Atun. 2011).

For most patients the key challenges relate to access and affordability of treatment. Health system capacity to meet these challenges can be enhanced by the development of efficient and innovative models of care that are tailored to community needs.

Effective care strategies that are developed for people living with HIV can also have broader health system benefits (Rabkin et al. 2012). For example, in Ethiopia the lessons learned in developing HIV care programs are now informing the clinical management of diabetes (UNAIDS 2012).

Botswana.
Image: Samantha Marx.

Tuberculosis

Tuberculosis (TB) is a serious but treatable infectious disease caused by the bacterium *Mycobacterium tuberculosis* that has potentially killed more people through history than any other microbial pathogen (Daniel 2006). In ancient Greece Hippocrates introduced the name 'phthisis', or consumption, to describe the physical wasting caused by the disease. Despite its long presence in human society and significant efforts to control it, TB is the second leading cause of death from infectious diseases worldwide – after HIV– and is a major global public health problem (WHO 2012e).

Around one-third of the world's population is estimated to have a latent infection with the TB bacterium, of which around 10% will develop the disease during their lifetime (WHO 2012i). Nine million people develop TB each year, and around 1.4 million people die from the disease each year (WHO 2012e). Without treatment the infection is almost always fatal. TB most commonly affects the lungs (pulmonary TB), but it can also affect other parts of the body (extra-pulmonary TB) such as the central nervous and lymphatic systems. People at higher risk of TB disease include elderly people, infants and people with compromised immune systems, such as people with HIV or diabetes.

The introduction of antibiotic treatments for TB in the 1950s resulted in cure rates of up to 90% (WHO 2012e), and contributed to incidence and mortality rates declining up until the 1980s, particularly in developed nations. The emergence of drug-resistant strains and HIV co-infection has however seen a global resurgence of TB. The disease burden is now concentrated in developing nations, and over 80% of the world's TB cases are in just 22 nations, 18 of which are in tropical Asia and Africa (WHO 2012e).

Trends

Incidence, prevalence and mortality data are essential to understanding TB risk and burden. Accurate reporting of TB cases is however a major challenge, particularly in low income nations with under-resourced health systems (see Box 6.2.7). Global reporting rates have improved from 40% in 1995 to 66% in 2011, and TB burden estimates are calculated using models that consider the number of notifications, the estimated degree of underreporting, mortality data and trends in neighbouring nations (WHO 2012e).

'Let us vow to end the neglect of TB and to end deaths from this disease in our lifetime.'

Ban Ki Moon
Secretary-General of the United Nations (2013)

Number of new cases
The Tropics bears a disproportionate share of the global TB burden, with an estimated 4.9 million new cases in 2010 (see Table 6.2.8). This represents 56% of new cases, despite the Tropics representing 41% of the world population. The number of new cases in the Tropics peaked in 2003 at 5.2 million, and has since declined by 5%. The number of new cases in the Rest of the World also peaked in 2003 at 4.2 million, and has since declined by 8%.

The global decline in new TB cases is attributable to a combination of global TB diagnosis and treatment programs, as well as biological, social and economic factors such as increased access to improved sanitation and higher per capita health expenditure (Dye et al. 2009). Globally, treatment success rates (that is, the proportion of people who are cured or who complete their treatment) for TB have improved from 57% in 1990 to 85% in 2010 (WHO 2012e). However, success rates vary significantly between nations. In the Russian Federation for example, drug resistant TB is more prevalent and treatment failure rates are high. In the Tropics, Northern Africa & Middle East and Oceania the number of new cases per year has not peaked as yet.

Although the number of new cases has been declining in recent years, in most tropical regions there were more new cases in 2010 than there were in 1990, with the exceptions of the Caribbean, Central America and South America. Across the Caribbean the number of new cases varies considerably by nation, with regional aggregates dominated by Haiti which accounted for almost 75% of new cases in 2010. TB control efforts in Mexico, Brazil and Peru since 1990 have contributed to the consistent downward trend in the number of new cases of TB in Central America and South America, with decreases of 36% and 42% respectively from 1990 to 2010.

Central & Southern Africa, South Asia and South East Asia consistently account for around 90% of new cases in the Tropics, with Central & Southern Africa's proportion increasing from 26% in 1990 to 33% in 2010. The number of new cases of TB in all three regions peaked in the early 2000s, and has since fallen most rapidly in South Asia (see Table 6.2.9). However, the number of new TB cases in Northern Africa & Middle East and Oceania has been increasing since 1990.

Incidence
Globally TB incidence (the number of new cases per 100,000 population) was relatively stable in the 10 years to 2000, but has since been in steady decline, falling by 13% since 2000 to be 127 in 2010. In the Tropics TB incidence decreased by 16% to 172, and in the Rest of the World it decreased by 14% to 95. The TB incidence in the Tropics is consistently around 80% higher than in the Rest of the World.

Despite the declining global trend TB incidence is still higher than in 1990 in around 25% of nations, many of which were suffering from a high TB burden in 1990. In the Tropics TB incidence was highest in Central & Southern Africa in 2010 at 240 new cases per 100,000 population (see Figure 6.2.11). Although this is significantly higher than in most other tropical regions it represents a 23% decline from the peak of 313 in 1999. Except for Oceania, which experienced an increase, TB incidence fell in all tropical regions between 1990 and 2010, at rates of between 0.4% and 4.2% per annum. Since 1990 the most dramatic declines have occurred in Central America and South America, where TB incidence fell by 58% and 53% respectively to 2010 (from 71 and 109 cases per 100,000 respectively in 1990 to 30 and 52 in 2010). In 2010 these two regions had the lowest TB incidence in the Tropics.

Oceania is the only region in the Tropics where TB incidence has increased since 1990, from 193 to 214 in 2010. This was due to increasing rates in Papua New Guinea where TB incidence increased from 308 to 348 (13%), and was supported by increases in three small Pacific Island nations – two of which had increases of more than 200%. PNG has the greatest number of TB cases in Oceania and accounted for 92% of new cases in the region in 2010.

Around 3,600 people die from TB in Papua New Guinea each year, and the high and growing prevalence of drug resistant TB is a significant public health concern (Simpson et al. 2011). Limited health service capacity and coverage, inadequate drug supplies, poor treatment adherence (Amini et al. 2012) and overcrowded living conditions (Government of Papua New Guinea 2010) are contributing factors.

Deaths
Worldwide an estimated 1.4 million people died from TB in 2011, a 26% decline from 1.9 million in 1990 (WHO 2012e), with the Tropics consistently representing around 60% of global TB deaths. TB is also a major cause of child mortality globally (see Box 6.2.8).

Globally the TB mortality rate (deaths per 100,000 people) has fallen faster and for longer than TB incidence, decreasing by nearly 40% from 1990 to 2010. Between 1990 and 2010 the mortality rate decreased by 42% to 21 per 100,000 in the Tropics, and by 39% to 10 in the Rest of the World. The mortality rate in the Tropics is more than double that in the Rest of the World.

In the 20 years to 2010 the TB mortality rate has fallen in all regions of the Tropics (see Figure 6.2.12), though the pace of decline has varied considerably – from a 9% decline in the Caribbean to 75% in Central America. South America, Central America, Northern Africa & Middle East and South East Asia each experienced declines in the TB mortality rate of 50% or more. Oceania overtook South Asia in 2009 as the region with the highest TB mortality rate, with 31 deaths per 100,000 people in 2010.

Drug resistance

Drug-resistant TB is a major threat to global TB control (Raviglione et al. 2012), with two levels

Table 6.2.8 **Number of new tuberculosis cases***

	1990	1995	2000	2005	2010	% change since 1990	% change since peak
Tropics	**4,061**	**4,533**	**5,015**	**5,117**	**4,911**	**21**	**-5**
Central & Southern Africa	1,057	1,367	1,661	1,728	1,642	55	-6
Northern Africa & Middle East	147	159	166	172	177	21	n.a
South Asia	1,246	1,355	1,464	1,519	1,452	17	-5
South East Asia	1,255	1,336	1,426	1,427	1,390	11	-11
Caribbean	32	31	34	34	31	-3	-12
Central America	67	57	48	41	40	-42	-42
South America	240	210	196	172	153	-36	-36
Oceania	16	18	22	24	27	63	n.a
Rest of the World	**3,664**	**3,901**	**4,073**	**4,105**	**3,850**	**5**	**-8**
World	**7,725**	**8,435**	**9,088**	**9,222**	**8,761**	**13**	**-6**

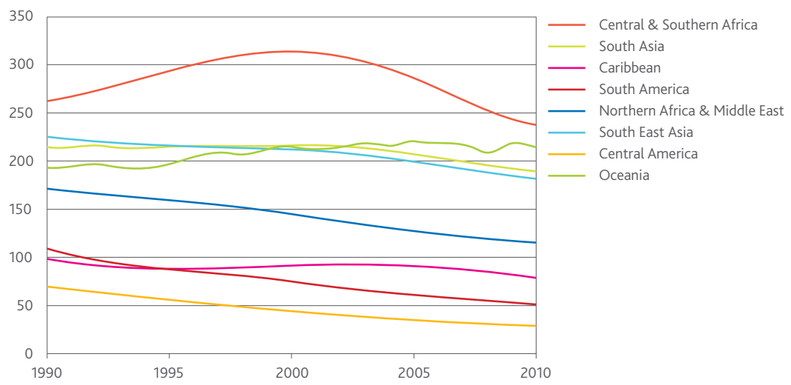
Source: WHO (2013f), UN (2013a), State of the Tropics project.
*Thousands ('000s)

of resistance: multi-drug resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB). The major factor contributing to TB drug resistance is inappropriate treatment, including poor compliance (Liang 2012). It is estimated that only 7% of MDR-TB cases are reported and that of these less than one-fifth are managed according to international guidelines (Nathanson 2012). These low detection and treatment rates increase the risk of drug resistant TB spreading, and represent a major challenge for global control efforts.

Compared with the treatment regimen for 'common' TB, MDR-TB requires more expensive and toxic drugs that need to be provided for a prolonged period (20 months, compared with six months). Cure rates are also lower and the treatment can have multiple and serious side-effects. Of the 12 million cases of TB in 2011 an estimated 630,000 (around 5.3%) were MDR-TB (WHO 2012e). The highest proportion of new TB cases that are MDR-TB are in nations of the former Soviet Union, where it can be up to 32% as in Belarus. In China and India the proportion of new TB cases with MDR-TB is much lower (5.7% and 2.1% respectively), but they account for the largest number of MDR-TB cases, together representing 50% of the global burden (Nathanson 2012).

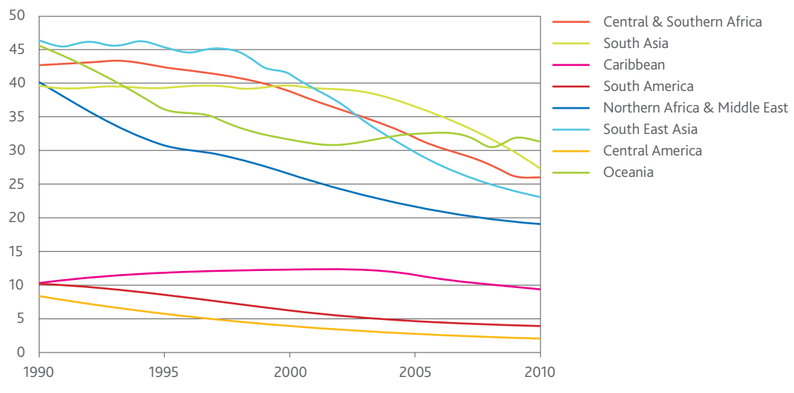
Incidence of MDR-TB is thought to be rising in some nations, but accurate assessments of global trends are hampered by data availability. Diagnosis and treatment of MDR-TB is a particular challenge in many low- and middle-income nations where resources and laboratory capacity are constrained. High rates of drug susceptibility testing and the provision of appropriate treatment for all TB patients with drug-resistant strains are key factors that report declining MDR-TB incidence. XDR-TB is virtually untreatable, and was reported in 77 nations in 2010. In a number of nations with high incidence of XDR-TB – typically in Africa and former states of the Soviet Union – over 10% of drug resistant cases are estimated to be XDR-TB (Nathanson 2012).

Figure 6.2.11 **Tuberculosis incidence – the Tropics**



Source: WHO (2013f), UN (2013), State of the Tropics project.

Figure 6.2.12 **Tuberculosis deaths – the Tropics**



Source: WHO (2013f), UN (2013), State of the Tropics project.
Note: Figures exclude deaths where HIV is a co-morbidity. Rates are not age-standardised.

Box 6.2.7 Tuberculosis diagnostics

Effective TB control is underpinned by fast and accurate diagnostic capacity. The limitations of conventional diagnostic methods, however, are constraining TB control efforts, particularly in developing nations.

Sputum smear microscopy is the most commonly used diagnostic test for TB in low- and middle-income nations, while diagnosis using culture techniques in a laboratory is the 'gold reference' standard. Despite their widespread use, both methods have a number of limitations. Sputum smear microscopy was developed more than 100 years ago and is only able to detect 50% of positive cases (Chaisson & Martinson 2008), is unable to detect extra-pulmonary TB and cannot identify drug resistance (WHO 2012e). Culture techniques are more expensive, require advanced laboratory facilities (which are limited in many high-burden nations) and can takes weeks for results. Both methods have additional limitations when it comes to detecting TB in children. Most children have extra-pulmonary TB (which is harder to detect than pulmonary TB), tend to present with a lower number of the TB bacteria (again, making it harder to detect), and many are unable to expectorate sputum (WHO 2012e).

The lack of rapid, effective and affordable diagnostics for TB is a significant bottleneck in control efforts (Raviglione et al. 2012). Limited laboratory infrastructure, particularly in developing nations, is also a major factor contributing to low TB detection and notification rates globally (66% of TB cases, 7% of MDR-TB cases and an even smaller proportion of XDR-TB cases) (WHO 2012e, WHO 2013l).

New diagnostic tests for TB – such as 'Xpert MTB/RIF', a new rapid and accurate molecular test that is able to detect drug resistance – are currently being developed and rolled out (WHO 2012e). The effectiveness of TB control efforts will be enhanced as new tests become more readily available among vulnerable populations globally, and as laboratory capacity (including trained personnel) is increased.

Daru Hospital and TB Testing Centre. Image: DFAT, AusAID.

Key risk factors for tuberculosis

Key risk factors for TB include low socioeconomic status, HIV infection, diabetes, smoking and alcohol and drug abuse (WHO 2011c). The importance of these risk factors to TB control is most clearly highlighted by the links between HIV and TB. The HIV epidemic was a significant contributor to the global resurgence of TB in the 1980s, and currently around 10% of the people who develop TB each year also have HIV, with most of these people living in Africa.

TB is often referred to as a 'disease of the poor', and its burden is greatest in developing nations and among people with limited access to health services and medicines (Broekmans & Paluzzi 2004). Crowded housing and poor working conditions can increase the risk of TB transmission while factors such as chronic malnutrition can weaken the immune system of people with latent TB, and increase the risk of developing the disease.

Diabetes is also a key risk factor for TB. People with diabetes are around three times more likely to develop TB than people without diabetes (Baker et al. 2011). The global burden of diabetes is increasing, notably in nations with a high TB burden. With diabetes incidence predicted to increase by 69% in developing nations and by 20% in developed nations between 2010 and 2030 (Shaw et al. 2010), the convergence of diabetes and TB may hamper TB control efforts.

Looking forward

With TB incidence declining globally the United Nations has achieved its Millennium Development Goal to halt and begin to reverse the spread of TB by 2015. But significant challenges remain. The Stop TB Partnership (hosted by the World Health Organisation), aims to halve 1990 TB death rates by 2015 and to eliminate TB as a public health problem by 2050 (Stop TB Partnership 2013). While death rates are decreasing globally, in a number of highly-burdened nations the HIV co-epidemic, drug resistance and poor socio-economic conditions are hampering the rate of improvement.

Looking forward, a key factor in reducing the burden of TB is improving access to timely, reliable and affordable diagnostic and treatment services, especially in high-burden developing nations (Keshavjee & Farmer 2012). In addition, the close association between TB and poverty and linkages with other chronic diseases suggests that TB control efforts need to be multidisciplinary, and must address key social determinants of health.

Box 6.2.8 Tuberculosis in children

TB is in the top 10 causes of child mortality worldwide (Swaminathan & Rekha 2010), but it has been a low global public health priority for many years as adults with infectious pulmonary TB have received the greatest attention (WHO 2012e). With less than 4% of estimated cases among children reported – compared with 66% of all cases – TB in children is referred to as a 'hidden pandemic' (WHO 2012l).

Diagnostic difficulties contribute to underreporting of TB in children (see Box 6.2.7). Poor linkages between paediatric clinicians and surveillance systems also contribute (WHO 2012e). For these and other reasons the inclusion of children in national TB surveys is not recommended by the World Health Organisation, meaning that global datasets incorporate estimates of the TB burden among children that have a high degree of uncertainty.

The World Health Organisation's 17th annual Global TB Report 2012 is the first to include estimates of the burden of TB in children, estimating 490,000 new cases and 64,000 deaths each year (WHO 2012e). In high burden nations a high proportion of TB cases are children (estimated at around 20-40%) compared with less than 5% in nations with effective TB control programs (Swaminathan & Rekha 2010). While in developed nations most childhood TB cases are detected and have good outcomes, children with TB in developing nations are more likely to be poor and malnourished leading to higher death and lower treatment success rates.

Apart from the direct impacts that TB has on children with the disease, children are also affected by TB in families and communities. In 2009 almost 10 million children were orphans as a result of losing a parent to TB (WHO 2012e). Women are particularly at risk as they account for a large proportion of the world's poor, and because TB tends to progress more quickly in women of childbearing age. TB is a leading cause of death in women during pregnancy, and particularly among women living with HIV (WHO 2012l). TB also increases the risk of premature birth and low birth weight babies, and young children whose mothers die are vulnerable to premature death (WHO 2012l).

Young TB patients in PNG. Image: DFAT, AusAID.

Malaria

Malaria is a serious and sometimes fatal disease caused by four *Plasmodium* parasite species that are spread to people by *Anopheles* mosquitoes. An ancient disease, malaria is likely to have had a substantial influence on human populations over thousands of years (CDC 2012a). At the height of its global distribution an estimated 90% of the world's population was at risk, with the disease extending as far north as the Arctic Circle. Since the 1897 discovery that mosquitoes transmit the disease control efforts have dramatically reduced its global distribution. In 1900 around 77% of the global population was at risk of malaria, while today it is around 50%, with the vast majority living in the Tropics (Cibulskis et al. 2011).

Provided that mosquito control, diagnosis and treatment programs are properly implemented, malaria is an entirely preventable and treatable disease (WHO 2012c). However, malaria remains a leading cause of death globally, particularly among children who account for around 85% of deaths from the disease (WHO 2013a). Reflecting that malaria is a globally significant health issue with a disproportionate impact on children, in 2010 it was the fifth highest cause of years of life lost due to premature death, up from sixth highest in 1990 (Lozano et al. 2012).

Malaria is currently considered endemic (that is, it is able to maintain itself within a population) in 104 nations and territories worldwide – five of which are in a prevention of reintroduction phase, with the transmission of malaria ongoing in the other 99 (See Figure 6.2.17). Partly due to more intense malaria transmission occurring in warmer climates near the equator (CDC 2010b), 80 of the 99 nations are wholly or partly in the Tropics. The disease is also strongly correlated with conditions of poverty, with mortality rates higher in low-income nations and in poorer populations within nations. Around 80% of malaria cases occur in just 17 nations and 80% of deaths in just 14 nations, with sub-Saharan Africa accounting for 91% of the world's malaria deaths (WHO 2012c).

A range of factors such as emerging drug and insecticide resistance led to the abandonment of many malaria eradication efforts from the 1970s and, since then, initiatives have tended to focus on malaria 'control', or reducing transmission to a level where it is no longer a public health issue (CDC 2012a). Significant investments in control and treatment programs since 2000 have substantially reduced the global burden of malaria. The number of new cases has decreased by 17% since then, and the mortality rate has fallen by 25% (UN 2012a). However, monitoring trends is a major challenge as current surveillance systems do not detect the vast majority of cases.

Trends

Limited surveillance data, particularly for high-burden nations, means that estimates are used to assess the distribution of malaria across nations and over time (see Box 6.2.9). Estimates are derived from reported cases and modeled relationships between malaria transmission, incidence and mortality trends and intervention coverage. Of the 99 nations with ongoing malaria transmission, 58 report sufficient data to allow trend assessments for the period 2000 to 2011. These data suggest that the World Health Assembly (WHA) malaria burden reduction target of 75% between 2000 and 2015 is likely to be met in 50 nations, and reductions of between 50-75% are likely to occur in a further four (WHO 2012c). However, the 50 nations that are likely to meet the target are low burden nations, accounting for only 3% of cases in 2000. Nonetheless, even in high burden nations where reporting and data are generally of poor quality, greater disease control efforts over the past 15 years are recognised to have had a substantial impact in averting a large number of cases and deaths, though greater investment is needed to reach the WHA target (WHO 2012c).

Malaria cases

Malaria case estimates for the 99 nations with ongoing malaria transmission (80 of which are wholly or partly in the Tropics) are provided in the World Malaria Report 2012. Globally, there were 219 million cases of malaria in 2010, with more than 211 million of these cases (96%) occurring in the Tropics. In the Tropics, Central & Southern Africa carries the highest malaria burden, with nearly 160 million cases at a rate of 23,181 cases per 100,000 people in 2010 (see Figure 6.2.13 and Figure 6.2.14). This region accounted for 75% of malaria cases in the Tropics and, combined, the six highest burden nations in the region (Nigeria, Democratic Republic of the Congo, Tanzania, Uganda, Mozambique and Cote d'Ivoire) accounted for 47% of global malaria cases in 2010.

Northern Africa & Middle East had the second highest number and rate of cases, with over 24 million cases at a rate of 15,431 per 100,000 population. Tropical India had the highest number of cases among the Asian nations in the Tropics. Despite relatively few cases of malaria in Oceania it has the third highest rate, at 10,802 cases per 100,000 population, driven by high rates in Papua New Guinea. Central America had both the lowest number and rate of malaria cases in the Tropics.

Malaria mortality

Globally 660,000 people are estimated to have died from malaria in 2010. Over 650,000 of the deaths were in the Tropics (99%), with 534,000 in Central & Southern Africa (see Figure 6.2.15). Central & Southern Africa also has the highest death rate from malaria, at 78 deaths per 100,000 population (see Figure 6.2.16). Combined, the Democratic Republic of the Congo and Nigeria, both of which are located in Central & Southern Africa, account for over 40% of global malaria deaths. Children under the age of five years are particularly vulnerable, accounting for 85% of deaths in 2010.

'We know there are still many things to do in the village and in other villages to get rid of this illness from the whole world.'

Pesseyi, 15 years old
Togolese national (2013)

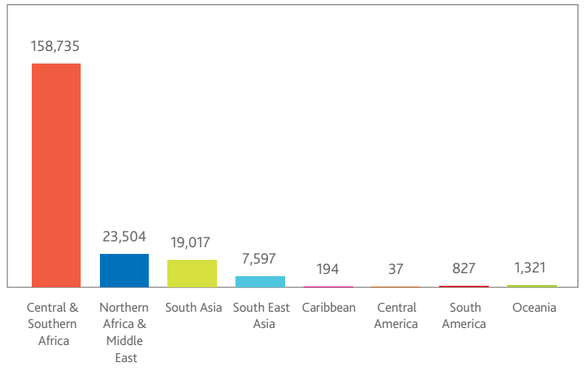
Northern Africa & Middle East had the second highest number and rate of deaths in the Tropics in 2010, with around 76,000 deaths and a mortality rate of 50 in 100,000. The third highest mortality rate was in Oceania with 26 deaths per 100,000 people, reflecting the high malaria burden in Papua New Guinea. Central America had both the lowest number and rate of deaths from malaria in the Tropics.

Malaria diagnosis and treatment

In addition to vector control (see Box 6.2.10), effective malaria control relies on early diagnosis and prompt treatment with effective medicines (WHO 2010a). The type of treatment depends on infection severity, drug susceptibility and the species of parasite that causes the infection. *P. falciparum* is the malaria parasite responsible for 85% of malaria cases worldwide and almost all malaria fatalities. *P. vivax*, the second major parasite species, is responsible for 70-90% of cases in Asia and South America. *P. vivax* is less life-threatening than *P. falciparum*, but has a wider geographic range as it is tolerant of lower ambient temperatures, is more transmissible and can reside undetected in the liver for years (CDC 2010b). With early detection and correct treatment malaria cure rates can exceed 90% (WHO 2010a).

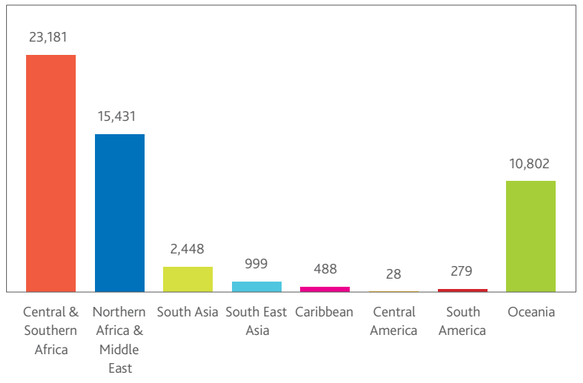
Diagnostic testing for malaria is essential to confirm suspected cases and to detect the parasite type. Common tests include malaria microscopy (which requires laboratory capacity) and rapid diagnostic testing (such as finger-stick blood testing, which does not require a laboratory). While the number of patients examined by microscopy remains very low in some regions, it is generally increasing. In addition, the distribution of rapid diagnostic tests increased 370-fold between 2005 and 2011, mostly in Africa (WHO 2012c). Increased availability of diagnostic tools has facilitated expansion of parasitological testing globally, from 68% of suspected cases in 2005 to 77% in 2011 and, in Africa, from 20% to 47% (WHO 2013k). However, the number of treatments distributed still outweighs the number of diagnostic tests performed, indicating that many patients still receive treatment without confirmatory diagnosis (WHO 2013k).

Figure 6.2.13 **Number of malaria cases – the Tropics, 2010 (thousands)**



Source: WHO (2012c), Cibulskis et al (2011), State of the Tropics project.

Figure 6.2.14 **Malaria prevalence – the Tropics, 2010 (cases per 100,000 population)**



Source: WHO (2012c), Cibulskis et al (2011), State of the Tropics project.

Box 6.2.9 Limited malaria data

Time series data on the global malaria burden are critical for effective planning and evaluation of malaria control efforts (Cibulskis et al. 2011). However, generating reliable estimates is a major challenge due to insufficient surveillance and incomplete reporting of data.

Surveillance systems that record malaria cases and deaths are present in all nations where malaria is endemic, but case detection rates vary considerably between nations. Globally it is estimated that only 10% of malaria cases were detected in 2010, with the rate even lower in high burden nations (WHO 2012c). Even where surveillance data are provided it is often not sufficiently reliable to assess trends. Diagnostic difficulties can also be a contributing factor, notably in nations where health system capacity is limited (Bremen 2001).

As a result, reliable assessments of malaria trends is not currently possible in 41 nations which, combined, account for around 85% of estimated cases (WHO 2012c). The subsequent need to generate estimates for these nations can lead to wide variations in global estimates from different organisations. For example, the World Malaria Report 2012 estimates 660,000 deaths from malaria in 2010, while different predictive models estimate between 929,000 and 1,685,000 deaths (Murray et al. 2012).

An urgent task for the international community is to assist high burden nations to improve diagnostic testing, surveillance and routine health information systems (WHO 2012c). Improved data collection will allow for more informed decision making in global malaria control.

Malaria testing training in Nigeria. Image: Rick Scarvetta, US Army.

Key populations at risk

Around 50% of the global population is at risk of malaria infection (Hay et al. 2004), with the vast majority living in the Tropics. Although a range of factors affect distribution and transmission risks (see Box 6.2.10), malaria is strongly correlated with poverty. More than any other significant public health disease, malaria disproportionately affects the poorest 20% of the global population (Barat et al. 2004). Poorer populations tend to have less access to preventive tools such as insecticide-treated nets or diagnostic and treatment services (Barat et al. 2004), putting them at greater risk of infection and death.

In high burden areas malaria poses a particular risk to people who have little or no immunity, particularly children, pregnant women, people living with HIV and international travelers from non-endemic areas). Children in high burden nations are particularly at risk as partial immunity to malaria develops over years of exposure to malaria parasites. In 2010 malaria was the single greatest cause of death among children aged between one and four years, causing around 21% of deaths (Lozano et al. 2012), and children under five accounted for 85% of malaria deaths globally (WHO 2013a).

Emerging malaria parasite resistance to treatment drugs is compounding malaria control challenges. Poor treatment practices, inadequate patient adherence to prescribed medications and continuing availability of non-recommended drugs are contributing factors. In response to the challenge of drug resistance the World Health Organisation launched the Test, Treat, Track initiative in 2012 to focus attention on evidence-based approaches to malaria control and the need for better surveillance systems. International funding for malaria control continues to increase, although at a slower rate than in the decade from 2000 to 2010 when malaria funding increased dramatically, from less than US$100 million to US$1.7 billion (WHO 2012c).

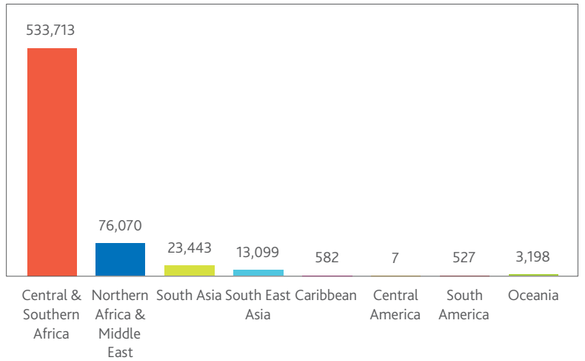
Malaria infection in pregnant women is associated with greater risk of severe illness and death than in non-pregnant women due to a reduced immune response and the tendency for malaria parasites to reside and replicate in the placenta (CDC 2011b). In addition to maternal mortality, the disease is associated with a high risk of miscarriage, premature delivery and low birth weights. Due to the higher risk of death from malaria among children and pregnant women, malaria control and elimination efforts are essential if Millennium Development Goals to reduce maternal and child mortality are to be met.

Looking Forward

The World Health Assembly target is to reduce the global malaria burden by 75% from 2000 levels by 2015, and the Millennium Development Goals aim to halt and begin to reverse the incidence of malaria by 2015. While the global malaria burden has been decreasing since 2000 (WHO 2012c, UN 2012a), estimates suggest that progress among nations is mixed. An accurate assessment of trends is hampered by a general lack of reliable surveillance data from the most affected nations.

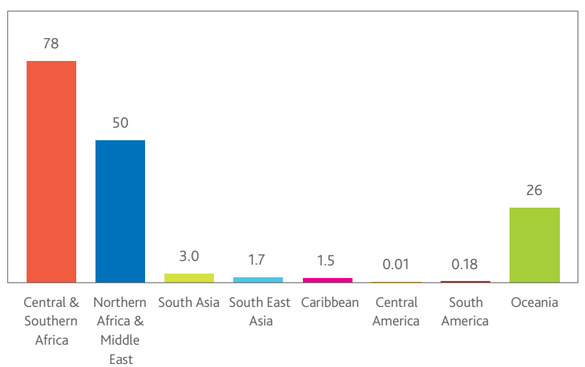
Global funding for malaria control has increased dramatically over the past 15 years. However, it is unlikely to be sufficient to reach reduction targets (WHO 2012c). Beyond current control efforts the more ambitious goal of malaria elimination and eradication will require as yet undeveloped tools such as vaccines and new generation drugs. In addition, as previous malaria control and elimination efforts have demonstrated, progress can only be sustained if nations are able to build health system capacity and improve socioeconomic conditions (WHO 2011b).

Figure 6.2.15 **Deaths from malaria - the Tropics 2010**



Source: WHO (2012c), Cibulskis et al (2011), State of the Tropics project.

Figure 6.2.16 **Malaria mortality rate - the Tropics 2010 (deaths per 100,000 population)**



Source: WHO (2012c), Cibulskis et al (2011), State of the Tropics project.

Box 6.2.10 Vector distribution and control

Malaria is transmitted to people through mosquito bites, with around 50 species of *Anopheles* mosquito recognised as the main malaria 'vectors' (Hay et al. 2010). These mosquitoes are found in every nation except Antarctica (CDC 2012b), although a number of other critical factors affect malaria distribution and transmission risks. Urbanisation, rainfall, temperature, changes in land use and housing type all influence mosquito abundance, species composition and mosquito biting rates (Cibulskis et al. 2011).

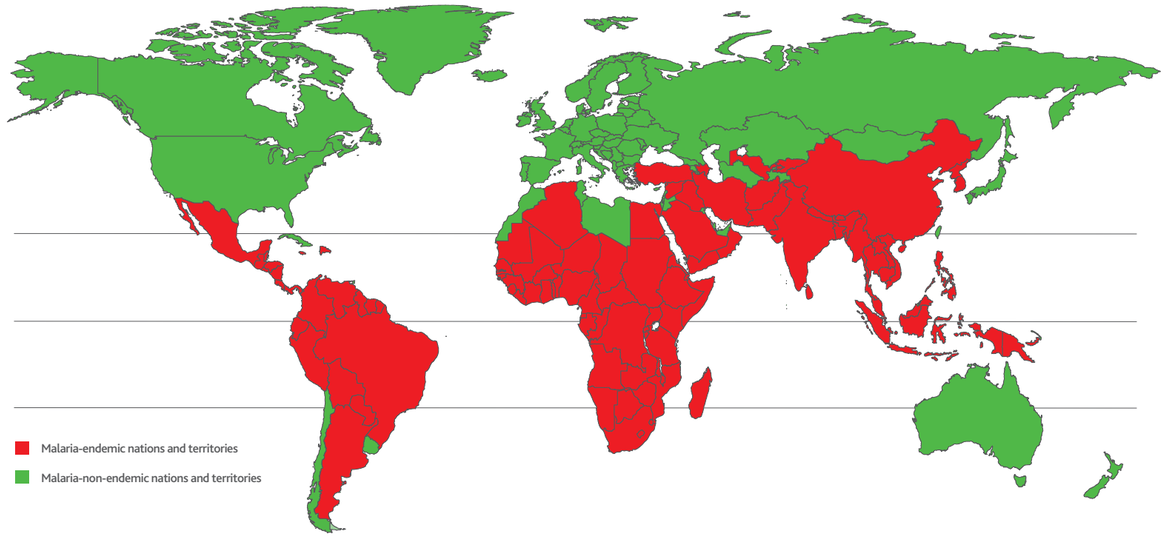
Vector control is the main way to prevent malaria transmission at the population level, and to date has contributed significantly to malaria control successes (WHO 2013o). Significant reductions in the global distribution of malaria through the 20th century were largely attributable to the control of mosquito breeding sites from 1900 and the large-scale use of insecticides from the 1940s (Hay et al. 2004). Modern vector control mechanisms include the use of insecticide-treated mosquito nets (ITNs), indoor residual spraying (IRS) and larval control.

Among malaria-endemic nations access to ITNs is increasing. In sub-Saharan Africa for example, the percentage of children sleeping under ITNs is estimated to have increased from 2% in 2000 to 39% in 2010 (UN 2012a). In addition, the proportion of at-risk populations protected by IRS has increased from less than 5% in 2005 to 11% in 2010. However, global funding for malaria control has plateaued since 2010, affecting ITN distribution and other initiatives (WHO 2012c). A growing challenge to control efforts is mosquito resistance to the insecticides used in ITNs and IRS, which has been detected in 64 nations.

Climate change is affecting temperature, rainfall, humidity and land use patterns, and is predicted to have an effect on vector distribution and malaria control before 2050 (Ermert et al. 2012). While in some areas malaria distribution is predicted to contract over the coming decades, in others (such as highland and sub-tropical areas) it is likely to expand. Climate change will also affect malaria transmission by influencing mosquito longevity and the development of malaria parasites in the mosquito (Fernando et al. 2010). Even without the effects of climate change, the continuing presence of *Anopheles* mosquitoes in nations where malaria has been eliminated (such as in western Europe and the United States) means that reintroduction of the disease is a constant risk (CDC 2010b).

Mosquito nets for malaria control. Image: Bill and Melinda Gates Foundation.

Figure 6.2.17 **Malaria endemic nations and territories**



Malaria-endemic nations and territories are: Democratic Republic of the Congo, Cameroon, Chad, Congo, Central African Republic, Gabon, Equatorial Guinea, Sao Tome and Principe, Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Mayotte, Rwanda, Somalia, Sudan, Tanzania, Uganda, Angola, Botswana, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe, Nigeria, Niger, Burkina Faso, Ghana, Mali, Côte d'Ivoire, Guinea, Senegal, Benin, Sierra Leone, Togo, Liberia, Guinea-Bissau, Mauritania, Gambia, Cape Verde, Algeria, Egypt, Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Mexico, Haiti, Dominican Republic, Jamaica, Argentina, Paraguay, Bangladesh, Bhutan, India, Nepal, Sri Lanka, China, Democratic People's Republic of Korea, South Korea, Cambodia, Timor-Leste, Indonesia, Lao People's Democratic Republic, Malaysia, Burma/Myanmar, Philippines, Thailand, Vietnam, Papua New Guinea, Solomon Islands, Vanuatu, Afghanistan, Iran, Kyrgyzstan, Pakistan, Uzbekistan, Azerbaijan, Iraq, Oman, Saudi Arabia, Syrian Arab Republic, Yemen, Turkey.

Dengue and other neglected tropical diseases

Neglected tropical diseases[11] (NTDs) are a group of 17 infectious diseases[11] that affect at least 1 billion people worldwide, primarily the poorest communities in the Tropics and subtropics, and kill more than 500,000 people annually (Hotez et al. 2006). NTDs mostly cause chronic conditions that can lead to long term disabilities or disfigurement, and significantly affect people's productive and social lives which can act to entrench poverty. NTDs have historically received less policy attention and funding than diseases such as HIV and malaria because they generally pose little threat to the populations of developed nations, and are largely concentrated in rural areas (WHO 2012d).

Dengue is a mosquito-borne viral NTD that is most prevalent in tropical and subtropical regions. Its global distribution and public health burden is highly uncertain, but it is estimated that around half of the world's population is at risk of the disease (Brady et al. 2012), and there are no vaccines or drugs to treat it. The incidence of dengue is estimated to have increased 30-fold over the past five decades due to factors such as rapid urbanisation, global travel, environmental change (WHO 2007) and ineffective vector control (Guzman et al. 2010). Dengue is now the most rapidly-spreading mosquito-borne viral disease in the world, and is a major global public health threat (WHO 2012d, WHO 2012n).

A small percentage of people with dengue develop dengue haemorrhagic fever (DHF), which has an average case fatality rate of 5% (Gubler 2004) and is responsible for around 22,000 deaths per year (WHO 2012g). Appropriate disease management with well-trained health personnel and good facilities can reduce DHF mortality to below 1%, compared with case fatality rates as high as 40% in populations that lack access to appropriate health care (Gubler 2004). Although dengue is responsible for fewer deaths than malaria (another mosquito-borne disease), it is a significant cause of disability that places considerable strain on health services and causes substantial economic losses.

Trends

World Health Organisation (WHO) regional offices and the global dengue surveillance system DengueNet publish reported cases of dengue by nation and year, but systemic underreporting mean they significantly understate the true disease burden (Bhatt et al. 2013). Factors contributing to underreporting include low levels of health care access, misdiagnosis and incomplete recording of data in national systems. Studies of hospital case numbers and dengue incidence in the general community suggest that only around 30% of people estimated to have 'apparent'[12] dengue present to formal healthcare facilities (Bhatt et al. 2013). Also, as there are no uniform criteria for reporting dengue cases to WHO, some nations report only severe dengue cases, others report all cases and still others report only cases that have been confirmed in a laboratory (Suaya et al. 2006).

The burden of dengue across Africa is largely unknown due to insufficient data from endemic nations. Low awareness by health care providers, low levels of diagnostic testing and limited surveillance capacity are contributing factors. In parts of Africa where there is recognised over-diagnosis of malaria, dengue may be misdiagnosed as malaria as the cause for febrile illness (Amarasinghe et al. 2011). Nonetheless, there is some evidence that dengue outbreaks in Africa are increasing in size and frequency (WHO 2012g).

Data limitations hinder international comparisons and the assessment of trends over time, which in turn affects resourcing and program development for dengue control. WHO's Global strategy for dengue prevention and control aims to estimate the true burden of dengue by 2015.

Dengue burden

While only 2.4 million dengue infections were reported in 2010 (WHO 2013e), WHO estimates that there are 50-100 million infections worldwide each year across more than 100 endemic nations (WHO 2012g). Recent research suggests that the global burden of dengue is significantly higher than WHO estimates, with around 390 million infections per year (Bhatt et al. 2013). Of these, 96 million are apparent infections, with the remainder being 'inapparent' infections that are mild or asymptomatic. These inapparent infections have no immediate implications for clinical management but are of public health significance as a reservoir for future infection.

In the period between 2008 and 2011, most of the apparent dengue infections, 72% (or 70 million infections per annum), occurred in the Tropics, with the majority of infections in the Rest of the World occurring in nations that border or straddle the Tropics.

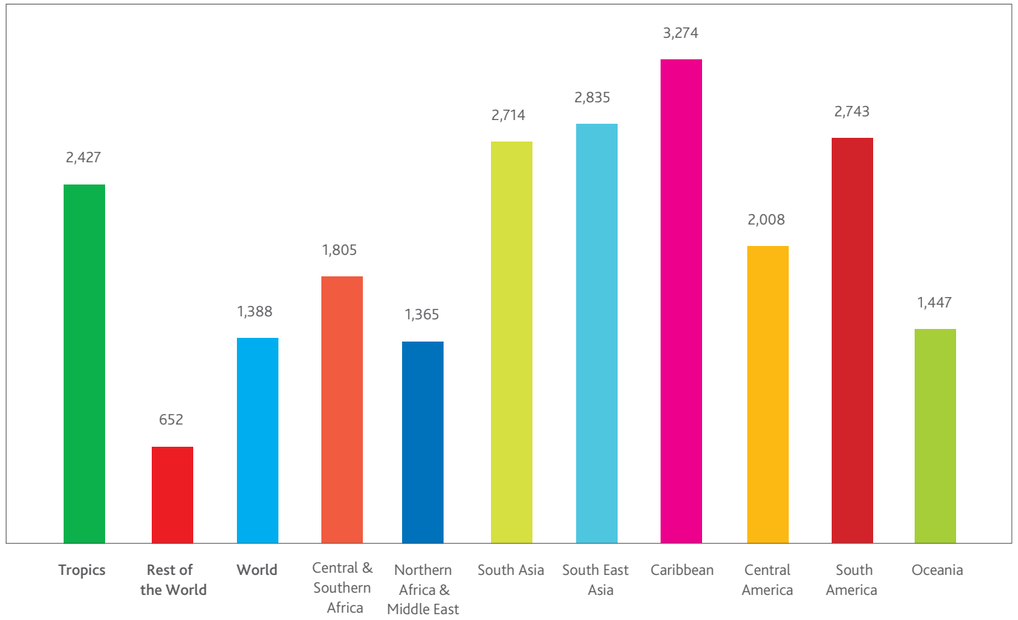
In the Tropics, the Caribbean has the highest rate of dengue infections at 3,274 cases per 100,000 population (see Figure 6.2.18). South East Asia and South Asia carry the greatest number of infections with around 20 million infections per year which, combined, account for 61% of infections in the Tropics. With around 19 million infections each year, tropical India alone accounts for 27% of dengue infections in the Tropics. Other nations with more than 1 million infections each year are Indonesia, Brazil (see Box 6.2.11), Nigeria, China, Philippines, Vietnam, Thailand, Mexico, Bangladesh and Colombia.

More than 12 million apparent infections occur each year in Central & Southern Africa, indicating a substantial burden in a region where dengue is largely hidden (that is, there are no reported cases). Oceania carries the lowest number with around 170,000 infections per year, or 0.3% of infections in the Tropics. The number of cases reported to WHO represents a very small fraction of estimated apparent infections in the Tropics – ranging from 0% in the African regions to 11% in South America (see Figure 6.2.19).

[11] The 17 NTDs are: dengue, rabies, trachoma, Buruli ulcer, endemic treponematoses (yaws), leprosy (Hansen disease), Chagas disease, human African trypanomiasis (sleeping sickness), leishmaniasis, cysticercosis, dracunculiasis (guinea-worm disease), echinococcosis, foodborne trematode infections, lymphatic filariasis, onchocerciasis (river blindness), schistosomiasis and soil-transmitted helminthiases.

[12] Dengue infections that result in visible symptoms sufficient to disrupt a person's daily routine (Bhatt et al, 2013).

Figure 6.2.18 **Apparent dengue infections, 2008-11 (infections per 100,000 population)**



Source: Bhatt et al (2012), State of the Tropics project.

The incidence of apparent dengue infections per 100,000 population is 2,427 in the Tropics and 652 in the Rest of the World. In the Tropics, after the Caribbean, the highest incidence is in South East Asia with 2,835 cases per 100,000, South America with 2,743 and South Asia with 2,714. Northern Africa & Middle East has the lowest incidence at around 1,365 infections per 100,000.

Data on dengue mortality are limited, but is estimated to be increasing as people are being exposed to different virus types more often, which increases the risk of developing DHF (Mangold & Reynolds 2013, WHO 2013h). In some Asian and Latin American nations severe dengue is already a leading cause of serious illness and death among children.

Vector distribution and control

While effective diagnostics have recently been developed, there is currently no vaccine or drugs to treat dengue. As such, transmission of the disease can only be prevented by reducing human-vector contact. Substantial vector control efforts over time have not stemmed the spread of dengue, but continuing efforts in this area are important as many health systems are not adequately resourced or prepared for dengue outbreaks, especially in developing nations. A single person with dengue entering an area populated by both a dengue vector and human hosts can lead to a dengue outbreak, further underscoring the significance of vector control.

The primary vector of dengue is the *Aedes aegypti* mosquito, which is found in tropical climates in urban habitats, and breeds mostly in man-made containers. Because the mosquito is highly adapted to the domestic environment its abundance is correlated with increasing urbanisation. Dengue is also spread by *Aedes albopictus*, which is found in both tropical and temperate regions. Once unique to Asia, the geographic range of *Aedes albopictus* – and dengue – has expanded globally as a result of international trade (Higa 2011). The increased range of dengue vectors has also expanded the geographic range of all four types of dengue virus (serotypes), so that epidemics caused by multiple serotypes are more frequent. This has significant public health relevance as prior infection with one virus type increases the risk of developing severe dengue in subsequent infection with a different virus type (Chen & Vasilakis 2011).

The emergence of insecticide resistance is a major challenge for the control of dengue vectors, and climate change is likely to increase the endemic range of dengue as global temperatures increase (Racloz et al. 2012). Higher temperatures also enhance reproduction of the vector mosquitos, shorten the incubation period of dengue viruses and make transmission to humans more likely. To address the many vector control challenges greater effort is now being taken to integrate programs across dengue and other mosquito-borne NTDs such as Chagas disease and lymphatic filariasis.

Box 6.2.11 Dengue in Brazil

Dengue is a major public health problem in Brazil, where outbreaks have caused significant illness, death and economic burden. Brazil is now cited as an example of the worsening global situation (WHO 2012g). Along with India, Indonesia and Nigeria, Brazil is one of the most highly endemic nations in the world, with more than five million apparent infections each year (Bhatt et al. 2013).

Between January and April 2008 an outbreak of dengue in the state of Rio de Janeiro alone saw more than 158,000 reported cases, over 9,000 hospital admissions and 230 deaths, with the military mobilised to assist with the vector control and health care response. Although around US$1 billion was being spent annually in the nation on dengue prevention and control, another outbreak in 2010 resulted in more than 1.2 million reported cases across the nation, and further outbreaks have been reported in 2011 and 2013 (WHO 2012g).

The extent of these dengue outbreaks is particularly significant given the Americas was virtually free of dengue from the 1950s to the 1970s, following the purported eradication of *Aedes aegypti* in a continent-wide vector control campaign (Shepard et al 2011). Uncontrolled urbanisation and waste management in major cities in Latin America from the 1970s have contributed to the return of the vector, and the resurgence of dengue across the region.

As well as the direct impacts on human health dengue also has an economic impact in terms of health system costs and lost productivity. Excluding surveillance and vector control activities, the average cost of dengue illness in the Americas between 2000 and 2007 was estimated at US$2.1 billion per annum, with Brazil accounting for 42% (Shepard et al. 2011). Brazil commits around US$500 million each year to vector control, but efforts to stem the spread of *Aedes aegypti* continue to be unsuccessful.

Dengue control education in Brazil. Image: Fotos GOVBA.

Global burden of neglected tropical diseases

Neglected tropical diseases are caused by a variety of viruses, bacteria and parasites, and represent a diverse set of diseases and pathologies, but each shares a much higher prevalence and persistence among impoverished communities (WHO 2013e). NTDs are among some of the most common infections in the 2.5 billion people who live on less than $2 a day, although the true burden of these diseases is uncertain. While NTDs are commonly estimated to affect over 1 billion people (WHO 2012m), other estimates suggest that soil-transmitted helminth infections alone affect around 2 billion people (WHO 2013w). There is growing international recognition that a large

Box 6.2.12 Eradication, elimination and control of neglected tropical diseases

Until recently NTDs have received limited global attention or funding relative to their global burden. For example, between 2003 and 2007 only 0.6% of overseas development assistance for health was dedicated to NTDs (Liese & Schubert 2009), and NTDs are not directly mentioned in the United Nations Millennium Development Goals.

The release by WHO in 2010 of its first global report on NTDs was a turning point in raising global awareness and funding for the prevention and control of NTDs. Reducing the burden of NTDs is now on the post-2015 global development agenda (UN 2013b), and a number of targets have been set for the eradication (permanent reduction of disease incidence to zero), elimination (interruption of disease transmission), and control (reduction of disease incidence and impact) of NTDs (WHO 2013e).

As there is significant diversity among the 17 NTDs in terms of their distribution, transmission, vector involvement and pathology a 'one size fits all' set of interventions is not feasible. Strategies have been developed to reflect disease characteristics and local conditions, and include vector control, preventive medication, intensified disease management and collaboration between human and veterinary public health services. Increased attention and funding has already expanded access to low-cost packages of essential medicines (referred to as 'preventive chemotherapy') for millions of people at risk of some of the most prevalent NTDs. At less than US$0.50 per person annually, this intervention is recognised as one the world's most cost-effective public health strategies (Hotez 2013).

Poverty and environmental exposure to pathogens are primary risk factors for NTDs, and progress towards the eradication of these diseases will only be achieved if the key social determinants of health are addressed, such as access to safe water, waste disposal and treatment, basic sanitation and improved living conditions (WHO 2012n). Improving health systems in endemic areas is also essential. The eradication of NTDs is therefore closely linked with other development goals, and reducing their burden will benefit broader socioeconomic development in many impoverished communities.

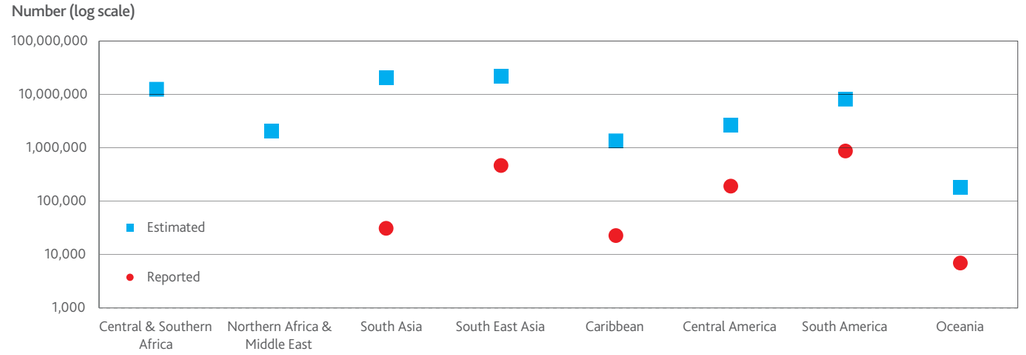
Administering albendozole, Sri Lanka. Image: GSK.

proportion of the world's population suffers the devastating health and socioeconomic impacts of NTDs, and this is leading to a greater commitment to research as well as the development of global eradication, elimination and control targets and programs (see Box 6.2.12).

The most common NTDs are the three main soil-transmitted helminth (STH) infections (hookworm, ascariasis, and trichuriasis), dengue, schistosomiasis and lymphatic filariasis. Co-infection with multiple NTDs is also common. STH infections are contracted through contact with worm eggs in contaminated soil and, although fatal in only the most serious cases, they threaten the nutritional status of around 2 billion people worldwide, many of whom are already undernourished (WHO 2013w). STH infections can have long term health, social and economic impacts by retarding the growth and development of children, compromising maternal and infant health and reducing the productivity of workers (Hotez 2009). Schistosomiasis is contracted through contact with larval forms of trematode worms released by freshwater snails and is responsible for around 280,000 deaths each year in Africa (CDC 2011a), where it is the most significant water-based disease from a public health perspective (Steinmann et al. 2006). Lymphatic filariasis, a mosquito-borne parasitic infection, is responsible for millions of people suffering from elephantiasis and urogenital swelling, which significantly impacts the quality of life of sufferers through disability and social and economic marginalisation (Litt et al. 2012). An overview of the 17 NTDs and their general epidemiological trends is provided in Table 6.2.9.

In 2010 it is estimated that NTDs were responsible for over 26 million Disability Adjusted Life Years (DALYs)[13], or around 5% of all DALYs caused by communicable diseases worldwide, up from 4% in 1990 (Murray et al. 2012). The global distribution of this burden varies considerably, and is greatest in sub-Saharan Africa.

Figure 6.2.19 **Apparent and reported dengue cases 2008-2011 – the Tropics (annual average)**



Source: Bhatt et al. (2012), WHO (2013m), State of the Tropics project.

Looking forward

NTDs are closely linked with a number of social determinants of health, particularly poverty, which is considered to be the 'root cause' as well as consequence of many of these diseases (Aagaard-Hansen et al. 2010). Reflecting this, the elimination, eradication and control of NTDs has been described as 'the ultimate expression of fairness' (WHO 2013e). In the past decade there has been a significant increase in commitment from major pharmaceutical companies, governments and non-government organisations to reduce the burden of these diseases among the world's poorest populations.

A key dengue control target is, by 2020, to reduce mortality and morbidity by at least 50% and 25% respectively from 2010 levels (WHO 2012g). However, the global dengue burden is increasing and major challenges include limiting the public health risk posed by the expanding dengue vector range and demographic changes favourable to dengue transmission. Limited surveillance data to assess progress also presents a challenge. New tools are urgently needed for dengue diagnosis and vector control, and further research is required to develop medicines and vaccines (WHO 2012n). Experience suggests that vector control is feasible and, despite the challenges, novel vector management strategies (Hoffmann et al 2011) are being developed, suggesting that real reductions in dengue transmission are possible in the near future.

[13] A disability adjusted life year (DALY) is a composite measure of disease burden which is calculated as the sum of years of life lost due to premature death, and the years of life lived with chronic ill-health or disability, taking into account the severity of ill-health. While a useful metric to quantify disability from diseases, the number of DALYs caused by NTDs may not fully reflect their chronic health impact, the effects of poverty on the disease experience and the role of NTDs in increasing the incidence of malaria, tuberculosis and HIV (King & Bertino 2008).

Table 6.2.9 **Neglected tropical diseases**

NTD	Disease type, health impact	Geographic distribution	Prevalence, mortality	Key trends	Treatment
Dengue	Mosquito-borne viral disease. Mild to severe flu-like symptoms. DHF case fatality rate 5%.	Primarily in tropical & sub-tropical regions.	Up to 390 million infections annually, with 22,000 deaths.	Incidence & distribution increasing worldwide.	No vaccine or specific medication for treatment.
Rabies	Zoonotic viral infection of the central nervous system. Initially flu-like, progressing to acute brain inflammation. Fatal without treatment.	Present on all continents except Antarctica. Most prevalent in Asia & Africa.	More than 15 million cases annually, with around 55,000 deaths.	Number of deaths decreasing over past decade.	Vaccine-preventable. No treatment once symptoms present.
Trachoma	Bacterial infection of the eye. Similar to conjunctivitis. Leading cause of blindness worldwide.	Endemic in 53 nations across Africa, Asia, Central America, South America & Middle East, and also in Australia.	More than 40 million infected, over 8 million at risk of irreversible blindness.	Significant reduction in prevalence over past two decades.	No vaccine. Curable with antibiotics.
Buruli ulcer	Bacterial infection. Ulceration, usually on legs and arms. Can cause deformity and disability. Exact mode of transmission unknown.	Found in 33 nations mainly in the Tropics & subtropics.	Between 5,000-6,000 cases reported from 15 of 33 nations yearly.	Less than 1 million cases globally, but trend increasing in some nations.	No vaccine. Curable with antibiotics, surgery may be required.
Endemic treponematoses (including yaws)	Bacterial infections comprising yaws, endemic syphilis & pinta. Skin lesions. Can cause deformity and disability.	Global extent not accurately known. Most cases are in the Tropics & subtropics.	Around 460,000 infectious cases of yaws in 1995.	Yaws eliminated in many nations including India.	No vaccine. Curable with antibiotics.
Leprosy (Hansen disease)	Bacterial infection. Skin lesions. Can cause progressive & permanent damage to skin, nerves, limbs and eyes.	Endemic in areas of Brazil, Indonesia, Philippines, Nepal, Congo, India, Madagascar, Mozambique & Tanzania.	Approximately 219,000 new cases in 2011.	Significant reduction from 5.2 million cases in 1985 to less than 1 million.	No vaccine. Curable with multi-drug therapy.
Chagas disease	Protozoal parasitic disease. Initially flu-like, progressing to cardiac, digestive and/or neurological alterations. Potentially fatal.	Endemic in 21 Latin American nations, but range is spreading.	Around 7-8 million infected in 2006-10.	Increasingly detected in some developed and Western Pacific nations.	No vaccine. Treatment more effective in acute than in chronic phase.
Human African trypanomiasis (sleeping sickness)	Protozoal parasitic disease transmitted by tsetse flies. Initially flu-like, progressing to neurological symptoms. Fatal without treatment.	Endemic in over 30 African nations.	Around 20,000 cases per year.	Burden decreasing since 2000.	No vaccine. Curable with treatment but less effective at later stage.
Leishmaniasis	Protozoal parasitic disease transmitted by phlebotomine sandflies. Skin lesions in cutaneous disease. Fever & enlarged spleen or liver in visceral disease. High fatality rate in visceral cases.	Prevalent in around 100 nations across every continent except Australia & Antarctica. Predominantly in Tropics, subtropics & southern Europe.	12 million infected, with around 50,000 deaths.	Distribution and number of cases have increased since 1993.	No vaccine. Curable with drug treatment.
Cysticercosis	Parasitic infection caused by larval cysts of pork tapeworm. Muscle swelling, cysts, vision changes. Seizures in neurocysticercosis. Leading preventable cause of epilepsy. Can be fatal.	Endemic in parts of Latin America, South Asia, South East Asia & sub-Saharan Africa.	Around 50-100 million infections worldwide. Neurocysticercosis in around 30% of people with epilepsy in endemic nations.	Frequency declining in developed nations. Prevalent in areas where pig tapeworm is common.	No vaccine. Treatment with anti-parasitic drugs and/or surgery.
Drancunculiasis (guinea-worm disease)	Parasitic infection with long thread-like worm. Pain in subcutaneous tissue progressing to ulcer, nausea, fever, vomiting. Can result in reduced mobility.	Reduction from 20 endemic nations across Africa, Middle East & South Asia in 1980s, to four in Africa in 2012.	Only 1,058 reported cases in 2011.	Approaching global eradication.	No treatment drugs available.
Echinococcosis	Zoonotic parasitic infection with tiny tapeworms. Symptoms depend on location of cysts in body (liver, lungs, brain, or other organs). Can be fatal.	Present worldwide. Highly endemic in parts of Mediterranean, Africa, eastern Europe, South America & central Asia.	More than 1 million infected worldwide.	Distribution increasing. Re-emerging as a public health problem.	No vaccine. Curable with treatment drugs and/or surgery.
Foodborne trematode infections	Parasitic infection with flatworms. Symptoms can be mild to severe depending on number of worms and location in body. Some parasites carcinogenic.	Cases reported in more than 70 nations. Most cases are in Asia & Latin America.	More than 56 million reported infections and 7,000 deaths in 17 nations in 2005.	Magnitude of public health problem largely unknown.	Preventive chemotherapy in endemic communities. Curable with treatment drugs.
Lymphatic filariasis	Mosquito-borne parasitic infection with filarial worms. Elephantiasis, skin rashes, abdominal pain. Can cause disfigurement & loss of mobility.	Endemic in 72 nations. Most common in Tropics & subtropics.	Approximately 115 million cases.	Progress being made to eliminate as a public health problem.	Curable with treatment drugs. Chronic cases may require surgery.
Onchocerciasis (river blindness)	Parasitic infection with filarial worm transmitted by blackflies. Skin disease and visual impairment/blindness.	Most prevalent in sub-Saharan Africa, but also present in some Latin American nations.	More than 25 million infected.	Burden has decreased significantly since 1970s.	Preventive chemotherapy in endemic communities. Treatment available.
Schistosomiasis (bilharzia, or snail fever)	Parasitic infection with trematode flatworms. Inflammatory immune responses can result in significant disability.	Prevalent in Tropics & subtropics. 90% of people requiring treatment live in sub-Saharan Africa.	At least 243 million people required treatment in 2011. Responsible for 280,000 deaths annually in Africa.	Control successful in several nations, but spreading into previously low or non-endemic areas.	Preventive chemotherapy in endemic communities. Curable with treatment.
Soil-transmitted heminthiases	Parasitic infections with intestinal roundworms. Heavy infections can lead to physical or cognitive growth retardation.	Widely distributed in Tropics & subtropics. Greatest numbers in sub-Saharan Africa, the Americas & Asia.	Up to 2 billion infected worldwide.	Number of school-age children receiving treatment in endemic areas increasing.	Preventive chemotherapy in endemic communities. Curable with treatment.

Source: Beaumier et al. 2013, Bhatt et al. 2013, CDC 2010a, CDC 2011a, CDC 2013, Hu et al. 2010, WHO 2012g, WHO 2012m, WHO 2012n, WHO 2012o, WHO 2012p, WHO 2013e, WHO 2013r, WHO 2013s, WHO 2013t, WHO 2013u, WHO 2013v WHO 2013w.

References

Aagaard-Hansen J, Chaignat CL. (2010). Neglected tropical diseases: equity and social determinants, in Blas E, Kurup AS (Eds), ***Equity, Social Determinants and Public Health Programmes***. World Health Organisation, Geneva.

Ahmed S, Qingfeng L, Liu L and Tsui AO. (2012). Maternal deaths averted by contraceptive use: An analysis of 172 countries, in ***Lancet* 380**(9837).

Amarasinghe A, Kuritsky JN, Letson GW, Margolis HS. (2011). Dengue virus infection in Africa, in ***Emerging Infectious Diseases* 17**(8).

Amini J, Poka H, Kumbu J, Pomat N, Ripa P, Tefuarani N, Vince J, Duke T. (2012). The crisis of tuberculosis in PNG: The role of older strategies for public health disease control, in ***PNG Medical Journal.*** March-June 55 (in press).

Amouzou A, Habi O, and Bensaid K. (2012). Reduction in child mortality in Niger: A countdown to 2014 country case study, in ***Lancet* 380**(9848).

Andersen AB, Thilsted SH, Schwarz AM. (2013). ***Food and Nutrition Security in Solomon Islands.*** Working Paper: AAS-2013-06. CGIAR Research Program on Aquatic Agricultural Systems, Penang.

Asamoah BO, Moussa KM, Stafstrom M and Musinguzi G. (2011). Distribution of causes of maternal mortality among different socio-demographic groups in Ghana; a descriptive study, in ***BMC Public Health* 11**(159).

Atun R. (2011). Building a Durable Response to HIV/AIDS: Implications for Health Systems, in Journal of ***Acquired Immune Deficiency Syndromes* 57**(Suppl 2).

Baker MA, Harries AD, Jeon CY, Hart JE, Kapur A, Lonnroth K, Ottmani AE, Goonesekara SD, Murray MB. (2011). The impact of diabetes on tuberculosis treatment outcomes: A systematic review, in ***BMC Medicine* 9**(81).

Barat LM, Palmer N, Basu S, Worral E, Hanson K, Mills A. (2004). Do malaria control interventions reach the poor? A view through the equity lens, in ***American Journal of Tropical Medicine and Hygiene* 71**(Suppl 2).

Barker DJ. (2012). Developmental origins of chronic disease: Sir Richard Doll Lecture, in ***Public Health* 126**(3).

Beaumier CM, Gillespie PM, Hotez PJ, Bottazzi ME. (2013). New vaccines for neglected parasitic diseases and dengue, in ***Translational Research***, (in press).

Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, Drake JM, Brownstein JS, Hoen AG, Sankoh O, et al. (2013). The global distribution and burden of dengue, in ***Nature* 496**(7746).

Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, Bryce J, Bustreo F, Cavagnero E, Cometto G, Daelmans B. (2010). Countdown to 2015 decade report (2000-10): Taking stock of maternal, newborn, and child survival, in ***Lancet* 375**(9730)

Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG, Jha P, Campbell H, Fischer Walker 8C, Cibulskis R, Eisele T, Mathers C. (2010). Global, regional and national causes of child mortality in 2008: A systematic analysis, in ***Lancet* 375**(9730).

Bloom DE, Cafiero ET, Jané-Llopis E, Abrahams-Gessel S, Bloom LR, Fathima S, Feigl AB, Gaziano, T., Mowafi M, Pandya A, et al. (2011). ***The Global Economic Burden of Non-Communicable Diseases.*** World Economic Forum, Geneva.

Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, Moyes CL, Farlow AW, Scott TW, Hay SI. (2012). Refining the global spatial limits of dengue virus transmission by evidence-based consensus, in ***PLoS Neglected Tropical Diseases* 6**(8).

Bremen JG. (2001). Ears of the hippopotamus: Manifestations, determinants and estimates of the malaria burden, in Bremen JG, Egan A and Keusch GT. (Eds), The Intolerable Burden of Malaria: A new look at the numbers, in ***American Journal of Tropical Medicine and Hygiene* 64**(1).

Broekmans J, Paluzzi JE. (2004). Interim Report of Task Force 5 Working Group on Tuberculosis. Millennium Project http://www.unmillenniumproject.org/documents/tf5tbinterim.pdf (accessed 13 March 2013).

Caballero B. (2007). The global epidemic of obesity: An overview, in ***John Hopkins Bloomberg School of Public Health* 29**(1).

CDC (2010a). Parasites – Cysticercosis, Epidemiology and Risk Factors. Centres for Disease Control and Prevention http://www.cdc.gov/parasites/cysticercosis/epi.html (accessed on 24 May 2013).

CDC (2010b). Where Malaria Occurs. Centres for Disease Control and Prevention http://www.cdc.gov/malaria/about/distribution.html (accessed on 22 March 2013).

CDC (2011a). The Burden of Schistosomiasis (schisto, bilharzia, snail fever). Centres for Disease Control and Prevention http://www.cdc.gov/globalhealth/ntd/diseases/schisto_burden.html (accessed on 24 May 2013).

CDC (2011b). Treatment of Malaria: Guidelines for Clinicians. Centres for Disease Control and Prevention http://www.cdc.gov/malaria/resources/pdf/clinicalguidance.pdf (accessed on 25 March 2013).

CDC (2012a). The History of Malaria, An Ancient Disease. Centres for Disease Control and Prevention http://www.cdc.gov/malaria/about/history/ (accessed on 19 March 2012).

CDC (2012b). Anopheles mosquitos. Centres for Disease Control and Prevention http://www.cdc.gov/malaria/about/biology/mosquitoes/ (accessed on 18 March 2013).

CDC (2013). Neglected Tropical Diseases: The Burden of Onchocerciasis (River Blindness). Centres for Disease Control and Prevention http://www.cdc.gov/globalhealth/ntd/diseases/oncho_burden.html (accessed on 23 May 2013).

Chaisson RE, Martinson NA. (2008). Tuberculosis in Africa – Combating an HIV-driven Crisis, in ***New England Journal of Medicine* 358**(11).

Chen R, Vasilakis N. (2011). Dengue: Quo tu et quo vadis?, in ***Viruses* 3**(9).

Cibulskis RE, Aregawi M, Williams R, Otten M, Dye C. (2011). Worldwide incidence of malaria in 2009: Estimates, time trends, and a critique of methods, in ***PLoS Medicine* 8**(12).

Curtis M. (2004). The obesity epidemic in the Pacific Islands, in ***Journal of Development and Social Transformation* 1**.

Daniel TM. (2006). The History of Tuberculosis: Historical Review, in ***Respiratory Medicine* 100**.

Dixon S, McDonald S, Roberts J. (2002). The impact of HIV and AIDS on Africa's economic development, in ***British Medical Journal* 324**.

Drake AJ, Reynolds RM. (2010). Impact of maternal obesity on offspring obesity and cardiometabolic disease, in ***Reproduction* 140**(3).

Dye C, Lonnroth K, Jaramillo E, Williams BG, Raviglione M. (2009). Trends in tuberculosis incidence and their determinants in 134 countries, in ***Bulletin of the World Health Organisation* 87**(9).

Ermert V, Finkl AH, Morse AP, Paeth H. (2012). The impact of regional climate change on malaria risk due to greenhouse forcing and land-use changes in tropical Africa, in ***Environmental Health Perspectives* 120**(1).

FAO (2003). HIV/AIDS: A Rural Issue. United Nations Food and Agriculture Organisation http://www.fao.org/FOCUS/E/aids/aids1-e.htm (accessed 21 January 2013).

Fernando SD, Wickremasinghe R, Wickremasinghe AR. (2010). Climate change and malaria: A complex relationship, in ***UN Chronicle* 47**(2).

Gortmaker SL. Swinburn BA, Levy D, Carter R, Mabry PL, Finegood DT, Hunag T, Marsh T, Moodie ML. (2011). Changing the future of obesity: Science, policy and action, in ***Lancet* 378**(9793).

Government of Papua New Guinea (2010). ***National Health Plan 2011-2020***. Volume 1, Policies and Strategies.

Gubler DJ. (2004). The changing epidemiology of yellow fever and dengue, 1900 to 2003: full circle? in ***Comparative Immunology, Microbiology and Infectious Diseases* 27**(5).

Guzman MG, Halstead SB, Artsob H, Buchy P, Farrar J, Gubler DJ, Hunsperger E, Kroeger A, Magolis HS, Martinez E, et al. (2010). Dengue: A continuing global threat, in ***Nature Reviews: Microbiology* 8**(12 Suppl).

Hay SI, Guerra CA, Tatem AJ, Noor AM, Snow RW. (2004). The global distribution and population at risk of malaria: past, present, and future, in ***Lancet Infectious Diseases* 4**(6).

Hay SI, Sinka ME, Okara RM, Kabaria CW, Mbithi PM, Tago CC, Benz D, Gething PW, Howes RE, Patil AP, et al. (2010). Developing Global Maps of the Dominant Anopheles Vectors of Human Malaria, in ***PLoS*** Medicine **7**(2).

Higa Y. (2011). Dengue vectors and their spatial distribution, in ***Tropical Medicine and Health* 39**(4 Suppl).

Hill K. (1990). The Decline in Childhood Mortality. School of Hygiene and Public Health, John Hopkins University https://jscholarship.library.jhu.edu/bitstream/handle/1774.2/936/WP90-07_Childhood_Mortality.pdf (accessed on 27 June 2013).

Hoffmann AA, Montgomery BL, Popovici J, Iturbe-Ormaetxe I, Johnson PH, Muzzi F, Greenfield M, Durkan M, Leog YS, Dong Y, et al. (2011). Successful establishment of Wolbachia in Aedes populations to suppress dengue transmission, in ***Nature* 426**(7361).

Hotez P. (2009). Devastating Global Impact of Neglected Tropical Diseases, in ***Microbe* 4**(8).

Hotez P. (2013). The disease next door, in ***Foreign Policy***, 25 March.

Hotez PJ, Molyneaux DH, Fenwick A, Ottesen E, Sachs SE, Sachs JD. (2006). Incorporating a rapid impact package for neglected tropical diseases with programs for HIV/AIDS, tuberculosis and malaria, in ***PLoS*** Medicine **3**(5).

Hotez PJ, Ottesen E, Fenwick A, Molyneux D. (2006). The neglected tropical diseases: the ancient afflictions of stigma and poverty and the prospects for their control and elimination, in ***Advances in Experimental Medicine and Biology* 582**.

Hsu J, Pitt C, Greco G, Berman P, Mills A. (2012). Countdown to 2015: Changes in official development assistance to maternal, newborn and child health in 2009-10, and assessment of progress since 2003, in ***Lancet* 380**(9848).

Hu VH, Harding-Esch EM, Burton MJ, Bailey RL, Kadimpeul J, Mabey DC. (2010). Epidemiology and control of trachoma: Systematic review, in ***Tropical Medicine and International Health* 15**(6).

IFRC (2011). ***Eliminating Health Inequities: Every Woman and Every Child Counts.*** International Federation of Red Cross and Red Crescent Societies with The Partnership for Maternal Newborn and Child Health, Geneva.

James WP. (2008). The epidemiology of obesity: The size of the problem, in ***Journal of Internal Medicine* 263**(4).

Johnson WD, Diaz RM, Flanders WD, Goodman M, Hill AN, Holtgrave D, Malow R, McClellan WM. (2008). Behavioural interventions to reduce risk for sexual transmission of HIV among men who have sex with men (Review), in ***Cochrane Database Systematic Review* 16**(3).

Karlsen S, Say L, Souza JP, Hogue CJ, Calles DL, Gulmezoglu M, Raine R. (2011). The relationship between maternal education and mortality among women giving birth in health care institutions: Analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health, in ***BMC Public Health* 11**:606.

Keshavjee S, Farmer PE. (2012). Tuberculosis, drug resistance and the history of modern medicine, in ***New England Journal of Medicine* 367**(10).

King CH, Bertino AM. (2008). Asymmetries of poverty: Why global burden of disease valuations underestimate the burden of neglected tropical diseases, in ***PLoS Neglected Tropical Diseases* 26**(3).

References | Continued

Liang L, Yu Q, Gao L, Hao Y, Liu C, Xie Y, Sun H, Yan X, Li F, Li H, et al. (2012). Factors contributing to the high prevalence of multi-drug resistant tuberculosis: A study from China, in *Thorax* **67**(7).

Liese BH, Schubert L. (2009). Official development assistance for health – how neglected are neglected tropical diseases? An analysis of health financing, in *International Health* **1**(2).

Litt E, Baker MC, Molyneaux D. (2012). Neglected tropical diseases and mental health: A perspective on comorbidity, in *Trends in Parasitology* **28**(5).

Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, Abraham J, Adair T, Aggarwal R, Ahn SY, et al. (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: A systematic analysis for the Global Burden of Disease Study 2010, in *Lancet* **380**(9859).

Lozano R, Wang H, Foreman KJ, Rajaratnam JK, Naghavi M, Marcus JR, Dwyer-Lindgren L, Lofgren KT, Phillips D, Atkinson C, Lopez AD, Murray CJL. (2011). Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis, in *Lancet* **378**(9797).

Mangold KA, Reynolds SL. (2013). A review of dengue fever: A resurging tropical disease, in *Pediatric Emergency Care* **29**(5).

Maternal Mortality Estimation Inter-agency Group (2013). Maternal Mortality. World Health Organisation, United Nations Children's Fund, United Nations Population Fund, United Nations Population Division and World Bank. WHO Global Health Observatory http://www.who.int/gho/maternal_health/mortality/maternal/en/index.html (accessed on 27 March 2013).

Menéndez C, Romagosa C, Ismail MR, Carrilho C, Saute F, et al. (2008) An Autopsy Study of Maternal Mortality in Mozambique: The Contribution of Infectious Diseases, in *PLoS* Medicine **5**(2).

Murray CJL, Rosenfeld LC, Lim SS, Andrews KG, Foreman KJ, Haring D, Fullman N, Naghavi M, Lozano R, Lopez AD. (2012). Global malaria mortality between 1980 and 2010: A systematic analysis, in *Lancet* **379**(9814).

Murray CJL, Vos T, Lozano R, Naghavi M, Flaxman AD, Michaud C, Ezzati M, Shibuya K, Salamon JA, Abdalla S. (2012). Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: A systematic analysis for the Global Burden of Disease Study 2010, in *Lancet* **380**(9859).

Nathanson E, Nunn P, Uplekar M, Floyd K, Jaramillo E, Lonnroth K, Weil D, Raviglione M. (2010). MDR Tuberculosis – Critical steps for prevention and control, in *New England Journal of Medicine* **363**(11).

Nzewi O. (2009). *Exploring Gender Issues and Men's Vulnerability to HIV/AIDS in sub-Saharan Africa.* Policy Brief 56. Centre for Policy Studies, Johannesburg.

de Onis M, Blössner M, Borghi E. (2010). Global prevalence and trends of overweight and obesity among preschool children, in *American Journal of Clinical Nutrition* **92**(5).

Ordi J, Ismail MR, Carrilho C, Romagosa C, Osman N, Machungo F, Bombi JA, Balasch J, Alonso PL, Menendez C. (2009). Clinico-Pathological Discrepancies in the Diagnosis of Causes of Maternal Death in sub-Saharan Africa: Retrospective Analysis, in *PLoS Medicine* **6**(2).

Plummer D. (2009). How risk and vulnerability become 'socially embedded': Insights into the resilient gap between awareness and safety in HIV, in Barrow C, de Bruin M, Carr R. (Eds) *Sexuality, Social Exclusion and Human Rights: Vulnerability in the Caribbean Context of HIV.* Ian Randall Publishing, Kingston.

Popkin BM, Adair LS, Ng SW. (2012). Global nutrition transition and the pandemic of obesity in developing countries, in *Nutrition Reviews* **70**(1).

Rabkin M, Melaku Z, Bruce K, Reja A, Koler A, Tadesse Y, Njoroge Kamiru H, Tsabedze Sibanyoni L, El Sadr W.(2012). Strengthening health systems for chronic care: leveraging HIV programs to support diabetes services in Ethiopia and Swaziland, in *Journal of Tropical Medicine* 2012, Article ID 137460.

Racloz V, Ramsey R, Tong S, Hu W. (2012). Surveillance of dengue fever virus: A review of epidemiological models and early warning systems, in *PLoS Neglected Tropical Diseases* **6**(5).

Rajaratnam JK, Marcus JR, Flaxman AD, Wang H, Levin-Rector A, Dwyer L, Costa M, Lopez AD, Murray CJL. (2010). Neonatal, postnatal, childhood, and under-5 mortality for 187 countries, 1970 2010: A systematic analysis of progress towards Millennium Development Goal 4, in *Lancet* **375**(9730).

Rajaratnam JK, Marcus JR, Levin-Rector A, Chalupka AN, Wang H, Dwyer L, Costa M, Lopez AD, Murray CJL. (2010). Worldwide mortality in men and women aged 15–59 years from 1970 to 2010: a systematic analysis, in *Lancet* **375**(9727).

Raviglione M, Marais B, Floyd K, Lonnroth K, Getahun H, Migliori GB, Harries AD, Nunn P, Lienhardt C, Graham S, et al. (2012). Scaling up interventions to achieve global tuberculosis control: progress and new developments, in *Lancet* **379**(9829).

Remais JV, Zeng G, Li G, Tian L, Engelgau MM. (2013). Convergence of non-communicable and infectious diseases in low- and middle-income countries, in *International Journal of Epidemiology* **42**(1).

Rodwell TC, Barnes RFW, Moore M, Strathdee S, Raich A, Moser KS, Garfein RS. (2010). HIV Tuberculosis coinfection in Southern California: Evaluating disparities in disease burden, in American *Journal of Public Health* **11**(S1).

Ross DA, Dick B, Ferguson J. (Eds) (2006). Preventing HIV/AIDS in Young People: A Systematic Review of the Evidence from Developing Countries. UNAIDS Inter-Agency Taskforce on Young People, World Health Organisation, Geneva.

Sachs J (2000). *Tropical Underdevelopment.* CID Working Paper No. 57. Center for International Development, Harvard University, Boston.

Sakaue M, Fuke Y, Katsuyama T, Kawabata M, Taniguchi H. (2003). Austronesian-speaking people in Papua New Guinea have susceptibility to obesity and type 2 diabetes, in *Diabetes Care* **26**(3).

Sharma SK, Mohan A, Kadhiravan T. (2005). HIV-TB co-infection: Epidemiology, diagnosis and management, in *Indian Journal of Medical Research* **121**(4).

Shaw JE, Sicree RA, Zimmet PZ. (2009). Global estimates of the prevalence of diabetes, in *Diabetes Research and Clinical Practice* **87**(1).

Shaw JE, Sicree RA, Zimmet PZ. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030, in *Diabetes Research and Clinical Practice* **87**(4).

Shepard DS, Coudeville L, Halasa YA, Zambrano B, Dayan GH. (2011). Economic impact of dengue illness in the Americas, in *American Journal of Tropical Medicine and Hygiene* **84**(2).

Simpson G, Coulter C, Weston J, Knight T, Carter R, Vincent S, Robertus L, Konstantinos A. (2011). Resistance patterns of multidrug-resistant tuberculosis in Western Province, Papua New Guinea, in *International Journal of Tuberculosis and Lung Disease* **15**(4).

Steinmann P, Keiser J, Bos R, Tanner M, Utzinger J. (2006). Schistosomiasis and water resources development: Systematic review, meta-analysis, and estimates of people at risk, in *Lancet* **6**(7).

Stop TB Partnership (2013). http://www.stoptb.org/about/ (accessed on 1 March 2013).

Suaya JA, Shepard DS, Beatty ME. (2007). Working Paper 3.2: Dengue: Burden of disease and costs of illness, in *Report of the Scientific Working Group on Dengue*. World Health Organisation, Geneva.

Suthar AB, Lawn SD, del Amo J, Getahun H, Dye C, Sculier D, Sterling TR, Chaisson RE, Williams BG, Harries AD, Granich RM. (2012). Antiretroviral Therapy for Prevention of Tuberculosis in Adults with HIV: A Systematic Review and Meta-Analysis, in *PLoS Medicine* **9**(7).

Swaminathan S, Rekha B. (2010). Pediatric tuberculosis: Global overview and challenges, in *Clinical Infectious Diseases* **50**(Suppl 3).

Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, Gortmaker SL. (2011). The global obesity pandemic: Shaped by global drivers and local environments, in *Lancet* **378**(9793).

UN (2009). *World Population Policies* 2009. United Nations Department of Economic and Social Affairs, New York.

UN (2010a). *Global Strategy for Women's and Children's Health.* United Nations, New York.

UN (2010b). *Health, Morbidity, Mortality and Development.* Resolution 2010/1. United Nations Economic and Social Council.

UN (2011a). *Political Declaration on HIV/AIDS: Intensifying our Efforts to Eliminate HIV/AIDS.* United Nations, New York.

UN (2011b). *The Millennium Development Goals Report 2011*. United Nations, New York.

UN (2012a). *The Millennium Development Goals Report 2012.* United Nations, New York.

UN (2012b). *World Mortality Report 2011*. United Nations, New York.

UN (2013a). *World Population Prospects: The 2012 Revision*. United Nations, New York.

UN (2013b). *Millennium Development Goals and Post-2015 Development Agenda.* United Nations Economic and Social Council, New York.

UN (2013c) *The Millennium Development Goals Report 2013* United Nations, New York.

UNAIDS (2009). *Estimating National Adult Prevalence of HIV-1 in Generalized Epidemics – Draft Manual.* Joint United Nations Programme on HIV/AIDS, Geneva.

UNAIDS (2010). *Women, Girls and HIV and AIDS.* Joint United Nations Programme on HIV/AIDS, Geneva.

UNAIDS (2011a). *Countdown to Zero. Global Plan Towards the Elimination of New HIV Infections Among Children by 2015 and Keeping their Mothers Alive: 2011-2015.* Joint United Nations Programme on HIV/AIDS, Geneva.

UNAIDS (2011b). *Global HIV/AIDS Response: Epidemic Update and Health Sector Progress Towards Universal Access.* Progress Report 2011. Joint United Nations Programme on HIV/AIDS, Geneva.

UNAIDS (2011c). *World AIDS Day Report:* How to get to zero: Faster, Smarter, Better. Joint United Nations Programme on HIV/AIDS, Geneva.

UNAIDS (2012). *UNAIDS Report on the Global AIDS Epidemic 2012.* Joint United Nations Programme on HIV/AIDS, Geneva.

UNICEF (2012a). *Levels and Trends in Child Mortality: Report 2012.* United Nations Children's Fund, on behalf of United Nations Inter-agency Group for Child Mortality Estimation. New York.

UNICEF (2012b). *Committing to Child Survival: A Promise Renewed.* Progress Report 2012. United Nations Children's Fund, New York.

Walley AJ, Blakemore AIF, Froguel P. (2006). Genetics of obesity and the prediction of risk for health, in *Human Molecular Genetics* **15**(2).

Wang H, Dwyer-Lindgren L, Lofgren KT, Rajaratnam JK, Marcus JR, Levin-Rector A, Levitz CE, Lopez AD, Murray CJL. (2012). Age-specific and sex-specific mortality in 187 countries, 1970-2010: A systematic analysis for the Global Burden of Disease Study 2010, in *Lancet* **380**(9859).

Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. (2011). Health and economic burden of the projected obesity trends in the USA and the UK, in *Lancet* **378**(9793).

WEF (2010). *Global Risks 2010*. World Economic Forum, Geneva.

References | Continued

WHO (2004). Estimated Total Deaths, by Cause and WHO Member State, 2002. World Health Organisation www.who.int/healthinfo/statistics/bodgbddeathdalyestimates.xls (accessed on 21 August 2012).

WHO (2007). *Report of the Scientific Working Group on Dengue.* World Health Organisation, Geneva.

WHO (2008a) *2008-2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases.* World Health Organisation, Geneva.

WHO (2008b). *Closing the Gap in a Generation: Health Equity Through Action on the Social Determinants of Health.* Final Report of the Commission on Social Determinants of Health. World Health Organisation, Geneva.

WHO (2010a). *Guidelines for the Treatment of Malaria.* World Health Organisation, Geneva.

WHO (2010b). HIV/AIDS. Fact Sheet No. 360. World Health Organisation http://www.who.int/mediacentre/factsheets/fs360/en/index.html (accessed on 24 January 2013).

WHO (2010c). *Global Status Report on Noncommunicable Diseases 2010.* World Health Organisation, Geneva.

WHO (2010d). Pacific Islanders pay heavy price for abandoning traditional diet, in *Bulletin of the World Health Organisation* **88**(10).

WHO (2011a). Deaths Estimates for 2008 by Cause for WHO Member States. World Health Organisation www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html (accessed on 10 November 2011).

WHO (2011b). *Eliminating malaria: Learning from the past, looking ahead.* Roll Back Malaria Partnership, World Health Organisation, Geneva.

WHO (2011c). *The Global Plan to Stop TB 2011-2015.* World Health Organisation, Geneva.

WHO (2012a). Estimated obesity prevalence, males and females, aged 15+, 2002, 2005, 2010. World Health Organisation Global Infobase https://apps.who.int/infobase/Comparisons.aspx (accessed on 24 August 2012).

WHO (2012b). *Trends in Maternal Mortality: 1990 to 2010.* WHO, UNICEF, UNFPA and The World Bank Estimates. World Health Organisation, Geneva.

WHO (2012c). *World Malaria Report 2012.* World Health Organisation, Geneva.

WHO (2012d). *Addressing Diseases of Poverty: An initiative to Reduce the Unacceptable Burden of Neglected Tropical Diseases in the Asia Pacific.* World Health Organisation, Sabin Vaccine Institute and Global Network of Neglected Tropical Diseases.

WHO (2012e). *Global Tuberculosis Report 2012.* World Health Organisation, Geneva.

WHO (2012f). MDGs. Fact Sheet No. 290. World Health Organisation http://www.who.int/mediacentre/factsheets/fs290/en/index.html (accessed on 10 January 2013).

WHO (2012g). *Global strategy for dengue prevention and control: 2012-2020.* World Health Organisation, Geneva.

WHO (2012h). TB/HIV Facts 2011-2012. World Health Organisation http://www.who.int/tb/publications/TBHIV_Facts_for_2011.pdf (accessed on 30 January 2013).

WHO (2012i). Tuberculosis. Fact Sheet No. 104. World Health Organisation http://www.who.int/mediacentre/factsheets/fs104/en/ (accessed on 31 January 2013).

WHO (2012j). Dengue and Severe Dengue, Fact Sheet No. 117. World Health Organisation http://www.who.int/mediacentre/factsheets/fs117/en/ (accessed on 14 May 2013).

WHO (2012k). *Global Tuberculosis Report 2012.* World Health Organisation, Geneva.

WHO (2012l). *No More Crying, No More Dying. Towards Zero TB Deaths in Children.* World Health Organisation, Geneva.

WHO (2012m). London Declaration on Neglected Tropical Diseases. World Health Organisation http://www.who.int/neglected_diseases/London_Declaration_NTDs.pdf (accessed on 12 May 2013).

WHO (2012n). *Accelerating work to overcome the global impact of neglected tropical diseases.* World Health Organisation, Geneva.

WHO (2012o). Buruli Ulcer. Fact sheet No. 199. World Health Organisation http://www.who.int/mediacentre/factsheets/fs199/en/ (accessed on 23 May 2013).

WHO (2012p). Leprosy. Fact Sheet No. 101. World Health Organisation http://www.who.int/mediacentre/factsheets/fs101/en/ (accessed on 23 May 2013).

WHO (2013a). Estimated Number of Malaria Deaths by Region. World Health Organisation Global Health Observatory http://apps.who.int/gho/data/view.main.14117?lang=en (accessed on 1 April 2013).

WHO (2013b). HIV Prevalence among the Population Aged 15-19 years. World Health Organisation http://www.who.int/healthinfo/statistics/indhivprevalence/en/index.html (accessed on 21 January 2013).

WHO (2013c). Maternal Health. World Health Organisation http://www.who.int/topics/maternal_health/en/ (accessed on 4 April 2013).

WHO (2013d). Noncommunicable Diseases. Fact Sheet No. 355.World Health Organisation http://www.who.int/mediacentre/factsheets/fs355/en/ (accessed on 16 May 2013).

WHO (2013e). *Sustaining the Drive to Overcome the Global Impact of Neglected Tropical Diseases: Second WHO Report on Neglected Tropical Diseases.* World Health Organisation, Geneva.

WHO (2013f). TB burden estimates. World Health Organisation http://www.who.int/tb/country/global_tb_database/en/ (accessed on 1 February 2013).

WHO (2013g). Child Health Epidemiology. World Health Organisation http://www.who.int/maternal_child_adolescent/epidemiology/child/en/ (accessed on 11 April 2013)

WHO (2013h). Impact of Dengue. Global Alert and Response. World Health Organisation http://www.who.int/csr/disease/dengue/impact/en/ (accessed on 14 May 2013).

WHO (2013i). Number of Deaths due to HIV/AIDS: Situation and Trends. World Health Organisation, Global Health Observatory http://www.who.int/gho/hiv/epidemic_status/deaths_text/en/index.html (accessed on 30 January 2013).

WHO (2013j). Obesity and Overweight. Fact Sheet No. 311. World Health Organisation http://www.who.int/mediacentre/factsheets/fs311/en/ (accessed on 13 May 2013).

WHO (2013k). Overview of Diagnostic Testing. World Health Organisation http://www.who.int/malaria/areas/diagnosis/overview/en/index.html (accessed on 17 April 2013).

WHO (2013l). TB Diagnostics and Laboratory Strengthening. World Health Organisation http://www.who.int/tb/laboratory/en/ (accessed on 7 March 2013).

WHO (2013m). Dengue Reported Cases. World Health Organisation Dengue Net http://apps.who.int/globalatlas/dataQuery/default.asp (accessed on 30 April 2013).

WHO (2013n). Diabetes. Fact Sheet No. 312. World Health Organisation http://www.who.int/mediacentre/factsheets/fs312/en/ (accessed 5 June 2013).

WHO (2013o). Malaria. Fact Sheet No. 94. World Health Organisation http://www.who.int/mediacentre/factsheets/fs094/en/index.html (accessed on 12 March 2013).

WHO (2013p). Number of deaths due to AIDS. World Health Organisation Global Health Observatory http://apps.who.int/gho/data/?vid=360# (accessed on 15 January 2013).

WHO (2013q). Rabies. Fact Sheet No. 99. World Health Organisation http://www.who.int/mediacentre/factsheets/fs099/en/index.html (accessed on 23 May 2013).

WHO (2013r). Treatment of Children Living With HIV. World Health Organisation http://www.who.int/hiv/topics/paediatric/en/index.html (accessed on 24 January 2013).

WHO (2013s). Chagas disease (American trypanosimiasis). Fact Sheet No. 340. World Health Organisation http://www.who.int/mediacentre/factsheets/fs340/en/index.html (accessed on 23 May 2013).

WHO (2013t). Lymphatic filariasis: Programme. World Health Organisation http://www.who.int/lymphatic_filariasis/disease/en/ (accessed on 23 May 2013).

WHO (2013u). Onchocerciasis Control Programme in West Africa. World Health Organisation. http://www.who.int/apoc/onchocerciasis/ocp/en/ (accessed on 23 May 2013).

WHO (2013v). Schistosomiasis. Fact Sheet No. 115. World Health Organisation http://www.who.int/mediacentre/factsheets/fs115/en/index.html (accessed on 23 May 2013).

WHO (2013w). Soil-transmitted Helminth Infections. Fact Sheet No. 366. World Health Organisation http://www.who.int/mediacentre/factsheets/fs366/en/ (accessed on 23 May 2013).

World Bank (2012). *The Economic Costs of Non-Communicable Diseases in the Pacific Islands: Final Report.* World Bank, Washington DC.

World Bank (2013). GDP per capita (constant 2000 $US). World Bank World Development Indicators http://data.worldbank.org/indicator (accessed on 16 May 2013).

Zaidi L, De Cock KM. (2013). The global epidemiology of HIV/AIDS, in Volberding PA, Greene WC, Lange JMA, Gallant JE, Sewankambo N (Eds). *Sande's HIV/AIDS Medicine: Medical Management of AIDS* (Second Edition). Elsevier Saunders, China.

Classroom in Laos.
Image: WB_Bart Verweij.

Working at Port au Prince Power station.
Image: Dominic Chavez, World Bank.

'Education is the linchpin of human development. It helps people fight poverty, and empowers them with the knowledge, skills and confidence they need to shape a better future.'

UNESCO 2011

Chapter 6.3

Society | Education and work

Workers in Vietnam.
Image: Mai Kai, World Bank Photo Collection.

Summary of education and employment indicators

	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Mean years of schooling 1980 to 2010	**3 – 6**	2 – 5	1 – 3	2 – 5	4 – 7	5 – 8	4 – 8	4 – 7	6 – 8	**6 – 9**	**5 – 8**
Youth literacy (%) 1989-1993 to 2005-10	**80 – 86**	67 – 72	52 – 66	69 – 84	95 – 98	86 – 89	90 – 96	92 – 98	80 – 78	**88 – 94**	**85 – 90**
Adult literacy (%) 1975-80 to 2006-10	**55 – 77**	37 – 63	23 – 56	42 – 65	71 – 94	75 – 84	76 – 90	77– 91	65 – 76	**72 – 88**	**66 – 84**
Unemployment Rate (%) 2000 to 2011	**6 -5**	7-6	9-9.4	4-4	5-4	10-9	3-5	10-8	4-3	**7-7**	**6-6**

Red: Situation is deteriorating
Green: Situation is improving

Education is the process of communicating knowledge, reasoning and judgment, and encompasses both teaching and learning. Literacy – which is a particular set of skills that are gained through formal or non-formal education – is considered essential to successful human development as it underpins active and informed citizenship, improved health outcomes and a greater range of options for employment. Reflecting the importance of education to individual empowerment and freedom, education is recognised as a fundamental human right[14].

At a national and regional level, education and literacy are key drivers of economic development, reflecting a nation's stock of human capital. Poverty, inequality, poor health and limited education opportunities are significant obstacles to increasing education rates, and are also challenges facing many nations in the Tropics. Basic literacy and numeracy skills increase a person's chances of finding paid employment and escaping poverty. Education is also strongly correlated with health and wellbeing, and the economic productivity of nations.

Employment is an important determinant of wellbeing at an individual, community and national level. Levels of occupation whether formal or informal have long been known to determine the relative happiness or wellbeing of people. Additionally, like education, employed people represent human capital; investments that businesses and governments make in order to promote growth and development. Unemployment represents under-utilised economic resources. At an individual and societal level, unemployment can have adverse impacts if large sections of the population are unemployed. Employment and unemployment are key economic and social indicators of an individual's wellbeing, providing income and self-actualisation benefits.

[14] Article 26 of the 1948 Universal Declaration of Human Rights states that 'everyone has the right to education'.

Headline indicator

Mean years of schooling of adults measures the average number of years of education received by people aged 25 years and older in their lifetime, based on education attainment levels of the population converted into years of schooling. Mean years of schooling is an indicator of the aggregate stock of human capital available in an economy and society, and is comparable across populations.

Supplementary indicators

Youth literacy; adult literacy; unemployment rate

Links to other dimensions

Poverty; health; economic output; crime and corruption; gender equality; science and technology; international trade and investment; communication.

Mean years of schooling

Is it getting better?

Mean years of schooling of adults almost doubled in the Tropics between 1980 and 2010, and although in 2010 adults in the Tropics had 2.5 fewer years of schooling than adults in the Rest of the World, mean years of schooling increased faster in the Tropics.

Youth literacy rates increased in all regions of the Tropics between 1989-1993 and 2005-10, except for in Oceania where youth literacy decreased slightly, and were overall consistently lower in the Tropics than in the Rest of the World. The number of illiterate youth in the Tropics decreased over this period but the number of illiterate youth increased by around 50% in Central & Southern Africa and Oceania.

The adult literacy rate increased in all regions of the Tropics between 1975-80 and 2006-10, and increased faster in the Tropics than in the Rest of the World, although rates remained considerably lower in the Tropics than in the Rest of the World in 2006-10. Despite these improvements, the number of illiterate adults in the Tropics increased.

The global unemployment rate increased slightly between 2000 and 2002 before falling consistently to 2007, in line with stronger economic growth. In 2008 and 2009 the global financial crisis resulted in major falls in economic activity and confidence, and a sharp increase in the global unemployment rate. In the Tropics however, the unemployment rate has declined steadily and only showed a small increase in 2009 before returning to pre-crisis levels.

Classroom in Guatemala. Image: Maria Fleishman, World Bank Photo Collection.

Schooling contributes to a nation's stock of human capital, with greater levels of education linked to improved economic growth, increased labour productivity, greater social mobility and equality (Hannum & Buchmann 2005).

The most direct benefits of education relate to personal health and income, as well-educated individuals tend to live longer, make more informed health choices and have higher incomes, with one extra year of schooling increasing an individual's earnings by up to 10% (UNESCO 2011a). Globally it is estimated that people with only primary school education earn on average 77% less than those who finished secondary school, and 240% less than university graduates (Barro & Lee 2010). A mother's education level has also been shown to be more important to a child's survival than household income (UNDP 2013).

Trends

Globally the proportion of people who attended school has increased significantly over the past 50 years, from 57% in 1960 to 85% in 2010 (UNDP 2010a), as has the mean years of schooling. For adults the mean years of schooling[15] increased from 4.9 years in 1980 to 7.6 years in 2010 (see Figure 6.3.1). The years of formal schooling received by an adult in the Rest of the World is consistently higher than in the Tropics, and the gap has narrowed only marginally since 1980. In the Tropics the mean years of schooling increased from 2.9 years in 1980 to 5.9 years in 2010, and in the Rest of the World from 5.7 to 8.5 years.

All regions in the Tropics increased the adult mean years of schooling in the 30 years to 2010, with Central America, South America and the Caribbean having the largest increases, at 4.1, 3.8 and 3.3 years respectively (see Figure 6.3.2). Oceania had the smallest improvement, increasing by 1.2 years but from a higher base. In percentage terms Northern Africa & Middle East, Central & Southern Africa and South Asia had the strongest growth, though for each it was from a very low base. Northern Africa & Middle East tripled its adult mean years of schooling between 1980 and 2010 but, at 3.3 years in 2010, it is still well below all other regions of the Tropics.

Improvements in adult mean years of schooling varied substantially across the tropical regions, and there has been considerable change in the rankings since 1980. Notably, Oceania has fallen from having the highest level of adult mean years of schooling in the Tropics in 1980 to third in 2010, behind the Caribbean and Central America.

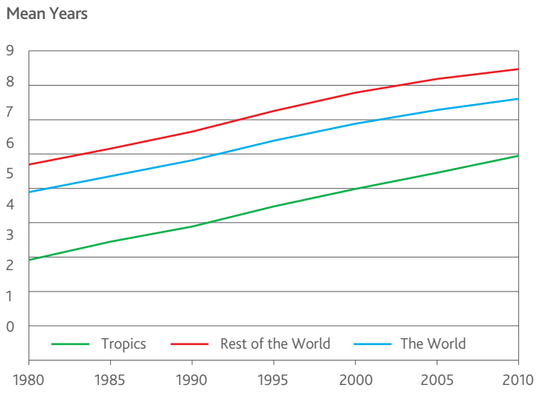
Human capital and economic growth

The concept of human capital arose in the 1960s out of recognition that people's knowledge, skills, health or values cannot be separated from economic value. Education, training, and health are considered to be the most important investments in human capital, and the connection between education and training and economic growth has received increasing attention over the past few decades (Izushi & Huggins 2004). Nations that have sustained high economic growth over the long-term have generally invested considerably in the education of their citizens (UNDP 2013).

Education can contribute to economic growth by encouraging innovation, improving labour productivity, and by creating an environment that is better able to create, disseminate and apply new technologies. Increases in mean years of schooling tend to coincide with increases in economic output, and each additional year of average schooling has been shown to increase the average annual economic growth rate by almost 0.4 percentage points (Hanushek et al. 2008). Reflecting this, there is a clear relationship between adult mean years of schooling and gross national income per capita (see Figure 6.3.3).

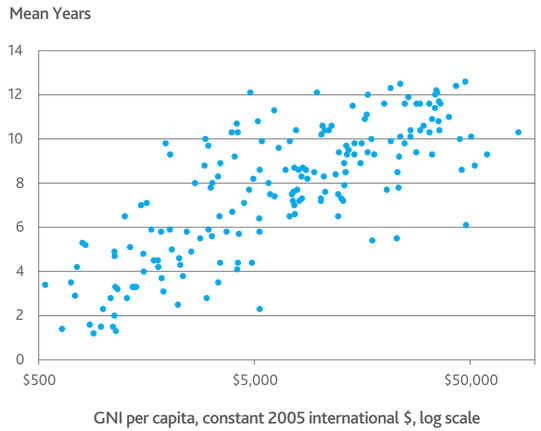
[15] Mean years of schooling of adults is the 'average number of years of education received by people aged 25 and older in their lifetime, based on education attainment levels of the population converted into years of schooling based on theoretical durations of each level of education attended' (UNDP 2010).

Figure 6.3.1 **Adult mean years of schooling**



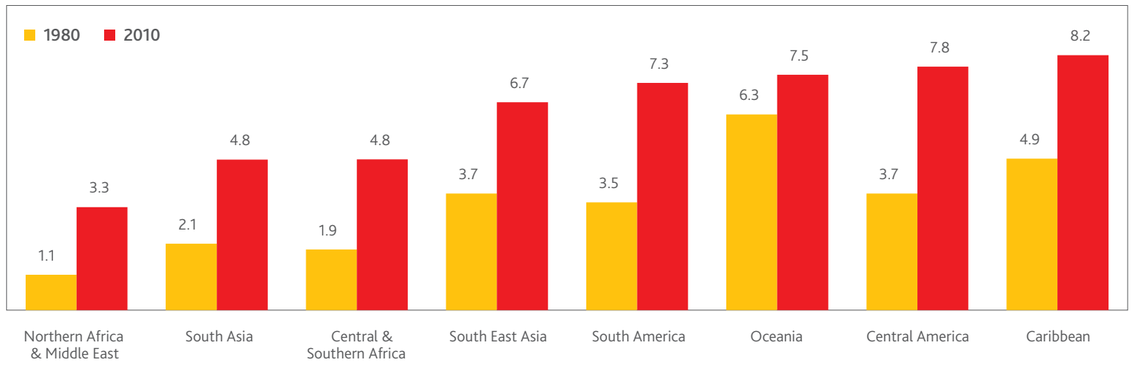
Source: Barro & Lee (2010), State of the Tropics project.

Figure 6.3.3 **Mean years of schooling of adults and gross national income per capita, 2011**



Source: Barro & Lee (2010), UNDP (2011), State of the Tropics project.

Figure 6.3.2 **Adult mean years of schooling**

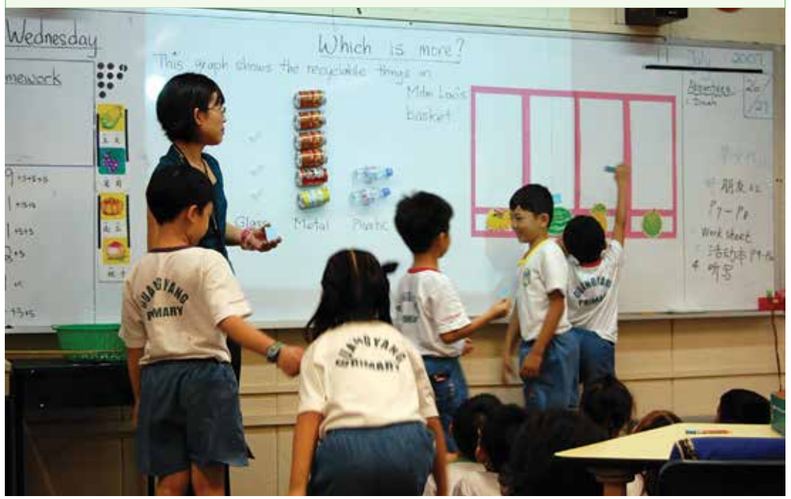


Source: Barro & Lee (2010), State of the Tropics project.

Box 6.3.1 Human capital and economic growth in Cuba and Singapore

Cuba has developed substantial human capital through investment in education, with expenditure on education averaging about 9% of GDP between 1980 and 2010 (UNESCO 2012b). At 10.2 years, Cuba's adult mean years of schooling was in the top 25% of nations in 2010 (Barro & Lee 2010), and it also has universal youth literacy and near universal adult literacy. Cuba's highly educated stock of human capital has not however translated into stronger economic growth, and it ranks 103rd out of 187 nations in terms of gross national income (GNI) per capita (UNDP 2011). Cuba's relatively weak economic performance is attributed to poor management across a range of policy areas including exchange rates, micro-enterprise, agriculture, labour, foreign investment infrastructure renewal and trade embargoes (Ritter 2010).

Singapore also has a strong education system with mean years of schooling at 8.8 years in 2010. In contrast to Cuba though, education has driven economic growth by successfully matching supply with demand for education and skills (OECD 2011). Singapore is one of the wealthiest nations in the world, ranking 4th among 187 nations in GNI per capita (UNDP 2011). Between 1959 and 1978 the education system successfully expanded basic education to support Singapore's labour-intensive manufacturing sector, and between 1979 and 1996 the shift to a skill-intensive economy was supported by an emphasis on producing a more technically-skilled labour force (OECD 2011). From the 1990s, Singapore's education system has responded to the growth of the global knowledge economy by focusing on innovation, creativity and research, and has been successful in producing highly-skilled, flexible workers with advanced critical thinking and self-learning skills (OECD 2011). The complementary relationship between education and economic development in Singapore has also been supported by factors such as investment in teacher and leadership capacity, ambitious standards and assessments, and a culture of continuous improvement (OECD 2011).



Classroom in Singapore. Image: Cassandra Turner.

Mean years of schooling may not however fully reflect a nation's stock of human capital as it does not consider quality of education, which is a key factor in expanding human capabilities (UNDP 2013). Research suggests that increased quality of schooling (as measured by improved cognitive skills of students), accounts for a large proportion of the economic growth traditionally attributed to additional years of schooling (Hanushek et al 2008).

The contribution of education to economic growth is influenced by many other factors, including the structure of the economy, the distribution of wealth and government policy settings (Ranis et al. 2000), while 'social capital' associated with cultural norms, interpersonal trust and social networks also influence economic growth and its prospects (Woodhall 2001). Case studies of Cuba and Singapore indicate that strong management across a range of policy areas is necessary to maximise the economic and social return from investments in human capital (see Box 6.3.1).

Looking forward

Mean years of schooling has increased globally over the past 30 years, including a significant increase in the Tropics. However, in 2010, adults in the Tropics received 2.6 years less of formal education than adults in the Rest of the World, suggesting a lower level of human capital in the Tropics. Challenges for low income nations in the Tropics to increase education levels include reaching marginalised and disadvantaged groups, reducing income and gender inequality, increasing participation in post-primary education, providing training for out-of-school and adult students and improving the quality of provided education (World Bank 2011).

Literacy | Youth literacy

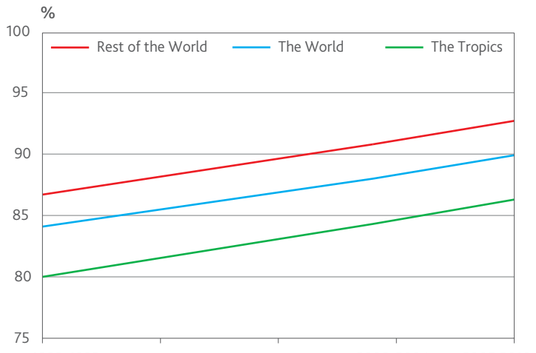
Young adults represent a major global resource. As a group, young adults aged between 15 and 24 years (referred to here as 'youth') are at a stage of life where they are acquiring greater independence, awareness and involvement in social, economic and political issues. Teenagers and adults in their early 20s are beginning to act as agents for innovations that will affect development prospects at the local, national and international levels. Education and training can help to prepare young adults for their expanded roles in society, and literacy – as it is the foundation for most learning – plays an important role in maximising an individual's capacity to gain employment, as well as to engage in and influence society.

In 2010 there were around 1.2 billion people aged 15-24 (17% of the global population), with one out of ten people in this group lacking basic writing, reading and numeracy skills. Primary school is where most people acquire basic literacy skills, and although the proportion of children attending primary school has seen significant improvement, globally around 67 million primary school age children were not enrolled in school in 2009 (UNESCO 2011b). Youth literacy remains a significant problem in many nations.

The youth literacy rate[16] reflects the quality of basic education and its degree of inclusiveness. Some children are excluded from educational opportunities due to social inequalities linked with gender, ethnicity, wealth or location, each of which can increase the likelihood of illiteracy. While inequalities between girls and boys can influence school attendance rates, the most significant inequalities exist between rural and urban children, with rural children twice as likely to be out of school as children from urban areas (UNESCO 2011b).

As a basic requirement for future learning and thus human capital creation, high literacy rates are critical to the future development of both individuals and nations.

Figure 6.3.4 **Youth literacy rate**



Source: UNESCO (2007, 2012a), UN (2013), State of the Tropics project.

Trends

In the Tropics the youth literacy rate increased from 80% in the period 1989-93 to 86.3% in 2005-10, while in the Rest of the World it increased from 86.7% to 92.7% (see Figure 6.3.4). There has been little convergence in the literacy rates between the Tropics and the Rest of the World over this period, with the gap consistently around 5.6 percentage points.

In the 20 years to 2010 the youth literacy rate in the Tropics increased at an average rate of 0.4% per annum compared with 0.3% in the Rest of the World, increasing by 6.3 percentage points in the Tropics compared with 5.3 percentage points in the Rest of the World. As the proportion of the youth population living in the Tropics increased from 39% in 1990 to 44% in 2010, literacy rates in the Tropics had a slightly greater impact on global outcomes in 2010.

Of the tropical regions Northern Africa & Middle East had the greatest improvement in the youth literacy rate, with average growth of 1.9% per annum (more than six times the global rate), although this was from a low base of 52%. Modest improvements in Central & Southern Africa over this period has seen it being overtaken by Northern Africa & Middle East by 2005-10, and it now has the lowest youth literacy rate of the tropical regions. South Asia also had considerable growth, with the youth literacy rate in the region increasing by 1% per annum on average, more than three times the global rate of growth.

With the exception of Oceania, where the youth literacy rate declined marginally, the remaining tropical regions experienced growth of 0.1% to 0.4% per annum in the 20 years to 2010. In Central & Southern Africa the youth literacy rate increased modestly despite starting from a low base, while for the other regions the modest rates of improvement reflected a relatively high starting point in 1989-1993. In 2010 South East Asia, Central America and South America each had youth literacy rates above the global rate of 89.9%. The fall in the youth literacy rate in Oceania was due to Papua New Guinea, where the increase in the literate youth population did not keep pace with the increase in the youth population. Poverty, relatively poor health outcomes and rural geography present range of unique education challenges in Papua New Guinea (see Box 6.3.2).

Globally the number of illiterate youth decreased from 157 million in 1990 to 121 million in 2010. In the Rest of the World the number of illiterate youth fell from 80 million to 49 million (-39%), while the Tropics had only a modest decrease, from 77 million to 72 million (-7%). The gap in the number of illiterate youth between the Tropics and the Rest of the World increased significantly, and in 2010 the Tropics had almost 50% more illiterate youth than in the Rest of the World.

Nonetheless, the number of illiterate youth declined in six of eight tropical regions in the 20 years to 2010. The largest falls were in in South America (-62%), South East Asia (-49%), Central America (-45%) and South Asia (-33%). The number of illiterate youth increased in Central & Southern Africa and Oceania, by 12 million (50%) and 134,000 (47%) respectively.

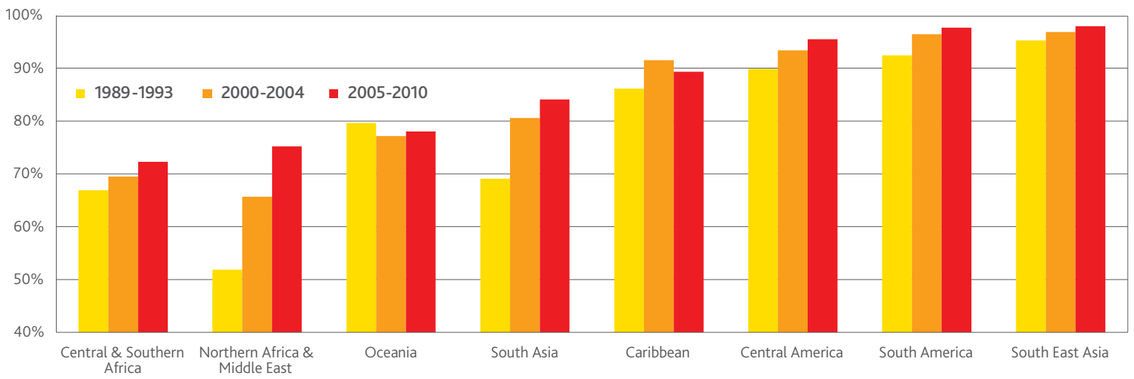
Primary school education

Attendance at primary school is the most effective way of increasing youth literacy, with out-of-school youth having limited opportunities to develop or maintain literacy skills (UN 2012). Primary education provides children with basic reading, writing and mathematics skills, as well as elementary-level understanding of subjects such as history, geography and science. Recognising the importance of primary education to creating opportunities in life, the Millennium Development Goals aim to ensure that all children will be able to complete a full course of primary schooling by 2015 (UN 2003).

Primary school enrolment rates have increased worldwide since 1999, and in 2010 it was 97% in developed regions and 90% in developing regions. Global primary school completion rates have also increased, from 81% in 1999 to 90% in 2010 (UN 2012). Nonetheless, progress in reducing the number of out-of-school children has slowed considerably since 2004 (UN 2012), and the number of illiterate youth is considerable. Substantial barriers to improved education and literacy also persist, especially with respect to urban/ rural status, gender, ethnicity and disability. For example, girls of lower secondary school age are less likely to be in school than boys, even though girls and boys have similar chances of completing primary school education in most nations. Encouragingly though, the gender gap in youth literacy rates

[16] The youth literacy rate is 'the number of persons aged 15 to 24 years who can both read and write with understanding a short simple statement on their everyday life, divided by the population in that age group. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations' (UNESCO 2009).

Figure 6.3.5 **Youth literacy – the Tropics**



Source: UNESCO (2012a), UN (2013), State of the Tropics project

tends to be narrowing with the global focus on universal access to primary education (UN 2012).

The contribution of basic primary school education to youth literacy rates can be complemented with age-specific out-of-school programs aimed specifically at reducing youth illiteracy. Despite global recognition that young adults are critical to future development prospects, there is a general lack of youth-targeted literacy programs (UNESCO 2008). As a consequence, many young people tend to participate in adult literacy programs which may not be effective or suitable (UNESCO 2008). The need for targeted programs is underscored by the significant problems faced by illiterate youth, such as low self-esteem and self-knowledge, as well as limited basic life, communication and money management skills (Butler & Ignatowski 2010). Each of these factors can significantly affect the opportunities that an individual has to reach their potential.

Box 6.3.2 Youth literacy in Papua New Guinea

Oceania is the only region in the Tropics where youth literacy decreased between 1990 and 2010, from 79.6% to 78.0%, which was due to declining rates in Papua New Guinea (PNG). With one in three young people in the nation illiterate, youth illiteracy is recognised as a major problem, and the number of illiterate youth is predicted to increase to 2015 (UNICEF 2011).

PNG accounts for a large and increasing proportion of Oceania's youth population, estimated at 60% in 2010. This cohort is critical to making the nation more economically productive and socially resilient, but obstacles such as poverty, limited employment opportunities and rural/urban inequalities continue to limit young people's access to opportunities and resources (UNICEF 2011). Increasing literacy rates in PNG is a major challenge. A largely rural population, poor health outcomes and a diverse culture with more than 800 languages provide multiple barriers. The government of PNG considers literacy to be at the 'heart of human development and lifelong learning (necessary) to alleviate poverty', and has achieved some recent progress in broadening access to formal education.

Organisations such as AusAID and the World Bank have also sponsored investments in vocational education and training and 'second chance' education opportunities, but the reach and impact of these investments have been limited (UNICEF 2011). Increasing youth literacy rates alone will not be sufficient to ensure better prospects for young people, and will need to be accompanied by polices which improve governance and strengthen and broaden economic activity and employment opportunities (UNICEF 2011).

Buk blong Pikinini (Books for Children), PNG. Image Ness Kerton, AusAID.

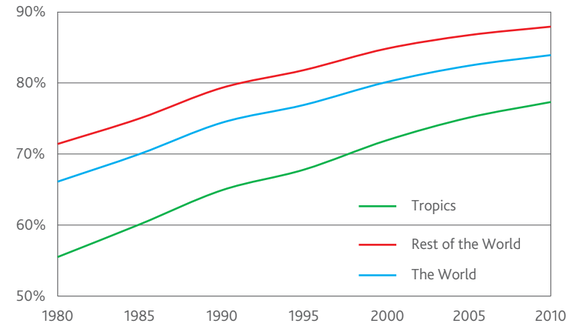
Literacy | Adult literacy

The adult literacy rate[17] is a basic measure of a nation's stock of human capital that is readily comparable across nations. In a rapidly changing, technology-driven world adult literacy is an essential underpinning of a nation's economic development, yet around 16% of the world's adult population is illiterate.

As awareness about the importance of literacy to individual and societal wellbeing grows, there has been a rapid expansion in formal schooling, mass literacy campaigns and, to a lesser extent, adult learning programs. Adult literacy programs have tended to be overshadowed by a greater focus on improving child and youth literacy rates through primary and secondary education. Globally, adult literacy programs typically receive only around 1% of national education budgets (UNESCO 2006). Nonetheless, investments to improve child and youth literacy rates have contributed to significant improvements in adult literacy rates in most nations. The rate of improvement has not been universal across nations however, and those with low literacy rates are generally characterised by prolonged conflict, economic decline or other major social issues (UNESCO 2011c).

At the household level adult literacy can have a major impact on family income and wellbeing. Literate parents, and particularly mothers, tend to have healthier children who are 50% more likely to survive past the age of five (UNESCO 2011a), and literate people tend to earn higher incomes and to have better employment opportunities (Cree et al. 2012).

Figure 6.3.6 Adult literacy rate



Source: Source: UNESCO (2012a), UN (2013), State of the Tropics project.
* Six years to 1980.

Trends

Adult literacy rates in the Tropics are considerably lower than in the Rest of the World, though the gap has narrowed since 1975-80. In 1975-80 the adult literacy rate in the Tropics was 55% compared with 71% in the Rest of the World – a 16 percentage point difference. In the 30 years to 2010 the gap narrowed to 11 percentage points, with the Tropics having an adult literacy rate of 77% and the Rest of the World 88% (see Figure 6.3.6).

The Tropics experienced a threefold growth in the number of literate adults in the period between 1975-80 and 2006-10 – from 0.5 billion to 1.5 billion. The Rest of the World started from the significantly higher position of 1.4 billion literate adults in 1975-80, doubling to 2.7 billion in 2006-10. Compared to 1975-80, in 2006-10 there were 1 billion more literate adults in the Tropics and 1.3 billion more in the Rest of the World.

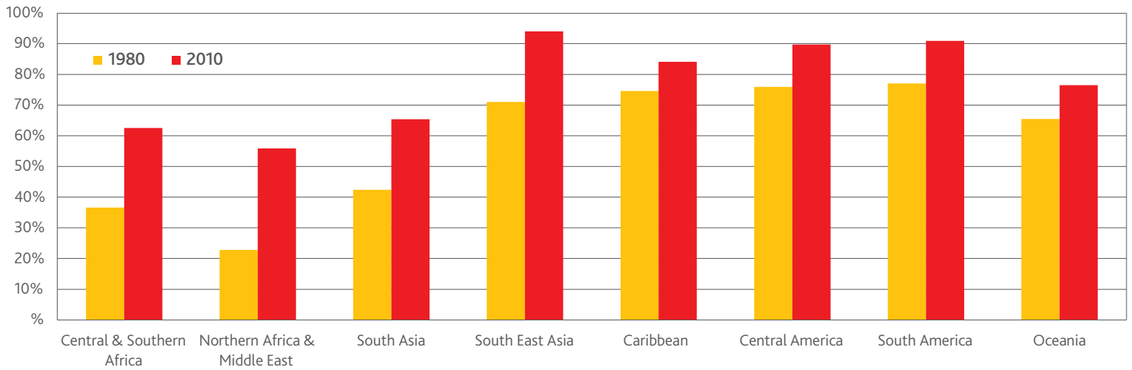
In the 30 years to 2010 the literacy rate in the Tropics increased at an average rate of 1.1% per annum compared with 0.7% in the Rest of the World. Adult literacy rates improved significantly in all regions of the Tropics, and those with the lowest starting point (Northern Africa & Middle East, Central & Southern Africa and South Asia) report the greatest improvements (see Figure 6.3.7). Despite the gap reducing slightly, adult literacy rates in these three regions are still well below the other tropical regions. South East Asia also reported a strong improvement, with the adult literacy rate increasing by 23 percentage points to 94%.

South East Asia has had the highest adult literacy rate of the tropical regions since 1990, when it first exceeded the Caribbean, Central America and South America. This followed ten years of significant improvements in adult literacy rates. The major movement in the ranking of the tropical regions is that South East Asia has moved from fourth in 1980 to first in 2010.

Comparing growth in the adult population with the adult literate population provides an

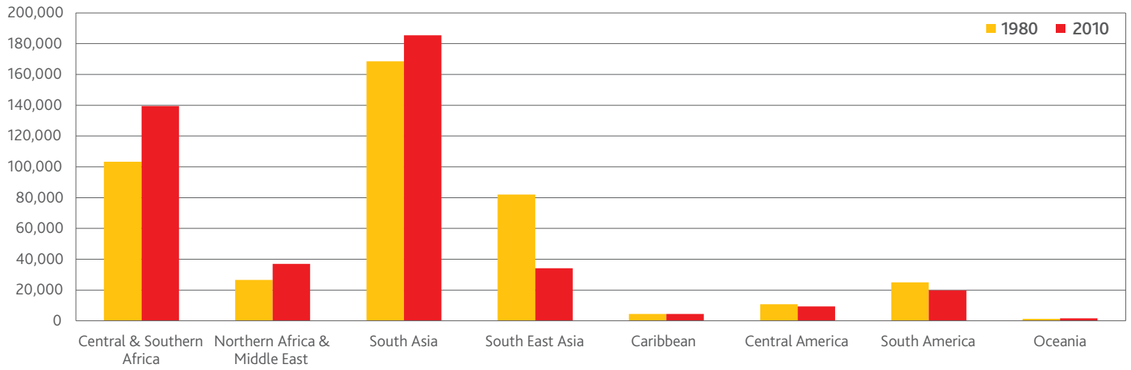
[17] The adult literacy rate is 'the percentage of population aged 15 years and over who can both read and write with understanding a short simple statement on his/her everyday life. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations' (UNESCO 2009).

Figure 6.3.7 **Adult literacy rates – the Tropics**



Source: UNESCO (2012a), UN (2013), State of the Tropics project.

Figure 6.3.8 **Adult illiterate population (thousands) – the Tropics**



Source: UNESCO (2012a), UN (2013), State of the Tropics project.

indication of the success of post-primary school adult education programs. Where the increase in the number of literate adults exceeds the increase in adult population, it suggests that adult literacy programs have been implemented successfully. In the Tropics, South East Asia had the strongest result with growth in the adult literate population more than 15% greater than growth in the adult population. South America and Central America also experienced a greater increase in the number of literate adults relative to the adult population. This did not occur in the other regions of the Tropics.

In the Tropics the number of illiterate adults increased from 420 million in 1975-80 to 430 million in 2006-10, an increase of just over 2%. Over the same period the illiterate population in the Rest of the World fell from 550 million to 375 million, a decrease of 32%. As such, the Tropics' proportion of the global illiterate population increased from 43% in 1975-80 to 53% in 2006-10.

Despite international efforts, the number of illiterate adults increased in four of the eight tropical regions in the 30 years to 2010, with only South East Asia, South America, Central America and the Caribbean experiencing a decline. The number of illiterate adults in South East Asia declined by 58% over this period (see Figure 6.3.8).

South Asia, Central & Southern Africa and Northern Africa & Middle East accounted for almost 85% of the adult illiterate population in the Tropics in 2006-10. Despite significant improvements in adult literacy rates, these regions have had a substantial increase in the number of illiterate adults. In South Asia the adult illiterate population increased from 169 million in 1975-80 to 185 million in 2006-10, from 103 million to 139 million in Central & Southern Africa, and from 27 million to 37 million in Northern Africa & Middle East. Improvements in adult literacy rates in these regions have coincided with significant increases in primary education net enrolment rates (though from a low base). Improved enrolment rates are not matched by primary school completion rates, which is an indicator of literacy, education system quality and student progression. Nonetheless, nations in sub-Saharan Africa have the lowest primary education enrolment and completion rates in the world (UN 2012).

Despite significant improvements in adult literacy rates, the legacy of high fertility rates has contributed to the high number of illiterate adults in these regions. The African regions of the Tropics had an average fertility rate of 5.6 children per woman in 2010 (compared with 2.1 in the Rest of the World). Coupled with relatively low primary education enrolment and completion rates, this means a significant number of children in Africa enter the adult population illiterate. With life expectancy increasing, adult literacy programs are essential to reduce the number of illiterate adults in Africa, particularly if primary school net enrolment and completion rates remain relatively low.

The Education for All movement

The Education for All (EFA) initiative was established by the United Nations and World Bank in 1990 with a commitment to provide basic education to all people. In the absence of a literacy-specific Millennium Development Goal, in 2000 the EFA committed to closing the gap between existing and full literacy by 50%. As the global illiteracy rate was 20% in 2000, the target is for 90% literacy by 2015. Governments of 164 nations have committed to this adult literacy goal.

In 2003 the United Nations' Literacy Decade was established with a goal to increase literacy rates. The Literacy Decade highlighted the literacy crisis in many nations and also placed adult literacy on the agenda of governments (see Box 6.3.3).

To meet the EFA target the global community has focused on improving outcomes in those nations with the lowest literacy rates and significant illiterate populations. Running between 2006 and 2015 the United Nations' Literacy Initiative for Empowerment (LIFE) specifically targets the 36 nations with adult literacy rates below 50% or an illiterate adult population of more than 10 million. Of the 36 targeted nations, 29 are located in the Tropics. In the period 1995-2004 to 2005-09 adult literacy rates in the target nations increased by 3.1 percentage points on average compared with a 1.9 percentage point increase globally (UNESCO 2012a). However, even with global support three of the 32 LIFE nations for which data are available experienced a decrease in adult literacy rates, and 24 reported an increase in the illiterate population.

National progress towards the EFA adult literacy goal is mixed, and globally the adult literacy rate has only increased from 80% in 2000 to 84% in 2010, well below the 90% targeted for 2015. Despite widespread government support for the adult literacy goal, often this has not translated to improved outcomes.

Costs of illiteracy

Economic and social inequalities can contribute to unequal access to education and literacy programs, and marginalised social groups often have higher rates of illiteracy (UNESCO 2010). Factors contributing to adult illiteracy include poverty, malnutrition, poor health, migration, child labour and lack of access to education services tailored to adults (Martinez & Fernandez 2010). An inability to read or write can trap individuals in a poverty cycle from a young age, which can limit opportunities for employment or career progression. Completing the cycle, the factors associated with illiteracy

increase the chances of poor health and a greater reliance on welfare or crime for income (Cree et al. 2012).

In addition to impacts at the individual level, illiteracy incurs major costs at the national level in terms of lost productivity, as well as impacts on health and many other social outcomes. Research quantifying the impacts of illiteracy highlight that literacy programs represent an investment in human capital and long-term social and economic productive capacity. In 2012 the cost of illiteracy to the global economy was estimated at US$1.19 trillion, representing 2% of gross domestic product in developed nations, 1.2% in emerging nations and 0.5% in developing nations (Cree et al. 2012). The economic costs of illiteracy are associated with lost earnings, limited employability, lost business productivity and lost wealth creation opportunities. Illiterate adults tend to earn 30-42% less than literate adults and their income is unlikely to grow significantly through their working life (Cree et al. 2012). The social costs of illiteracy are mostly associated with health issues, increased crime and welfare payments.

Box 6.3.3 Literate Brazil program

Despite having a relatively high adult literacy rate, Brazil is one of the top ten nations in terms of the number of illiterate adults. To address this, in 2003 the government initiated the Literate Brazil Program (LBP), with a goal to provide learning opportunities for citizens that had not received basic primary education (that is the first eight years of schooling) or had failed to complete it (UNESCO 2012b). The LBP targets disadvantaged groups such as the indigenous population, fishers, small farmers, seasonal workers, prison inmates, child laborers and people with disabilities. Municipalities with adult illiteracy rates higher than 25% are assigned priority status.

The LBP provides financial support to existing and successful local literacy initiatives. This decentralised approach allows literacy programs to be tailored to the needs of participants. For example, literacy textbooks can be published in local languages and reflect local circumstances. Classes last between 6 and 12 months and, to 2012, around 8 million people had participated in the program. On graduation participants are encouraged to continue their education.

The LBP has contributed to the rise in adult literacy in Brazil from 86% in 2000 to 90% in 2009.

Adult education, Brazil. Image: Gui Tamburus.

Literacy | Youth and adult literacy rates

Youth literacy rates tend to be higher than adult literacy rates, largely reflecting increased access to primary and secondary education among younger generations. Globally, the gap between youth and adult literacy rates has narrowed from 9.5 percentage points in 1989-1993 to 5.8 percentage points in 2005-10[18]. Although the gap between youth and adult literacy rates is larger in the Tropics, adult literacy rates in the Tropics are converging on youth literacy rates considerably more rapidly than in the Rest of the World.

In the Tropics the gap between youth and adult literacy rates narrowed in all regions, though at varying rates. In the Caribbean the gap varied by less than by one percentage point, while in Central & Southern Africa and Oceania it closed by more than eight percentage points.

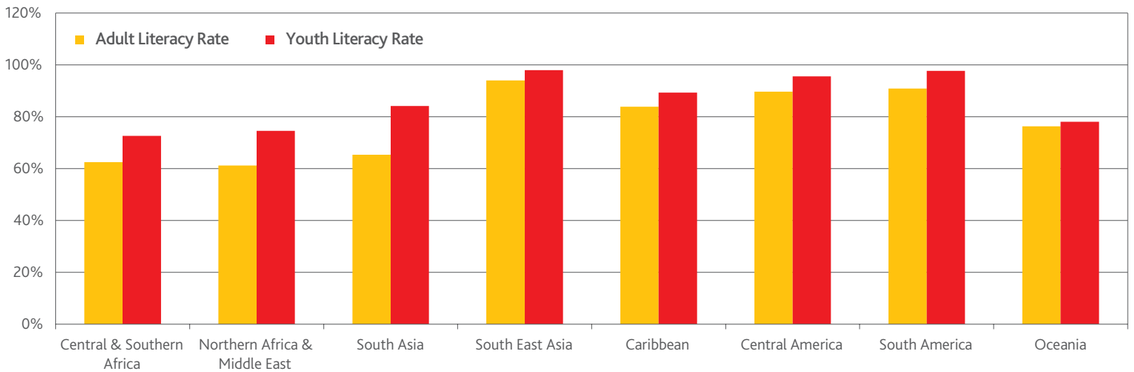
In Oceania this was associated with modest improvements in adult literacy rates combined with a fall in the youth literacy rate. Youth and adult literacy rates in the Tropics are shown in Figure 6.3.9, with the largest disparities being in South Asia, Central & Southern Africa and Northern Africa & the Middle East.

Looking forward

Reducing the number of illiterate people requires an ongoing commitment to strategies that both minimise illiteracy among children and deliver programs to address adult illiteracy. This commitment is especially needed in the Tropics where, despite significant improvements in literacy rates, the number of illiterate youth and adults continues to increase. In addition to education-specific policies, strategies that combat poverty are also likely to contribute to improved educational and literacy outcomes, and contribute to economic and social development.

[18] When comparing youth and adult literacy rates a consistent list of nations and time periods is used. This may result in slight variations in adult literacy rates reported here and in the adult literacy section.

Figure 6.3.9 **Youth and adult literacy – the Tropics, 2005-10**



Source: UNESCO (2012a), UN (2013), State of the Tropics project.

Unemployment rate

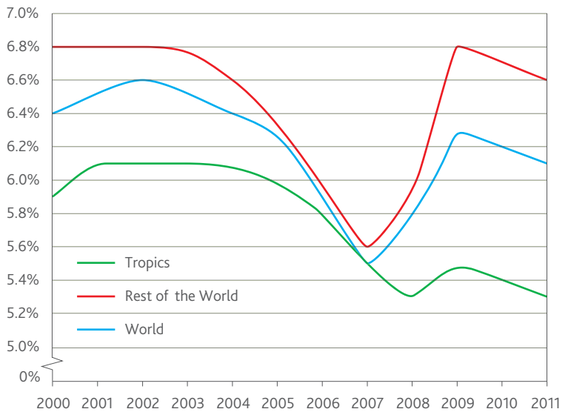
Unemployment is the excess supply of labour relative to demand, and represents the under-utilisation of labour resources in the economy. The unemployment rate is the proportion of the labour force that is unemployed. Rising unemployment is indicative of future falls in national output, the loss of tax revenue and increased government spending on social benefits where such benefits exist. High unemployment can also have social impacts if it increases the risk of crime or leads to xenophobia. At the individual level, for people that were previously employed the loss of a job can result in lower income and living standards, the loss of marketable skills and, in the case of prolonged unemployment, increased risk of health and psychological problems (McKee et al. 2005).

Globally around 40 million new people enter the labour market each year (ILO 2012a), and the prospects of gaining employment are heavily influenced by an individual's skill levels and importantly, economic conditions. Weak economic conditions generally mean greater competition amongst job seekers for employment, particularly amongst low skill workers. In that sense, the global financial crisis in 2008 had profound and widespread consequences for employment creation. The global employment to population ratio was 60.3% in 2011, a 0.9 percentage point drop compared with pre-crisis levels, or a reduction of around 50 million jobs (ILO 2012b). The International Labour Organization (ILO) estimates that the global labour force was 3.3 billion in 2012. In the same year, 200 million people were unemployed and a further 900 million people were employed, but living on less than $2 a day. That is, more than one in three labour force participants were either unemployed or in the group referred to as the 'working poor' (ILO 2012a).

Trends

The unemployment rate tends to be countercyclical to economic activity, meaning that when the economy is booming the unemployment rate tends to be low, and when economic growth is weak the unemployment rate is high. The global unemployment rate increased slightly between 2000 and 2002 before falling consistently to 2007, in line with stronger economic growth. In 2008 and 2009 the global financial crisis resulted in major falls in economic activity and confidence, and a sharp increase in the global unemployment rate. Economic conditions have improved since then and the unemployment rate has started to fall, if only modestly (see Figure 6.3.10).

Figure 6.3.10 **Unemployment rate**



Source: ILO (2011b), State of the Tropics project.

Changes in the unemployment rate in the Tropics and the Rest of the World have followed a broadly similar pattern over the past 10 years, but with a notable difference in the rate itself (see Figure 6.3.10). Since 2000 the unemployment rate in the Tropics has, on average, been 0.7 percentage points lower than in the Rest of the World, and economic growth has been 2.2 percentage points (or 65%) higher on average. In the Tropics the unemployment rate increased from 5.9% in 2000 to 6.1% in 2002, followed by a fall to 5.3% in 2008. There was a one-year lag between the worst impacts of the financial crisis on labour markets in the Rest of the World and the Tropics, and the impacts in the Tropics were quite modest compared with what transpired in many developed nations in the Rest of the World. By 2011 the unemployment rate in the Tropics had returned to pre-crisis levels, while in the Rest of the World it was still a full percentage point higher.

The unemployment rate for the Tropics is principally driven by the three most populous regions – Central & Southern Africa, South Asia and South East Asia – which represent around 70% of the labour force. Although there have undoubtedly been GFC-related impacts, relative to the Rest of the World, each of these regions has experienced strong economic growth since 2000, and this is reflected in unemployment rates.

Unemployment rate movements in the Rest of the World have been more significant, falling by 1.2 percentage points to 5.6% between 2003 and 2007. The impact of the GFC on the unemployment rate in the Rest of the World was swift and severe, especially in 2009. By 2009 the unemployment rate was back at 6.8%, though there have been some modest declines since then. The United States of America accounts for 8% of the labour force in the Rest of the World, and has a strong influence on reported outcomes. The financial crisis had a significant impact on labour markets in the US, with the unemployment rate increasing from 4.6% in 2007 to 9.6% in 2010. In China – which accounts for nearly 40% of the total labour force in the Rest of the World – increases in the unemployment rate were modest, increasing from 3.9% in 2007 to 4.3% in 2010.

There is considerable variation in unemployment rates between regions in the Tropics, with the Caribbean, Northern Africa & Middle East and South America consistently reporting higher unemployment rates during the reporting period (see Figure 6.3.11). With the exception of Cuba, unemployment rates are relatively high in all nations in the Caribbean. Most nations in South America contribute to the high regional rate, while in Northern Africa & Middle East movements in the unemployment rate have been very modest for all nations.

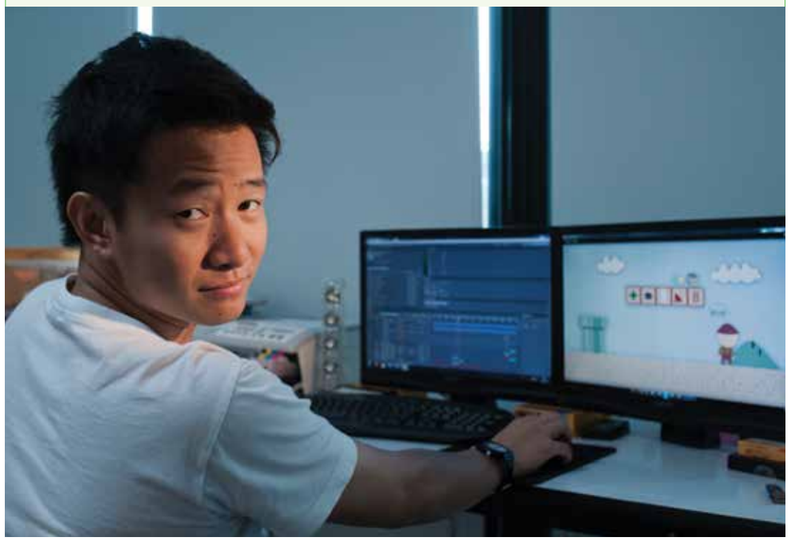
In Central America where tropical Mexico accounts for around 70% of the regional labour force, the North American Free Trade Agreement and remittances means that economic conditions are heavily influenced by events in the US (Villarreal 2010), with the unemployment rate falling steadily to 2007, before increasing rapidly. Unemployment rates in Central & Southern Africa, South Asia, South East Asia and Oceania have largely been unaffected by the financial crisis.

Box 6.3.4 Youth employment

Compared with adults, young people aged 15 to 24 are almost three times as likely to be unemployed as adults (ILO 2013a). In times of high unemployment this can translate to significant swings in the number of youth that are looking for work. At the peak of the financial crisis in 2009 around 76 million youths were unemployed (with a youth unemployment rate of 12.7%), up from 70 million in 2007 (11.5%).

The adverse labour market conditions for youth are also evident in employment rates. Globally the share of the working age population that is employed (referred to as the employment-to-population ratio), declined by one percentage point between 2007 and 2012 due to falling labour force participation and rising unemployment (ILO 2013b). Disaggregation by age group shows that rising youth unemployment and falling youth participation accounted for around half of the decline, despite accounting for less than 20% of the global labour force before the crisis. In other words, the contribution of youth to deteriorating labour market outcomes was disproportionate to its size (ILO 2013b). At the global level the youth employment-to-population ratio fell from 44.2% in 2008 to 42.3% in 2013, with the decline particularly pronounced in developed nations and in East Asia.

Factors contributing to young people finding it harder to secure work include a lack of experience and limited professional networks. For those in work there is also a higher risk of dismissal, as a lack of experience often translates into lower productivity. In the post-GFC environment it is estimated that more than 6 million young people have withdrawn from the labour force globally, preferring to continue their education or giving up on securing a job altogether.



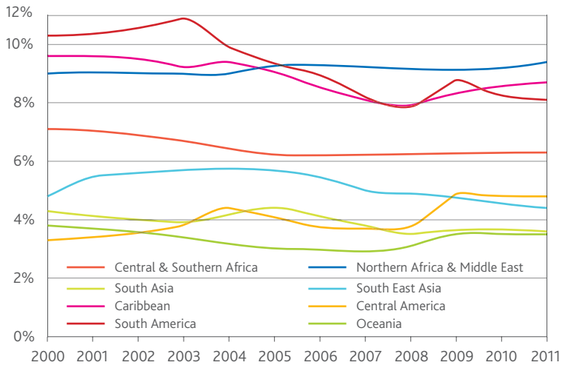
Young professional in Thailand. Image: Gerhard Jörén, World Bank Photo Collection.

Economic growth and labour markets

Higher unemployment is associated with weakening economic conditions, falling demand for goods and services and deteriorating business conditions and consumer confidence. In this environment, firms are hesitant to invest or hire, and there is a negative feedback loop between labour markets and the macro-economy, with the impacts typically being greater for the unskilled and the young (see Box 6.3.4). There also tends to be a considerable lag from the start of an economic recovery and employment growth (ILO 2012b). This is because there is already some degree of under-utilised labour in the workforce, and employers will tend to delay employment decisions until there is some degree of certainty regarding the strength and sustainability of the recovery.

The global financial crisis affected each nation in a different way. The extent of these effects was dependent on a nation's vulnerability to external shocks and its integration with the global economy (UNIDO 2011). As such, many developed nations were impacted more severely when compared with developing and emerging nations.

Figure 6.3.11 Unemployment rates in the Tropics



Source: ILO (2011b), State of the Tropics project.

Long-term unemployment, underemployment and decent work

The unemployment rate alone does not reveal the full status of labour markets, as the duration of unemployment also matters. The longer that an individual is not working, the greater is the risk that they become less attached to labour markets and suffer from skills erosion and reduced employability. Long term unemployment can also increase the risk of social exclusion as, for many people, their identity, social networks and sense of connection with society revolves around work.

Long term unemployment refers to being unemployed for a year or more. The risk of long term unemployment is greatest during recessions, especially where there are also significant structural changes occurring in an economy. As economies are restructuring, a mismatch may arise between the supply of skills that is available in the stock of unemployed – and the demand of skills.

Unemployment rates should be interpreted with caution, as low unemployment rates in highly flexible labour markets can disguise extensive poverty if individuals simply cannot afford to be out of work. That is, high unemployment rates are more likely to exist in developed nations with low poverty rates, where people can afford to remain unemployed for longer periods of time (ILO 2011). Additionally, the ILO considers a person who has worked for at least an hour a week to be employed, which does not capture the reliability or the quality of the work.

The ILO introduced the concept of 'decent work' in 1999 and since then it has gained worldwide acceptance. It encompasses the view that "work is a source of personal dignity, family stability, peace in the community, democracies that deliver for people, and economic growth that expands opportunities for productive jobs and enterprise development" (ILO 2012c). It implies a certain level of social protection for workers, including guarantees of a safe working environment and facilitation of adequate retirement. The United Nations Millennium Development Goals also recognise the role of employment in poverty reduction, and include a target to achieve full and productive employment and decent work for all, including women and young people (ILO 2009).

The increase in informal employment[19] in many developing nations and temporary and precarious employment in developed nations suggests a shift in not just the number of jobs, but also the quality of those jobs (ILO 2012b). There is a growing demand from firms for increased flexibility in hiring and firing practices as a precaution for unexpected changes in economic activity, which results in an increase in the proportion of new jobs that are temporary or part time (ILO 2012b). Additionally, recent austerity measures introduced in some nations include labour market reforms which decrease social protections for workers and erode the power of collective bargaining.

Box 6.3.5 Unemployment and decent work in indonesia

Indonesia is one of the most populous nations in the Tropics and accounts for around 9.5% of its labour force. In recent years, there has been some progress towards the goal of increased 'decent' work but many challenges remain.

Assessments of employment quality in Indonesia suggest there are several significant challenges, including gender issues, youth unemployment and informal employment. In 2010 the employment-to-population rate and labour force participation rate for women were 31.4 and 32 percentage points below those of males respectively, and the unemployment rate for women was 2.6 percentage points higher (ILO 2011a). Also, the youth unemployment rate was 17.7 percentage points higher than the adult rate in 2009 (ILO 2013c).

More broadly there remain significant issues with respect to the stability and security of work, though there have been improvements in wages and conditions in recent years. For example, the working poverty rate[20] in Indonesia has declined from 25% in 1999 to 14% in 2010 and there have been significant improvements in occupational safety. The number of reported work-related injuries fell from 99,023 in 2005 to 10,034 in 2009, and there was also a significant drop in fatal injuries. The proportion of people working more than 48 hours a week has also decreased, from 41% in 1996 to 31% in 2010. However, these improvements have occurred in a labour market where there is no unemployment insurance, where many workers simply cannot afford to be unemployed, and where the share of workers in informal employment is around 60% of non-agricultural employment (ILO 2011a).

Nursing students in Indonesia. Image: Nugroho Nurdikiawan Sunjoyo World Bank Photo Collection.

Decent work is recognised as being instrumental in the reduction of poverty, and as a means of achieving equitable, inclusive and sustainable development (Pereira 2010). Monitoring it is difficult however due to a scarcity of data. In 2008 the ILO initiated its Monitoring and Assessing Progress on Decent Work (MAP) project. MAP covers 10 nations including Indonesia (see Box 6.3.5), and facilitates the identification and analysis of national decent work indicators for input to policy development (ILO 2011a). The aim is to increase full and productive employment, rights at work, social protection and social dialogue.

Looking forward

Although the unemployment rate in the Tropics is not as high as the Rest of the World, unemployment rate alone does not provide information on the conditions of employment, such as wages and hours of work.

Looking forward, economic prospects in many nations of the world are uncertain, affected by fragile banking sectors, weak aggregate demand and sovereign debt risks, notably in developed nations (UN 2011). Deterioration in any one of these areas can have flow-on effects to developing nations through trade and financial channels. Implementation of targeted and effective labour market policies is crucial to maintaining balanced economies, and reducing unemployment rates.

[19] Informal employment is employment that in law or practice is not covered or sufficiently covered by formal arrangements such as national labour legislation, income taxation, social protection or entitlement to certain employment benefits. This includes unregistered employees who do not have explicit, written contracts or are not subject to labour legislation; workers who do not have paid annual or sick leave or social security and pension schemes; most paid domestic workers employed by households; and most casual, short term and seasonal workers.

[20] Poverty status is defined at the household level: members of households that live on less than US$2 at purchasing power parity per person, per day are considered to be poor.

References

Barro R, Lee J-W. (2010). *Educational Attainment in the World 1950-2010.* http://www.voxeu.org/article/educational-attainment-world-1950-2010 (accessed on 19 September 2012).

Butler EP, Ignatowski C. (2010). *Literacy for Out-of-School Youth: A Program Guide.* United States Agency for International Development.

Cree A, Kay A, Steward J. (2012). *The Economic and Social Cost of Illiteracy: A Snapshot of Illiteracy in a Global Context.* World Literacy Foundation, Melbourne.

Hannum E, Buchmann C. (2005). Global Educational Expansion and Socio-Economic Development: An Assessment of Findings from the Social Sciences, in *World Development* **33**(3).

Hanushek EA, Jamison DT, Jamison EA, Woessmann L. (2008). Education and Economic Growth, in *Education Next* **8**(2).

ILO (2009). *Guide to the new Millennium Development Goals employment indicators.* International Labour Organisaion. Geneva.

ILO (2011a). *Decent Work Country Profile: Indonesia.* International Labour Organization, Geneva.

ILO (2012a). *Global Employment Trends 2012.* International Labour Organization, Geneva.

ILO (2012b) *World of Work Report 2012:* Better jobs for a better economy. International Labour Organization, Geneva.

ILO (2012c). *Decent Work Agenda.* International Labour Organization http://www.ilo.org/ (accessed on 7 December 2012).

ILO (2013a). *Global Employment Trends 2013.* International Labour Organization, Geneva.

ILO (2013b). *Global Employment Trends for Youth 2013. A generation at risk.* International Labour Organization, Geneva.

ILO (2013c). *Key Indicators of the Labour Market: Seventh Edition.* International Labour Organization http://kilm.ilo.org/kilmnet/ (accessed on 10 October 2013).

Izushi H, Huggins R. (2004). Empirical analysis of human capital development and economic growth in European regions, in Descy P, Tessaring M. (Eds), *Impact of education and training: Third report on vocational training research in Europe – background report.* Office for Official Publications of the European Communities, Luxembourg.

Martínez R, Fernández A. (2010) *The Social and Economic Impact of Illiteracy.* United Nations Educational, Scientific and Cultural Organization, Santiago.

McKee-Ryan F, Song Z, Wanberg C R, Kinicki AJ (2005). Psychological and Physical Wellbeing during Unemployment: A Meta-Analytic Study, in *Journal of Applied Psychology* 90(1).

OECD (2011). Singapore: Rapid Improvement Followed by Strong Performance, in *Lessons from PISA for the United States.* OECD Publishing, Paris.

Pereira J. (2010). *Decent Work and the Millennium Development Goals: A promising partnership.* SOLIDAR, Brussels.

Ranis G, Stewart F, Ramirez A. (2000). Economic Growth and Human Development, in *World Development* **28**(2).

Ritter A. (2010). *The Cuban Economy.* An Overview of Economic Policy in Cuba circa 2010. http://thecubaneconomy.com/articles/2011/03/an-overview-evaluation-of-economic-policy-in-cuba-circa-2010/ (accessed on 25 September 2012).

UN (2003). *Indicators for monitoring the Millennium Development Goals: Definitions, rationale, concepts and sources.* United Nations, New York.

UN (2011). *World Economic Situation and Prospects 2012.* United Nations, New York.

UN (2012). *The Millennium Development Goals Report 2012.* United Nations, New York.

UNDP (2010a). *Human Development Report 2010 – The Real Wealth of Nations: Pathways to Human Development.* United Nations Development Programme, New York.

UNDP (2011). *Human Development Report 2011 – Sustainability and Equity: A Better Future for All.* United Nations Development Programme, New York.

UNDP (2013). *Human Development Report 2013 – The Rise of the South: Human Progress in a Diverse World.* United Nations Development Programme, New York.

UNESCO (2006). *Literacy for Life. Education for All Global Monitoring Report.* United Nations Scientific, Educational and Cultural Organization, Paris.

UNESCO (2008). *The Global Literacy Challenge.* United Nations Educational, Scientific and Cultural Organization, Paris.

UNESCO (2009). *Education Indicators: Technical Guidelines.* United Nations Scientific, Educational and Cultural Organization, Paris.

UNESCO (2010). *Reaching the Marginalized: Education for All Global Monitoring Report.* United Nations Scientific, Educational and Cultural Organization, Paris.

UNESCO (2011a). *Education Counts: Towards the Millennium Development Goals.* United Nations Educational, Scientific and Cultural Organization, Paris.

UNESCO (2011b). *Out-of-school Children: New data reveal persistent challenges.* United Nations Educational, Scientific and Cultural Organization http://www.uis.unesco.org/Education/Pages/out-of-school-children-data-release.aspx (accessed on 20 June 2013).

UNESCO (2011c). *Education for All Global Monitoring Report, 2011. The hidden crisis: Armed conflict and education.* United Nations Scientific, Educational and Cultural Organization, Paris.

UNESCO (2012a). *Institute for Statistics Data Tables – Education.* United Nations Scientific, Educational and Cultural Organization http://www.uis.unesco.org/Education/Pages/default.aspx?SPSLanguage=EN (accessed on 1 August 2012).

UNESCO (2012b). *Literate Brazil Program.* United Nations Scientific, Educational and Cultural Organization http://www.unesco.org/uil/litbase/?menu=4&programme=50 (accessed on 25 June 2013).

UNICEF (2011). *The State of Pacific Youth 2011: Opportunities and Obstacles.* United Nations Children's Fund, Secretariat of the Pacific Community, Noumea.

UNIDO (2011). *The Global Financial Crisis and the Developing World: Impact on and Implications for the Manufacturing Sector.* United Nations Industrial Development Organization, Vienna.

Villlarreal MA. (2010) *The Mexican Economy after the Global Financial Crisis.* Congressional Research Service, Washington DC.

Woodhall M. (2001). Human Capital: Educational Aspects, in Smelser NJ, Baltes PB. (Eds). *International Encyclopedia of the Social and Behavioral Sciences.* Oxford: Elsevier.

World Bank (2011). *Learning for All: Investing in People's Knowledge and Skills to Promote Development.* World Bank Education Strategy 2020. The World Bank, Washington.

Making artifical limbs Cambodia.
Image: Masaru Goto, World Bank.

Essay 3

Health in the Tropics

Professor Janet Hemingway
Director of the Liverpool School of Tropical Medicine

Professor Hemingway initially trained as a geneticist and is currently Professor of Insect Molecular Biology and Director of the Liverpool School of Tropical Medicine, with 360 staff based in Liverpool, Malawi and several other tropical locations. She has 30 years of experience working on the biochemistry and molecular biology of specific enzyme systems associated with xenobiotic resistance. She is principal investigator on current projects well in excess of £55 million including the Bill and Melinda Gates Foundation funded Innovative Vector Control Consortium.

Commander of the British Empire (CBE) for services to the Control of Tropical Disease Vectors 2012, Inaugurated as a Fellow of the Academy of Medical Sciences in 2006. Inaugurated as a Fellow of the Royal College of Physicians in 2008. Conferred as Honorary Doctor of Science by Sheffield University in 2009. Elected as a Foreign Associate to the National Academy of Scientists, USA 2010. Elected as a Fellow to the American Academy of Microbiology 2011. Inaugurated as a Fellow of The Royal Society 2011.

Mother and child, vientiane.
Image: Stanisias Fradelizi.

Health in the Tropics

Professor Janet Hemingway

Key Messages

- Life expectancy has increased in the Tropics over the last 50 years
- Non-communicable diseases now account for more global deaths than infectious diseases, but infectious diseases still kill two thirds of people in sub-Saharan Africa.
- Major global initiatives to control or eradicate a number of high burden infectious diseases, such as malaria, TB and NTDs mean that this trend towards NCDs should accelerate throughout the Tropics in the next decade.
- Resistance to front line interventions may become a constraint to progress unless the pipeline of new interventions is refreshed.
- Our ability to generate accurate data with which to monitor progress and drive initiatives is a major issue that needs to be addressed.

Introduction

Health is an essential requirement for all individuals. Poor health has a detrimental impact on an individual's quality of life and productivity. Across the world there are major disparities in life expectancy, causes of mortality, and risk factors in health that are linked to environmental, social and economic factors.

The World Health Organisation (WHO) collates global data according to income or WHO region rather than tropical or non-tropical. These data highlights the obvious inequalities in many health indicators between high, middle and low income countries. As a significant proportion of low and middle income countries are in the Tropics, this variation is quite obvious when health indicators across tropical and non-tropical regions are compared. While these disparities are well documented, there is evidence the gap is narrowing for a number of key health indicators. The improvements are driven by economic development, increased advocacy and funding for tackling a number of major infectious diseases that are preventable and treatable, and increased political will to achieve key performance indicators that drive major improvements in health, both internationally and nationally. This overview outlines the major progress achieved in the last decade and the underlying agents for change. Major beneficial shifts in health can readily be tracked by monitoring shifts in life expectancy and causes of mortality. Improvements in quality of life through improved health are harder to quantify accurately at scale.

Table E3.1 **Major causes of mortality 2000 – 2011.**

Mortality cause	Low income	Lower middle income	Upper middle income	High income	World
1	Lower respiratory infection	Ischaemic Heart Disease	Stroke	Ischaemic Heart Disease	Ischaemic Heart Disease
2	HIV/AIDS	Stroke	Ischaemic Heart Disease	Stroke	Stroke
3	Diarrhoea	Lower respiratory infections	Chronic Obstructive Pulmonary Disease (COPD)	Lung Cancer	Lower respiratory infections
4	Stroke	COPD	Lung Cancer	Alzheimers	COPD
5	Ischaemic Heart Disease	Diarrhoea	Lower respiratory infections	COPD	Diarrhoea
6	Premature birth	Premature birth	Road injury	Lower respiratory infections	HIV/AIDS
7	Malaria	HIV/AIDS	Diabetes	Colon Cancer	Lung cancer
8	TB	TB	Liver Cancer	Diabetes	Diabetes
9	Malnutrition	Diabetes	Hypertensive heart disease	Hypertensive heart disease	Road Injury
10	Birth Asphyxia or trauma	Road injury	Stomach cancer	Breast Cancer	Premature birth

Source: WHO (2013)

Life Expectancy

Life expectancy is covered in detail elsewhere in the State of the Tropics, and reports that between 1950 and 2010 the gap between life expectancy in the Tropics and the Rest of the World has narrowed. Over this period life expectancy in the Tropics increased by 22.8 years to 64.4 years and infant mortality reduced by 36%. The rate of change of mortality and morbidity has increased over the last two decades influenced by a range of different factors.

Underlying life expectancy data are aggregated data, collected by the WHO to document the changing patterns of mortality. Table E3.1 provides the top ten causes of mortality in rank order over the last decade.

Non-communicable diseases (NCDs) accounted for two-thirds of global deaths in 2011 and infectious diseases for one-third. In 2000 the relative proportions were 60% NCDs and 40% infectious diseases. This rapid shift reflects the massive scale up in recent efforts to prevent and treat a number of major infectious diseases.

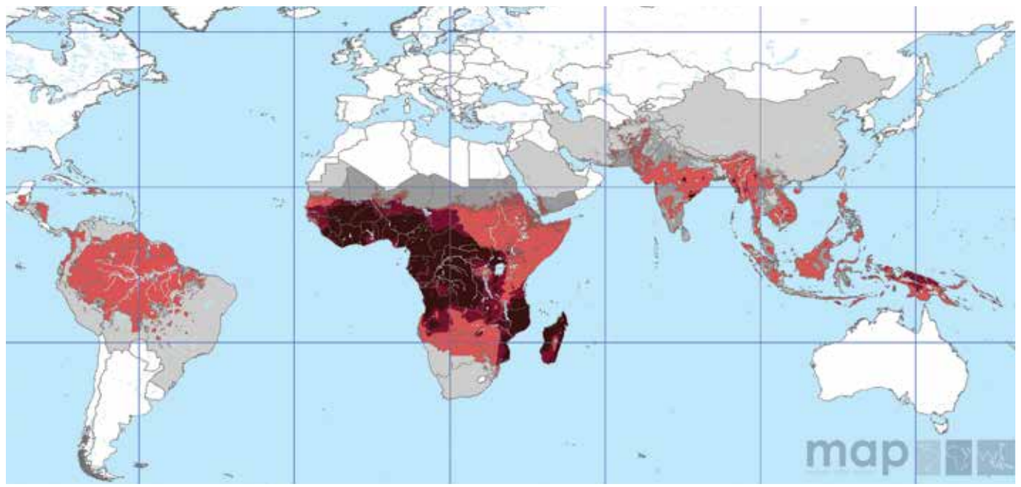
Although improvements in maternal and child mortality have been made these still remain unacceptably high. In 2011, 6.9 million children under the age of five died, 99% of these in low and middle income countries. Malaria, despite the enormous scale up in control activities still accounted for 14% of the under-five mortality in the Tropics.

There are differences in the age at which mortality occurs stratified by income. In high income countries 70% of deaths occur in the over 70s and only one in 100 occurs in an individual under 15 years of age. In low income countries 40% of deaths occur in individuals under 15 years and 20% in those over 70. The differences are predominantly due to the higher burden of infectious diseases and lower levels of access to appropriate maternal, neonatal and child health care. Efforts are being made to address these issues in many countries.

Infectious diseases

A number of infectious diseases occur at high levels in many parts of the Tropics. Many of these diseases are transmitted by insect vectors such as mosquitoes, sandflies or blackflies, and are ideally suited to transmission in warm, high

Figure E3.1 **The spatial distribution of *Plasmodium falciparum* malaria stratified by endemicity class in 2010.**



Source: Malaria Atlas Project (2014).

humidity environments. The spatial distribution of these diseases in some cases is now confined to the Tropics (see Figure E3.1 for *Plasmodium falciparum* malaria endemicity) and is largely driven by climate, as illustrated in Figure E3.2 for *P. vivax* malaria. Prevention of transmission of these diseases is significantly more difficult in the Tropics than in more temperate climates at the limits of the disease distribution. However, the figures, particularly in South East Asia and Latin America where the intensity of transmission of *P. falciparum* malaria has fallen dramatically despite having suitable climates for transmission, are encouraging.

The big three infectious diseases, AIDS, tuberculosis and malaria, are all preventable and treatable. The success rates of prevention and treatment for these diseases have been variable across the Tropics.

HIV

Improvements in HIV treatment have been dramatic since the HIV epidemic was first recognised in 1981. Individuals infected with HIV are now able to have relatively normal lives with access to the correct drugs and treatment regimes, but social stigma associated with HIV, inability to access treatment, sub-standard and/or counterfeit drugs entering the supply chain, and the potential of resistance developing to first line treatments are major threats to long term HIV prevention and treatment.

There were an estimated 35 million people living with HIV in 2012. As access to anti-retroviral therapy in low and middle income countries has improved, with 9.7 million people in these countries receiving treatment in 2012, the population living with HIV will continue to grow as fewer people die as rapidly from HIV and AIDs related causes. Expansion of long term treatment programmes, many with imperfect drug distribution channels and poor compliance will inevitably increase the rate at which resistance to essential HIV drugs is acquired.

While challenges persist in preventing new infections, there are opportunities to dramatically lower HIV incidence. These represent a mixture of drug treatment for those who are infected and behaviour change and prophylactic treatment for those at greatest risk. Antiretroviral therapies can reduce the risk of HIV transmission by as much as 96%, voluntary medical male circumcision by approximately 60%, pre-exposure antiretroviral prophylaxis by more than 40% among men who have sex with men and by 49% among people who inject drugs. The success with which these changes can be implemented will be highly variable given the highly heterogeneous nature across nationalities, cultural groups and their customs and practises.

HIV remains a major issue in the Tropics although in many countries there have been dramatic improvements over the last decade. This has been underpinned by better access to voluntary counselling and testing and high level advocacy for improved access to appropriate and timely treatment. Across sub-Saharan Africa, many countries have reduced HIV prevalence among young people (15–24 years), with HIV prevalence among young women and men falling by 42% from 2001 to 2012. However, HIV prevalence among young women remains more than twice as high as among young men throughout sub-Saharan Africa. Trends are mixed elsewhere, with the Caribbean experiencing substantial declines, but with no clear downward trend apparent in the Middle East or North Africa.

The epidemic continues to have a profound effect on female, male and transgender sex workers. Globally, female sex workers are 13.5 times more likely to be living with HIV than other women. In Uganda, Swaziland and Zambia, 7–11% of new infections are attributable to sex workers, their clients and clients' regular partners. HIV prevalence among sex workers varies across the world, from 22% in Eastern and Southern Africa (eight countries) and 17% in Western and Central Africa (17 countries) to less than 5% in all other regions. These surveys are typically conducted in capital cities and are not nationally representative, so the findings may not be applicable to the entire population. Such problems with data capture, analysis and extrapolation are common across the health sector.

While these downward trends are promising, increased political commitment and strategic action are still needed to reduce the number of adults who acquire HIV sexually. Globally sexual transmission will not be halved by 2015. In particular, key HIV prevention programme elements – including social-behavioural approaches, condom and lubricant promotion, male circumcision and HIV prevention programmes focused on key populations, such as men who have sex with men and sex workers – need to be scaled up and strategically combined to maximise the impact of finite funding and continue to drive down the rate of new infections.

Tuberculosis (TB)

TB is a major global health problem which has seen a resurgence in many countries. In 2012, an estimated 8.6 million people developed TB and 1.3 million died from the disease (including 320,000 deaths among HIV-positive people). Twenty-two high burden countries, many of which are in the Tropics, account for 80% of worldwide TB cases.

Estimates of TB infections have changed substantially since the 1990s, mainly with the recognition of the link between HIV and TB. In 1997 incidence per capita was highest in sub-Saharan Africa at 259 per 100,000 people. South East Asia had the highest number of cases (2.95million), followed by the Western Pacific (1.96 million). Africa had the highest rates of HIV cases that are co-infected with TB (1.2%) and the highest number of TB cases that were HIV positive (32%).

Resistance towards the drugs used for TB treatment is a threat to sustainable progress in driving down TB rates. There are internationally agreed targets for diagnosis and treatment of multidrug-resistant TB (MDR-TB), and new diagnostic technologies that are being rolled out into resource poor settings to facilitate this. Despite these technological improvements, in most countries with a high burden of MDR-TB, less than 25% of the people estimated to have MDR-TB were detected in 2012.

Malaria

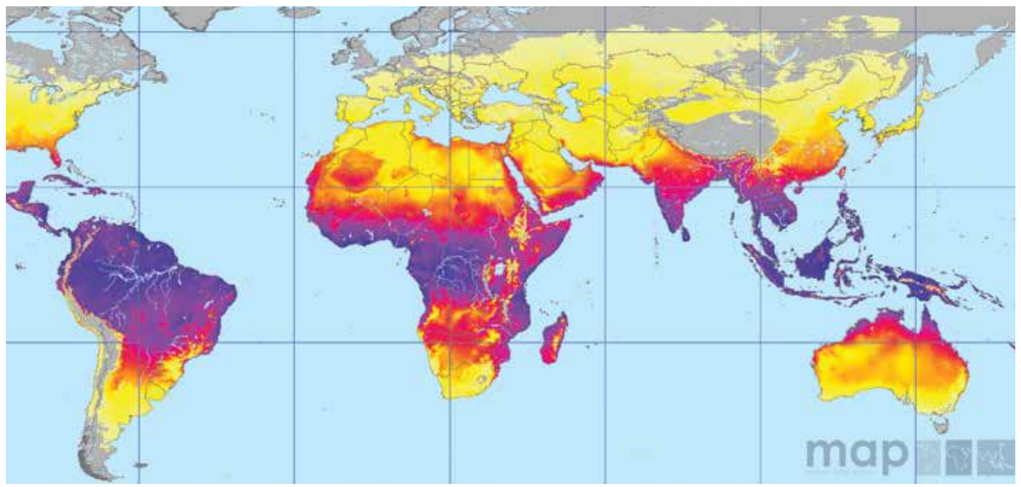
Malaria, which can be caused by infection with several *Plasmodium* parasites, has been a major causes of mortality and morbidity in the Tropics for centuries. Since 2000 expansion in the funding and coverage of malaria control operations has reduced malaria related incidence and mortality. Between 2000 and 2012 malaria mortality rates fell by 42% in all age groups and by 48% in children under 5. Malaria transmission still occurs in 103 countries, of these 59 have managed to reverse the trend of malaria incidence and 52 are on track to meet the Roll Back Malaria and World Health Assembly targets of reducing malaria incidence rates by 75% by 2015 compared to the 2000 baseline.

There is currently major debate on if, how and when malaria could be eradicated. A major WHO led programme in the 1960s was widely seen as a failure, despite notable successes in many countries. Renewed impetus for eradication of malaria has come from the Bill and Melinda Gates Foundation. They concluded that internationally the annual cost of sustaining malaria control was not achievable indefinitely, but scaling up over a finite period for eradication with the right tools, technologies, funding and political will was more feasible. To mark World Malaria Day 2014 (25 April), WHO published a manual to enable malaria-endemic countries to assess the feasibility of moving towards malaria elimination. Since 2000 many countries have declared elimination as a national goal. The new guide will provide countries with a comprehensive framework to assess different scenarios and timelines for reducing the disease burden and moving towards elimination, depending on programme coverage and funding availability.

Neglected tropical diseases (NTDs)

The term neglected tropical diseases was coined by Kenneth Warren of the Rockefeller Foundation in the early 1980s through his Great Neglected Disease Initiative. The concept was revived in 2003, when the first of two WHO meetings was convened to suggest that these diseases should be taken forward as a group, because they shared considerable geographical overlap and could better be addressed by creating synergies

Figure E3.2 **Temperature suitability index for *Plasmodium vivax* transmission in 2010**



Source: Malaria Atlas Project (2014).

between existing programmes. The term neglected comes from the disparity between the catastrophic impact in terms of disability-adjusted life years (DALYs) attributed to these diseases and the attention and funding they receive (0.6% of official development assistance for health).

The 17 NTDs identified by the WHO are given in Table E3.2. They result from four different causative pathogens. These diseases affect more than 1 billion people and are endemic in 149 countries.

Although these are a medically diverse group of infections caused by different pathogens, combining the advocacy and call to action on these diseases under a single banner has had a dramatic effect. In 2012 the WHO produced a road map aimed at accelerating the work to overcome the global impact of NTDs. Progress towards these end goals is now being closely monitored with encouraging but variable results. A large part of these programmes is an unprecedented mass drug distribution programme in all endemic countries. Table E3.3 shows the scale of this drug programme detailing the major donations that are being made by the pharmaceutical Industry to support this global effort.

While these large scale efforts should dramatically improve health outcomes for many in the Tropics a worrying trend is the rapid spread and increased transmission of dengue in urban areas. This expansion is linked to changes in the range of one of the two main *Aedes* mosquito vectors and difficulties in predicting and stopping epidemic sweeps of new serotypes of dengue into naïve populations.

Table E3.2 **The 17 Diseases that make up the NTDs.**

Virus	Protozoa	Helminth	Bacteria
Dengue/Severe dengue	Chagas disease	Cysticercosis/Taeniasis	Buruli ulcer
Rabies	Human African trypanosomiasis (sleeping sickness)	Dracunculiasis (guinea-worm disease)	Leprosy (Hansen disease)
	Leishmaniases	Echinococcosis	Trachoma
		Foodborne trematodiases	Endemic treponema-toses (including yaws)
		Lymphatic filariasis	
		Onchocerciasis (river blindness)	
		Schistosomiasis (bilharzia or snail fever)	
		Soil-transmitted helminthiases	

Source: WHO (2013)

Emerging and re-emerging diseases

About 75% of recently emerging infectious diseases affecting humans are diseases of animal origin, and approximately 60% of all human pathogens are zoonotic.

Zoonoses

Zoonotic diseases are contagious diseases spread between animals and humans. These diseases are caused by bacteria, viruses, parasites, and fungi that are carried by animals and insects. Examples are anthrax, dengue, Ebola haemorrhagic fever, *Escherichia coli* infection, Lyme disease, Plague, Q fever, salmonellosis, and West Nile virus infection

Transmission occurs where people come into contact with infected live poultry, rodents, reptiles, amphibians, insects, and other domestic and wild animals. A common way for these diseases to spread is through the bite of a mosquito or tick.

Recent emergence of such conditions as bovine spongiform encephalopathy (BSE) due to beef ingestion has alerted the medical profession to the dangers to humans of poor animal husbandry practices, such as feeding meat offal waste to cattle. Thankfully transmission has been limited as BSE can only be contracted by eating infected spine or brain tissue from infected animals.

Important bacterial zoonoses which remain problems in many tropical countries include brucellosis, bovine tuberculosis and listeriosis which can be contracted from unpasteurised dairy products.

Leptospirosis is a bacterial zoonosis of worldwide distribution. In tropical regions, the severe Weil's disease is caused by Leptospira carried by rodents and passed in their urine onto soil, water etc with humans being infected through the skin. Weil's disease may present with fever, jaundice, eye haemorrhages and renal failure and is a major hazard for banana farmers and sugar cane workers.

Important protozoan zoonotic infections include the human trypanosomiases. The African forms are transmitted by the bite of the tsetsefly (*Glossina* spp) while the South American form (Chagas' disease) is transmitted by triatomid bugs

Non-communicable diseases (NCDs)

Chronic conditions kill people at economically and socially productive ages and have a major effect throughout the Tropics. Much of the burden of chronic diseases is attributable to environmental and lifestyle factors, including tobacco consumption and decreased physical activity. NCDs are the major contributor to burden of disease in terms of disability adjusted life years (DALYs) in all regions apart from Sub-Saharan Africa. They are the underlying cause of more than half of deaths in adults aged 15-59 in all regions except South Asia and sub-Saharan Africa, where infectious diseases, result in one-third and two-thirds of deaths, respectively.

A similar trend of increased visibility and importance of NCDs is also been seen in Africa. The Global Burden of Disease Study, conducted in 2001, showed that 20% of deaths in sub-Saharan Africa were caused by NCDs. The majority (80%) of chronic disease deaths occur in low- and middle-income countries, reflecting both the size of these populations and the epidemiologic transition from infectious to chronic diseases.

Simple extrapolation from high to middle and low income settings to predict future trends may however be misleading. Cardiovascular disorders, cancer and injuries are consistently highly ranked NCDs. Half of cardiovascular disease deaths in low and middle income settings occur among people 30-69 years of age, which is >10 years younger than in more developed regions.

The NCD research agenda in the Tropics has evolved from learnings in high income countries. The current agenda focusses on evaluations of public health interventions (e.g. monitoring impact of tobacco control measures, voluntary restrictions

Table E3.3 **Major donations of medicines for controlling neglected tropical diseases made by the pharmaceutical industry**

Medicine Donation
Albendazole: Unlimited supply from GlaxoSmithKline for lymphatic filariasis worldwide and up to 400 million doses per year for soil-transmitted helminthiases school-age children worldwide; donations made through WHO
Amphotericin B liposome 445 000 vials from GILEAD for control of visceral leishmaniasis in highly endemic countries in South-East Asia and East Africa; donation made through WHO – combined with preferential price for WHO for other countries (US$18 per vial)
Azithromycin Donated by Pfizer in the context of a full SAFE strategy for the elimination of blinding trachoma; donated through the International Trachoma Initiative
DEC (diethylcarbamazine) Up to 2.2 billion tablets of 100 mg tablets by Eisai Co., Ltd., for the period 2013–2020; donation made through WHO
Eflornithine Unlimited quantity until 2016 from Sanofi for human African trypanosomiasis; donation made through WHO
Ivermectin Unlimited supply for as long as needed donated directly to countries by Merck & Co., Inc., for lymphatic filariasis and onchocerciasis; donated through the Mectizan Donation Program
Multidrug therapy (rifampicin, Unlimited supply for leprosy and its complications from Novartis; clofazimine and dapsone in blister donation made through WHO packs) and loose clofazimine
Mebendazole 200 million tablets annually from Johnson & Johnson for soil-transmitted helminthiases control programmes for children
Melarsoprol Unlimited quantity until 2016 from Sanofi for human African trypanosomiasis; donation made through WHO
Nifurtimox 900 000 tablets (120 mg) per year by 2017 from Bayer for treatment of Chagas disease and human African trypanosomiasis; donation made through WHO
Pentamidine Unlimited quantity by 2016 from Sanofi for human African trypanosomiasis; donation made through WHO
Praziquantel In 2007, Merck KGaA had committed to donating 200 million tablets of 600 mg praziquantel for distribution primarily to African school children. Having originally planned to end the project in 2017, Merck KGaA will continue its efforts to fight schistosomiasis indefinitely with an amount of 250 million tablets per year; donation made through WHO
Suramin Unlimited quantity by 2016 from Bayer for human African trypanosomiasis; donation made through WHO
Triclabendazole From Novartis for fascioliasis; donation made through WHO

Source: WHO (2013)

in salt and saturated fat in processed foods) and household and individual interventions (e.g. detection and treatment of high blood pressure; smoking cessation, diet and exercise advice; substitution of saturated with polyunsaturated cooking fats) in low- and middle-income countries. This may need to change substantially over the next decade, as most currently available interventions are appropriate for only a minority (i.e. the urban high-income populations of low- and middle-income countries) with scant attention paid to NCD prevention and control in urban poor and rural populations which still comprise the majority of the population in the Tropics.

Currently, health services for chronic diseases are fragmented, organisationally weak and are not rising to the challenge of preventing or managing chronic diseases in many low and middle income countries. As these diseases become increasingly important attention will need to shift to reform of the health services, although models will not be able to be adopted directly from those in high income countries.

Monitoring and evaluation

Significant progress has been made in improving health in the Tropics, but the ability to gather and analyse accurate data in the right formats and timescales can be an impediment to effective policy setting. While improvements to monitoring and evaluation systems have been made the implementation of these new systems is highly variable in different parts of the Tropics.

Health management information systems
Public health decision-makers, National health departments and other health professionals require accurate and timely information on the burden to the health service of disease-specific treatments, so they can accurately monitor and plan resource needs. A basic requirement is reliable national and sub-national data detailing the number of treatment events for a given disease or condition occurring at health facilities each month or year. In most tropical settings, this requirement is addressed with a health management information system (HMIS) that coordinates the routine acquisition of treatment records from health facilities and the transfer, compilation, and analysis of these data through district, regional, and national levels.

A perfect HMIS requires all health facilities to report promptly in all months, allowing a comprehensive quantification of treatment events through time and space across the health system. The reality of HMIS in many countries is far from this ideal. Typically, many facilities never report, or report only intermittently, resulting in spatially and temporally incomplete national data. Even following several decades of national government and donor investment in HMIS, the incomplete nature of routine national reporting remains an issue in many countries. There is an expectation that mobile phone technology may improve these systems, reducing the reliance on paper based record keeping and reporting, with information subsequently needing to be keyed into electronic systems, the full benefits of this technology have however yet to be realised.

Data quality
To evaluate the benefit of different health interventions and establish evidence-based policies and practises it is essential that data at local, national, regional and global levels are collected in a timely, appropriate and accurate format. Data are highly variable in type, quality and availability for many health indicators. This can lead to major discrepancies in the quoted global incidence, prevalence and deaths attributed to many causes. Faced with poor data coverage, national treatment burdens are often estimated using rudimentary methods to account for missing values. National and global trends are then calculated by extrapolating available data.

Data quality and consistent formats for data collation and reporting can be a major barrier to assessing trends and developing appropriate national and international policies. For example in 41 of the 103 countries where malaria transmission occurs it is not possible to assess trends in malaria transmission due to a combination of poor data quality, changes in diagnostic methods and different patterns of health service use. Unfortunately these countries account for 80% of all malaria transmission. Until these issues are addressed, progress towards reducing the burden of many diseases will be slowed. Lack of data may also make it difficult if not impossible to eradicate many of the major infectious diseases that are currently being targeted.

Drivers of recent pogress

General trends for many health indicators have been improving in the Tropics in the past two decades. There has been greater advocacy for resourcing better health care and a major shift in emphasis on setting, tracking and achieving major targets for improvement in health. This has changed the landscape for how a number of diseases, which carry a significant level of mortality and morbidity in the Tropics, are tackled. These combined initiatives have accelerated the rate of change, but much still remains to be done. In particular, initiatives aimed at driving the elimination of a number of infectious diseases need to be driven to completion, or the risk of disease rates rebounding when special efforts are withdrawn will remain.

The millennium development goals

The United Nations Millennium Development Goals (MDGs) are eight goals that the UN member states agreed to achieve by 2015. These were contained within the United Nations Millennium Declaration resolution that was adopted by the General Assembly in September 2000. The goals are simply represented pictorially in Figure E3.3. The MDGs were crafted to commit world leaders to combat poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women. Alongside a 2015 target for each MDG, there are a series of indicators to track progress from the 1990 baseline towards these targets. Many of these relate directly to health.

While many countries have made impressive gains in achieving their health related targets, others will fall far short of the targets by 2015. Many of the countries making the least progress are those afflicted by a high prevalence of HIV/AIDs, conflict and economic hardship.

Specific health related targets include:

4A: Reduce the under-five mortality rate by two thirds. The 1990 baseline was an estimated 12.6 million under-five deaths, this had declined by 47% by 2012. The global rate of decline has also accelerated from 1.2% per annum in 1990 – 1995 to 3.9% per annum between 2015 – 2012.

5A: Reduce the maternal mortality rate by three quarters. In 1990 there were an estimated 543,000 deaths, while this had declined to 287,000 by 2010 the rate of decline is less than half that required to achieve the MDG target by 2015. Maternal mortality rates are highest where women have poor access to reproductive health care and effective interventions. While this has improved globally over the period there are still major disparities in access. The starkest of these is in the proportions of births that are attended by skilled personnel. While this is above 90% in three of the six WHO regions, the figure in the African Region is less than 50%.

6A: To halt and begin to reverse the spread of HIV/AIDs, TB and malaria
6B: Achieve Universal access to treatment by 2010
The rate of new HIV infections has clearly declined with an estimated 2.3million people newly infected in 2012 a reduction of 33% on the new infection rate in 2001. Sub-saharan Africa accounted for 70% of all people who acquired HIV infections.

6C: To halt and reverse the incidence of malaria and other major diseases. In 2010 an estimated 219 million cases of malaria resulted in approximately 660,000 deaths. The majority of deaths are still in African children under the age of five.

The number of new TB cases worldwide has been falling slowly since 2006. In 2011 there were an estimated 8.7million new cases, of which about 13% were in people living with HIV. Mortality due to TB has fallen 41% since 1990. TB incidence rates have fallen in all six WHO regions. At 2% per year the rate of decline is slow. Globally by 2012, the TB

Figure E3.3 **Simplified overview of the eight Millennium Development Goals.**

Source: United Nations (2014).

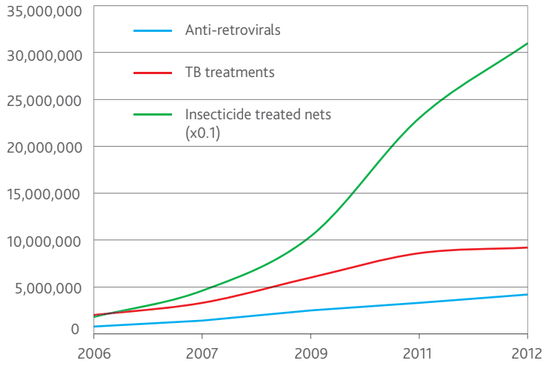
mortality rate had been reduced by 45% from the 1990 baseline. Hence, the target to reduce deaths by 50% by 2015 is within reach.

7C: To halve the number of people without sustainable access to safe drinking water and sanitation. Globally the access to safe drinking water target has been met, with 89% of people in 2011 having access to an improved source of drinking water. Access however has been uneven between regions, urban and rural areas and rich and poor.

The basic sanitation target will not be met by 2015.In 2015, approximately 2.5billion people still did not have access to basic sanitation facilities. There has been an increase of people living in urban areas without access to sanitation as shanty towns grow and migration trends into urban areas continue to increase.

8E: In co-operation with pharmaceutical companies, to provide access to affordable essential medicines in developing countries. This still remains an issue in much of the Tropics. Surveys in 2007 – 2102 showed that access to affordable generic medicines in low and middle income countries was only 57% via public sector outlets. Lack of availability forces patients to try and access medicines through the private sector where costs are five to 16 times higher.

Figure E.3.4 **Numbers of insecticide treated bed nets and treatments for TB and HIV funded by the The Global Fund to fight AIDS, tuberculosis and malaria.**



Source: UN (2013a), State of the Tropics project.

The Global Fund

In many low and middle income nations the significant resources required to fund large scale campaigns to control major diseases are often not available. Numerous bilateral aid mechanisms exist to try and cover this gap, but these are often poorly co-ordinated in the disease endemic country. A different model of supporting efforts to control three major diseases which are prevalent in the Tropics was created in 2002. The idea of establishing a global fund was discussed at a G8 summit in Okinawa, Japan, in 2000. The real commitment began to coalesce at the African Union summit in April 2001, continued at the United Nations General Assembly Special Session in June of that year, and was finally endorsed by the G8 at their summit in Genoa in July 2001. A Transitional Working Group was established to determine the principles and working modalities of the new organization, and the Global Fund came into being in January 2002.

The Global Fund to Fight AIDS, Tuberculosis and Malaria was created to dramatically increase resources for the fight against these diseases. The Global Fund provides a coherent and co-ordinated large scale funding package for each eligible country, linked to endemic county needs, through a managed application process. It does not manage or implement programs on the ground, relying instead on local experts.

Figure E3.4 shows the numbers of insecticide treated bednets for malaria control and treatments for TB and HIV that have been funded by this programme since 2006.

Philanthropic foundations

A notable trend over the last two decades has been the increased engagement of high net worth individuals in global health, either by direct donations or through foundations. The most notable of these is the Bill and Melinda Gates Foundation with annual disbursements of around US$6 billion.

These foundations have not only started to address the funding gap for research and development activities in health related areas that principally affect the poor, but they have also catalysed a new way of working with industry and the normative agencies. For example they have influenced the corporate social responsibility offerings of major pharmaceutical companies, who now donate millions of doses of drugs for NTD treatment and the country distribution systems through NGOs.

Alongside donations of existing products there is now a network of product development partnerships (PDPs) supported by public and philanthropic funding that work with industry to develop new drugs, vaccines, diagnostics, devices and public health insecticides. These PDPs have a portfolio of new products that will be needed to counteract resistance to drugs, antibiotics and insecticides, to improve diagnosis of many tropical diseases and to improve our ability to monitor and evaluate different interventions.

Conclusion

Health in the Tropics has broadly shown a number of dramatic improvements over the last two decades. The shift from infectious diseases to NCDs will force a move away from large scale vertical programmes into a network of health systems and health services strengthening as the population needs change. The level of interest and funding currently addressing global health issues is at an unprecedented high and the R & D and implementation bodies operating in this space have a responsibility to ensure that health benefits for all populations are maximised in a sustainable format from these initiatives. If these inputs are sustained the next decade should see further improvements in health throughout the Tropics. However, if interest, resources and advocacy decline then we will see resurgence in many infectious diseases.

San Juan de Dios Hospital in Guatemala.
Image: Maria Fleischmann.

References

The Global Fund (2014) *The Global Fund to fight AIDS, Tuberculosis and Malaria* http://www.theglobalfund.org/ (accessed May 2014).

Malaria Atlas Project (2014) *Malaria Atlas Project – Resources* http://www.map.ox.ac.uk/ (accessed May 2014).

United Nations (2014) *Millennium Development Goals*. http://www.un.org/millenniumgoals/ (accessed May 2014).

WHO (2013) *Sustaining the drive to overcome the global impact of neglected tropical diseases* World Health Organisation, France.

South Sudan.
Image: Arne Hoel World Bank.

Chapter 7

The Economy

Rupees.
Image: Addison Berry.

Chapter 7.1

Economy | Economic output and the government

Summary of economic output indicators

Indicator		Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Economic output (1980-2010)	Average annual growth	**2.1%**	0.6%	-0.5%	4.6%	4.3%	1.8%	0.5%	0.8%	1.2%	**2.0%**	**1.8%**
	GDP per capita*	**2,480-4,680**	1,310-1,590	4,060-3,460	950-3.670	1,620-5,680	5,670-9,730	8,240-9,700	7,220-9,260	8,890-12,530	**7,720-13,800**	**5,710-9,840**
Public sector debt service (1980-2010) **(% of GNI)**		**3.3-1.1**	4.1-1	2.8-1	0.7-0.5	1.8-1.1	2.5-2.0	4.2-1.9	3.9-1.1	N/A	**N/A**	**N/A**

*Measured at purchasing prices parity in constant 2005 international dollars.

The past 60 years has seen a dramatic rise in living standards across the world. Even nations that today are relatively poor enjoy living standards that were unprecedented 100 years ago. The reasons for this development are varied and complex, however economic growth is considered the most useful indicator for improvements in living standards. Nations that have strong economic growth are better able to reduce poverty rates, strengthen political stability, improve the quality of the natural environment and even diminish the incidence of crime and violence.

Government refers to the system by which a nation, state, or community is governed. It sets and administers public policy and exercises executive, political and sovereign power through customs, institutions, and laws. Decisions made by governments determine how public money is spent, invested and borrowed. Therefore, governments are often directly responsible for facilitating, encouraging and sometimes impeding progress in communities, states or nations.

Headline indicator

Gross domestic product per capita

An economy consists of labour, capital and land resources that produce the goods and services a society consumes. When economic growth is achieved through the more productive use of all resources – including labour – it results in higher per capita income and an improvement in average living standards. Increased productivity is important to economic development.

Supplementary indicator

Public sector debt burden

Public sector debt and deficits concern governments throughout the world. All nations have some form of public debt, but it is the ability to pay that debt that indicates whether it is sustainable or not. Total debt service is the sum of principal repayments and interest actually paid in foreign currency, goods, or services on long-term debt, interest paid on short-term debt and repayments (repurchases and charges) to the International Monetary Fund (IMF) and other creditors. Data are public and publicly guaranteed debt service as a percentage of gross national income (GNI).

Links to other dimensions

Gross capital formation, imports and exports, foreign direct investment.

Is it getting better?

Economic output:
Economic growth in the Tropics has outperformed the Rest of the World over the past 30 years. The Tropics is now estimated to represent 18.7% of global economic activity, up from 14.5% in 1980. South East Asia and South Asia have driven this increase with these two regions representing 10.3% of all global economic output, up from 4.6% in 1980. Despite this, GDP per capita in the Tropics was estimated to be only one-third that of the Rest of the World in 2010. Growth rates in Africa and South America have improved significantly over the past ten years, influenced by stronger demand for commodities, greater political stability and improved governance.

Public debt:
Public sector debt service burden has been improving across most regions of the Tropics over the past three decades. The debt service burden declined in the Tropics by two thirds (from ~3% of GNI to 1% of GNI) between 1980 and 2010.

Since the late 20th century, there has been a strong focus by the international community on reducing debt burdens in the world's poorest nations. Continuing to manage this debt into the future will be a challenge for all nations but particularly for highly indebted nations in the Tropics with unstable governments and shallow export bases.

Waterloo Street, Singapore. Image: William Cho.

Economic output

Across the world there are striking variations in living standards between the richest and the poorest nations. Nonetheless, for most of the world the past 60 years has seen rapid rise in living standards, and even nations that today are relatively poor enjoy living standards that were unprecedented 100 years ago (Weil 2009).

The interplay of environmental, social and economic factors determines living standards. It is generally agreed that important factors for improvements include urbanisation, industrialisation, opportunities for non-agrarian employment, improved education and health care, participation in the global economy and effective governance frameworks. Differences between and within nations with respect to the rate of progress in these variables will affect changes in living standards over time (Sinding 2009). As there is no composite measure that reliably reports each factor's contribution to living standards, economic activity and the income that it generates is generally accepted as a proxy measure of living standards.

The role of economic growth in contributing to improved living standards cannot be overstated as it is necessary – though not sufficient – for achieving social development. Nations that have strong economic growth are better able to reduce poverty rates, strengthen political stability, improve the quality of the natural environment and even diminish the incidence of crime and violence (Loayza & Soto 2002). Economic growth can also provide the resources for public programs that complement its benefits and correct its deficiencies, even if its direct beneficial impact to individuals is modest.

Economic activity is measured as the value of goods and services produced in an economy, and is influenced by a nation's resource endowment, supply of physical and human capital, and demand for the goods and services that it produces. Economic activity occurs in short term cycles which generate year-to-year fluctuations, but it is the long term trend of economic growth that determines how rich a nation is. Gross domestic product (GDP) is the most common measure of aggregate economic activity (see Box 7.1.1).

A large range of economic and social variables influence long term growth rates, including structural policies and institutions, political stability and external conditions. For example, industry and tax policies that create stable macroeconomic conditions are important for growth, while high and variable inflation constrains investment, and excessive tax burdens can distort efficient resource allocation. Institutional structures and policies that favour competition and flexibility in capital, labour and product markets and encourage innovation have a major impact on growth prospects, as do financial systems that direct capital to projects with the highest returns. Investment in physical and non-physical capital (such as education) is also critical for sustained economic growth (OECD 2003).

The interplay of each of these variables impacts productivity, which is a major factor influencing differences in economic growth rates across nations. Sustained productivity and economic growth is typically associated with higher real income, employment and living standards. When measured on a per capita basis GDP is recognised as a general indicator of personal income, and as a proxy for a nation's living standards.

Nonetheless, as the importance of long term environmental and social impacts of economic growth are being increasingly realised, more comprehensive measures of well-being have been developed[1]. However, the majority of these measures are still narrow in their perspective, only incorporating a small number of indicators. While useful for comparative purposes, the reality is that a broad range of other indicators also need to be assessed when considering societal well-being and progress.

[1]These include the United Nation's Human Development Indices and Yale University's Environmental Performance Index.

Trends

Gross domestic product

Global GDP measured at constant value purchasing power parity (PPP), increased at an average rate of 3.4% per annum in the 30 years to 2010. In the Tropics growth is estimated to have averaged 4.1% per annum over the same period, well above 3.2% growth per annum in the Rest of the World. Figure 7.1.1 shows that except for in the early 1980's and late 1990's, annual economic growth in the Tropics has outperformed the Rest of the World over the past 30 years.

Nonetheless, the performance of the regions of the Tropics has varied markedly (see Table 7.1.1). The evolving story in the Tropics (and the World) over the past 30 years is the emergence of South Asia and South East Asia as powerful economic regions. In 2010 these two regions accounted for 55% of economic output in the Tropics, up from 31% in 1980, and have accounted for close to 65% of economic growth in the Tropics in the 30 years to 2010. Central & Southern Africa, the Caribbean and South America also report solid growth, especially in the past 15 years. Growth rates in most other regions of the Tropics were below that of the Rest of the World in the 30 years to 2010, with Northern Africa & Middle East and Central and South America reporting the weakest growth.

Table 7.1.1 also shows a distinct shift in economic growth patterns over the past ten years. While the rate of growth is strengthening in most tropical regions, it has been deteriorating in the Rest of the World. The impact of the global financial crisis was a major factor in the Rest of the World's performance in the five years to 2010, though growth had already weakened substantially prior to that.

While South East Asia and South Asia reported consistently strong growth over the past 30 years, most other tropical regions, with the exception of Oceania, have endured periods of relatively weak growth through the 1980s and 1990s. This has changed dramatically in the past ten years, with the stronger performance reported in most tropical regions typically associated with government reforms coupled with improving commodity prices.

Solid economic growth in South East Asia and South Asia was reported across most nations, but in absolute terms has been dominated by the sheer size of the Chinese and Indian economies, and their very strong and sustained growth performance even though only tropical regions of these nations are included in the analysis.

In China, economic reforms commenced in the late 1970s have generated significant and consistent growth in investment and consumption, and China now participates extensively in world markets. In India, trade and economic reforms introduced since the mid 1980s have significantly increased its global competitiveness and contributed to a rapid expansion of the services sector.

Stronger economic growth in the Tropics has seen its proportion of global GDP increase from 14.5% in 1980 to 18.7% in 2010. Even globally the rise of South East Asia and South Asia is significant. In 2010 these two regions of the Tropics accounted for 10.3% of global economic output, up from 4.6% in 1980 (see Figure 7.1.2), and their significance to global economic activity has been accelerating in recent years. The two regions accounted for 13.8% of global economic growth in the 30 years to 2010, and their contribution to growth has increased in the past 10 to 15 years. In the 10 years to 2010 South East Asia and South Asia accounted for 17.1% of global economic growth.

Of note, Central and South America's proportion of global economic activity has fallen markedly over the past 30 years (see Figure 7.1.2). Weaker growth was particularly evident between 1980 and 2000. In Central America this reflected Mexico's 1982 debt crisis and 1995 financial crisis and, in South America, generally high political and economic risks and inflation. Growth rates in both regions have improved over the past ten years, supported by political stability in many countries, market-oriented reforms, trade liberalisation and, particularly in South America, strong global demand for commodities.

Box 7.1.1 Gross domestic product

GDP is the total value of goods and services produced in an economy after deducting the cost of resources used in the production process. GDP is a fairly comprehensive measure of economic activity, but does not account for consumption of capital in the production process (including the depletion or degradation of natural resources) and non-market activities such as unpaid household work.

GDP is a useful indicator as it condenses the complexity of national economic activity to a single number. Other benefits of GDP as a measure of economic activity are that a relatively standard definition is used by all nations, it is reported frequently, and some measure of GDP is available for almost every nation. As such, international comparisons are relatively easy and trends can be identified quickly.

GDP is reported in local currency units and can readily be converted to other units (such as US or international dollars) to facilitate international comparisons on a consistent basis. Controlling for price changes also allows for more reliable comparison of changes in economic activity over time. When price changes are controlled, data are referred to as being in 'chain volume', 'constant price' or 'real' terms.

A key point to note is that GDP is a measure of economic activity, not a measure of living standards – two quite separate concepts. The argument for using GDP as a proxy indicator of living standards or personal income is not that it is a good measure of the absolute level of living standards, but that living standards tend to change with per-capita GDP.

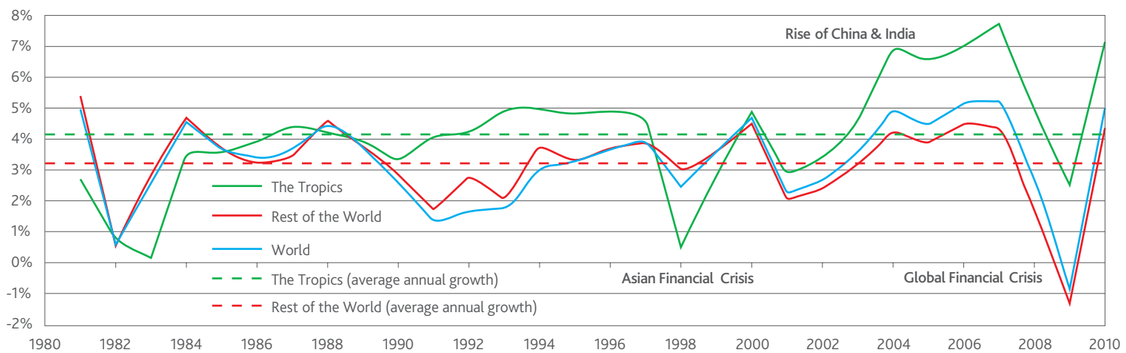
Mining truck. Image: Graeme Churchard.

Table 7.1.1 **Economic growth***

	Average annual growth (%)							
	1980 - 1985	1985 - 1990	1990 - 1995	1995 - 2000	2000 - 2005	2005 - 2010	1980 - 2010	2000 - 2010
Tropics	**2.1**	**3.9**	**4.6**	**3.6**	**4.8**	**5.8**	**4.1**	**5.3**
Central & Southern Africa	0.9	3.3	1.1	3.8	5.5	6.5	3.5	5.9
Northern Africa & Middle East	-3.2	3.4	2.6	3.3	4.3	3.6	2.3	3.9
South Asia	4.9	5.7	5.9	5.6	7.1	8.3	6.3	7.7
South East Asia	4.5	7.5	8.2	3.4	6.1	6.5	6.0	6.3
Caribbean	0.3	2.3	3.7	4.7	4.0	4.6	3.3	4.0
Central America	1.7	1.4	1.5	4.9	1.8	2.6	2.3	2.2
South America	0.9	2.1	3.3	1.7	3.1	4.5	2.6	3.8
Oceania	4.1	3.7	3.2	3.9	3.3	2.1	3.4	2.7
Rest of the World	**3.4**	**3.6**	**2.7**	**3.7**	**3.1**	**2.7**	**3.2**	**3.1**
World	**3.2**	**3.6**	**3.0**	**3.7**	**3.4**	**3.3**	**3.4**	**3.4**

Source: World Bank (2013) State of the Tropics project.
*Gross domestic product measured at purchasing prices parity in constant 2005 international dollars.

Figure 7.1.1 **Economic growth***



Source: World Bank (2013), State of the Tropics project.

Per capita gross domestic product

With the exception of Northern Africa & Middle East, all regions in the Tropics reported growth in GDP per capita in the 30 years to 2010 (see Table 7.1.2). Starting from the lowest base, South Asia reported the fastest growth in per capita GDP, increasing at an average rate of 4.6% per annum, followed by South East Asia which increased at 4.3% per annum.

When population growth exceeds economic growth, deterioration in GDP per capita and general living standards is implied. This is what has occurred in Northern Africa & the Middle East, where population growth averaged 2.8% per annum in the 30 years to 2010, and economic growth 2.3% per annum. Over the past decade stronger economic growth has driven improvements in GDP per capita, as population growth has remained relatively high, averaging 2.9% per annum.

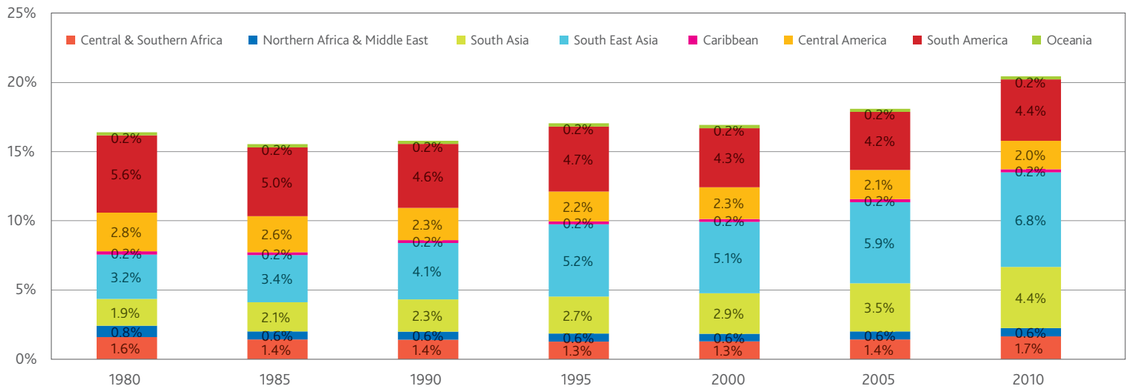
Living standards and demography

As population growth is primarily a function of fertility and mortality rates[2], GDP per capita is influenced by changes in these variables. That is, changes in living standards are a function of economic growth, but also of demographic change. Globally, fertility rates have declined over the past 60 years – from 4.97 in 1950 to 2.53 in 2010 – and in the developing world, declining birth rates and rising living standards have tended to go hand-in-hand. In the Tropics the absolute decline in fertility rates is even more dramatic than globally, down from 6.15 in 1950 to 3.35 in 2010 (see Table 7.1.3). Working in the opposite direction, life expectancy has increased markedly over the past 60 years, but its impact in terms of population growth is less significant.

Reductions in fertility contribute to changes in the structure of the population, increasing the size of the workforce relative to the number of children under the age of 15 and people over 65 (that is, the 'dependent' population). When fertility is high and a nation is 'young' there are a large number of dependent children in society. Similarly, as a population ages, the dependency ratio increases, as older people leave the workforce. But the switch from one to the other provides a window for economic development and poverty reduction – the so-called demographic dividend – as the twin impacts of an increase in the economically active population and a decrease in the dependent population increases income per capita outcomes.

[2] Figures for 'The Tropics' and 'Rest of the World' use nations for which the World Bank reports a minimum of 25 years of data (i.e. at least 80% of data points). 'World' figures are reported by the World Bank. For 2010 'The Tropics' and 'Rest of the World' represent 91.4% of world GDP. Nations excluded from the analysis include the Russian Federation (3.0% of the World Bank's global PPP in 2010), Poland and Taiwan (around 1% each), Ukraine (0.4%) and Czech Republic (0.4%). Nations in the Tropics that are excluded represented around 0.5% of global GDP in 2010, and include Cuba, Puerto Rico, Tanzania, Somalia and Zimbabwe. In the 30 years to 2010 the World Bank reports average global PPP GDP growth of 3.3% per annum, while the State of the Tropics abridged series estimates growth of 3.4% per annum.

Figure 7.1.2 **The Tropics – proportion of global economic activity***



Source: World Bank (2013), State of the Tropics project
* Gross domestic product measured at purchasing prices parity in constant 2005 international dollars

Rapid economic growth in South East Asia and Latin America has been attributed to this dividend, and more recently the growth of the working age population in South Asia has also had a positive impact on economic growth (Aiyar & Mody 2011). Although life expectancy throughout Africa and the Middle East has improved, this region has yet to experience the much lower fertility of other tropical regions, potentially slowing demographic transition (Bloom et al. 2003).

This is not to suggest that lower fertility is a necessary condition for economic development but, intuitively, lower fertility establishes conditions in which families and governments can invest more per capita in education and health, and in developing the human capital needed for sustained economic growth (Sinding 2009). In the Tropics the pace of decline in fertility rates has been particularly pronounced over the past 30 years.

Figure 7.1.3 plots GDP per capita and fertility rates for the Tropics in 2010 and shows the strong link between the two. Nonetheless declining fertility alone is not sufficient to ensure the demographic dividend translates to stronger economic growth and rising living standards. There is a need for these demographic changes to be complemented by sound policies that support economic growth. Traditionally this has been around factors such as governance, savings, investment, industry, fiscal and monetary policies and trade openness, but is now also increasingly cast in terms of the need to invest in human capital and development to sustain economic growth and improve living standards.

A key issue in economic development is whether economies that start out behind in terms of income per capita tend to grow faster and converge towards those that began ahead. Research around this concept is inconclusive, but it appears likely that convergence is constrained because of the imperfect mobility of factors of production (notably labour); different endowments (notably human capital); market segmentation (especially for services); and limited technology diffusion (especially related to distance, but also in applying technology developed in the temperate zone to tropical settings)(Sachs 2001). However general policy shifts towards greater deregulation of capital, labour and product markets in developing markets, are supporting growth and convergence. Nations will have different long run GDP per capita outcomes because of differences in government policies (e.g. taxation, property rights, infrastructure provision and services etc), social attitudes (e.g. saving, work effort, fertility etc.) and natural resource endowment.

Even if convergence does not occur it is important for tropical nations to pursue economic

Table 7.1.2 **GDP per capita***

	1980	1985	1990	1995	2000	2005	2010	1980 to 2010 (average annual growth %)
Tropics	**2,480**	**2,450**	**2,660**	**3,010**	**3,270**	**3,810**	**4,680**	**2.1%**
Central & Southern Africa	1,310	1,180	1,200	1,100	1,160	1,330	1,590	0.6%
Northern Africa & Middle East	4,060	2,700	2,710	2,810	3,040	3,220	3,460	-0.5%
South Asia	950	1,100	1,310	1,630	1,970	2,630	3,670	4.6%
South East Asia	1,620	1,830	2,390	3,160	3,490	4,350	5,680	4.3%
Caribbean	5,670	5,240	5,450	6,060	7,130	8,180	9,730	1.8%
Central America	8,240	8,070	7,780	7,660	8,930	9,140	9,700	0.5%
South America	7,220	6,680	6,710	7,230	7,260	7,850	9,260	0.8%
Oceania	8,890	10,110	11,470	11,590	11,620	12,450	12,530	1.2%
Rest of the World	**7,720**	**8,470**	**9,330**	**9,980**	**11,340**	**12,620**	**13,800**	**2.0%**
World	**5,710**	**6,110**	**6,670**	**7,130**	**7,970**	**8,870**	**9,840**	**1.8%**

Source: World Bank (2013) State of the Tropics project.
*Gross domestic product measured at purchasing prices parity in constant 2005 international dollars.

Box 7.1.2 Spreading the wealth

The distribution of income is an indicator of how the benefits of economic growth are shared across a nation's population, with a relatively 'equal' distribution suggesting that benefits are broadly shared. A criticism of economic growth as an indicator of changes in individual wellbeing is that in some countries national income growth has not been equally distributed across the population, with a large proportion of benefits accruing to the rich. In these instances economic growth's potential impact in reducing poverty and improving living standards are constrained. That is, inequality can dampen the poverty reduction impact of economic growth.

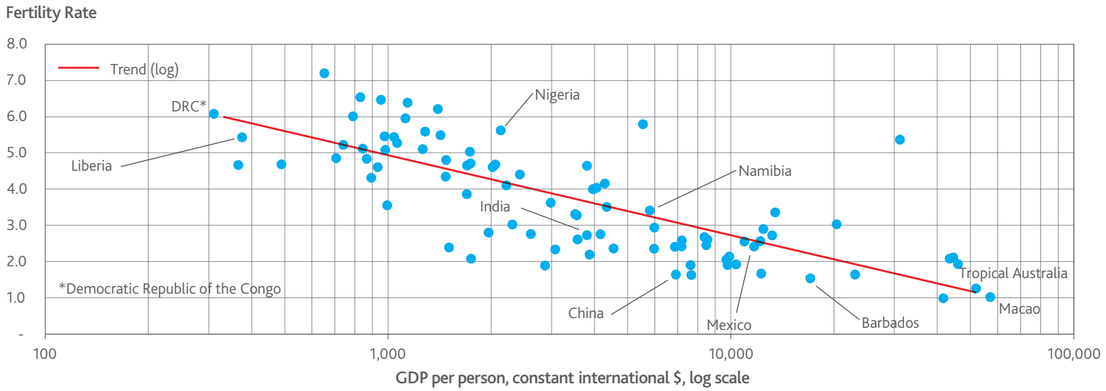
A number of measures are available to assess income distribution, including the share of national income accruing to the poorest 20% of the population, the proportion of the population living in poverty and the GINI index. Each measure has its strengths and weaknesses, and data for each is collected infrequently. The proportion of the population living in poverty is not an indicator of the distribution of income per se, but it does provide insight into how the benefits of economic growth filter down to the most vulnerable sections of society.

A benefit of poverty as an indicator is that conceptually it is easy to interpret, as fewer people living in poverty can be viewed as a socially positive outcome. Of the measures of income distribution, it also has the greatest number of data points. In developing nations of the Tropics it is estimated that 51% of the population was living on less than $1.25 per day in 1981, falling to 29% in 2008. The largest improvement was in South East Asia where the proportion of the population living in poverty fell from 70% to 20%, followed by South Asia (from 59% to 37%). Given population growth and changes in the distribution of income, despite a decrease in the proportion of the population living in poverty in South Asia the actual number of people living in poverty is estimated to have fallen only slightly, while in South East Asia there has been a significant reduction in the number of people living in poverty.

Poverty estimates calculated with PovcalNet: the on-line tool for poverty measurement developed by the Development Research Group of the World Bank. Available at:: http://iresearch.worldbank.org/PovcalNet/index.htm.

Vietnam. Image: United Nations Photo.

Figure 7.1.3 **The Tropics – proportion of global economic activity***



Source: World Bank (2013), State of the Tropics project
*Measured at purchasing price parity in constant 2005 international dollars.

Table 7.1.3 **Fertility rates**

								Change (#)	Change (#)	Change (#)
	1950-1955	1955-1960	1965-1970	1975-1980	1985-1990	1995-2000	2005-2010	1950-1980	1980-2010	1950-2010
Tropics	**6.15**	**6.17**	**6.06**	**5.24**	**4.48**	**3.75**	**3.35**	**-0.91**	**-1.89**	**-2.80**
Central & Southern Africa	6.56	6.59	6.75	6.93	6.72	6.14	5.58	0.38	-1.35	-0.98
Northern Africa & Middle East	6.76	6.83	7.03	7.25	7.09	6.39	5.57	0.50	-1.69	-1.19
South Asia	5.93	5.94	5.74	4.96	4.11	3.28	2.63	-0.96	-2.34	-3.30
South East Asia	5.94	5.95	5.92	4.46	3.44	2.44	2.21	-1.48	-2.25	-3.73
Caribbean	5.31	5.24	5.08	3.70	3.27	2.77	2.41	-1.61	-1.29	-2.90
Central America	6.74	6.81	6.66	5.39	3.98	3.15	2.62	-1.35	-2.77	-4.12
South America	6.38	6.38	5.74	4.51	3.37	2.70	2.22	-1.87	-2.30	-4.16
Oceania	5.36	5.48	5.04	4.52	4.01	3.79	3.44	-0.84	-1.07	-1.91
Rest of the World	**4.53**	**4.42**	**4.39**	**3.23**	**2.99**	**2.21**	**2.06**	**-1.30**	**-1.18**	**-2.47**
World	**4.97**	**4.91**	**4.85**	**3.85**	**3.45**	**2.73**	**2.53**	**-1.12**	**-1.32**	**-2.44**

Source: UN (2013), State of the Tropics project

Box 7.1.3 Productivity and economic growth

Economic growth is a function of factor accumulation (an increase in inputs to the economic process, such as a larger labour pool or more land under agriculture) and productivity improvements (more output from a given level of inputs). With accumulation, adding more inputs does not increase the income earned per unit of input, while productivity improvements generate more output and income per unit of input, including for the existing commitment of resources.

In most nations productivity is the primary determinant of growth in GDP per capita, and the link between living standards and productivity will become even more critical as societies age and the proportion of the population engaged in the labour force falls. Looking forward, productivity growth will be enhanced by the application of new technologies and organisational innovation, as well as government investment in infrastructure and policies that promote education and skills development.

Construction in Philippines. Image: Nonie Reyes, World Bank.

development as it is a necessary condition for social development. What are some of the conditions for economic development? Traditional economics points to increases in the factors of production such as labour (through increases in the working age population and/or participation rates), capital (capital deepening) and productive land. More efficient use of the factors of production – that is, improved productivity – is also crucial (see Figure 7.1.1 and Box 7.1.3), and the source of productivity improvements will vary from country to country. Critically underpinning how factors of production are utilised are government development policies, and the regulatory environment that supports industry development and entrepreneurship.

Looking forward

The need to balance economic and environmental sustainability is an issue for all nations. In many nations, and especially developing nations, achieving this balance will be a challenge as governments and populations strive to dramatically improve living standards and social conditions, while also maintaining the environment and political stability. There have been some cases of decoupling environmental pressures from economic growth, but often this has been associated with globalisation, and richer nations relocating environmental and social impacts to poorer nations. For all nations, pursuing short term economic development strategies that ignore environmental impacts is generally shown to be ill advised in the longer term.

Climate change is also an important consideration in future economic development, and is expected to have greater effects on the poor and other vulnerable people and nations (Metz et al 2007). Mitigation measures will be important policy considerations for larger tropical nations but adaptation to the impacts of climate change should be a serious policy consideration of all tropical nations.

Public sector debt service burden

Public sector debt and deficits concern governments throughout the world. All nations have some form of public debt, but it is the ability to pay that debt that indicates whether it is sustainable or not. Government debt is money owed by a national government. It can be categorised as internal debt (owed to local lenders) and external debt (owed to foreign lenders). Governments usually borrow by issuing securities, government bonds and bills. Low levels of debt are typically considered preferable to high levels (despite many high income nations also having high levels of debt), but what is really critical, is how funds are used and the capacity of the government to repay that debt. Debt 'crises' are caused not so much by the level of the debt but rather in the capacity to serve it (Sjaastad 1983).

Nations which struggle to meet their debt obligations are often faced with high unemployment and devalued currencies with flow-on effects to standards of living and development. Government revenue that could be allocated to public good programs is often diverted to service debt. One of the targets of the United Nations' Millennium Development Goals (MDGs) is to deal comprehensively with developing countries' debt, showing the importance of this indicator for the sustainable development of many nations (United Nations 2012).

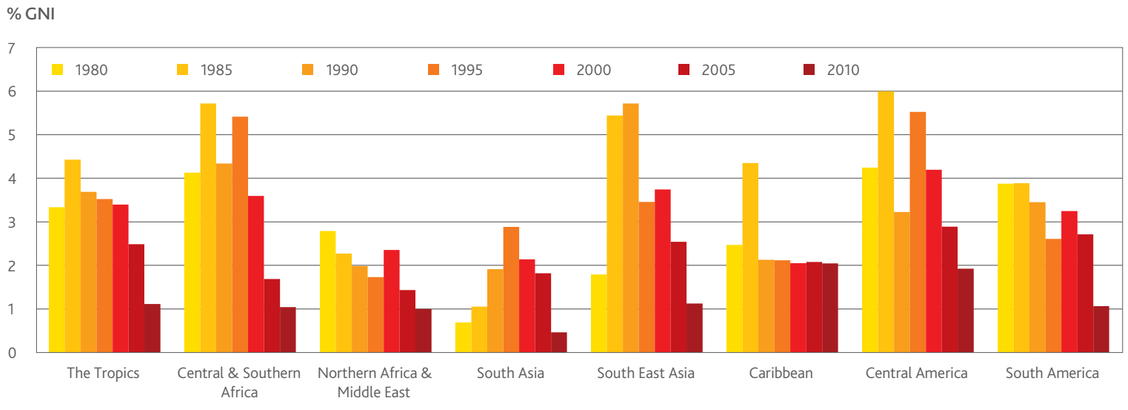
Many nations, especially poor nations, must borrow money to invest in capital and development projects, however, the combination of a narrow export base, poor policies and weak institutions place these nations at high risk of debt distress. Tension exists between taking on debt to finance national development strategies that encourage growth, and maintaining debt sustainability. Export shocks such as changes in commodity prices, particularly for natural resources, can have severe repercussions for nations with high debt burdens.

Total debt service is the sum of principal repayments and interest paid on long and short term debt and repayments to the International Monetary Fund (IMF) and other creditors. Data are public and publicly guaranteed debt service as a percentage of Gross National Income (GNI).

Trends

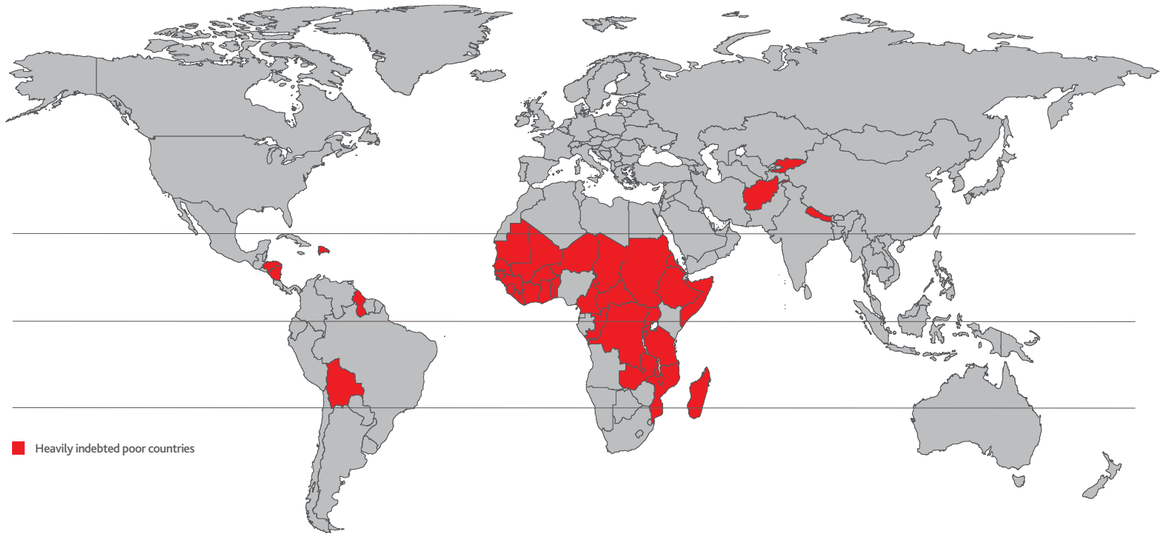
Although variable, public sector debt service burden has declined across most regions of the Tropics over the past three decades (see Figure 7.1.4). Remaining at more than 3% of GNI in the 1980s and 1990s, due to debt crises in Latin America and Africa, it has decreased rapidly since 2000 to be around 1% of GNI in 2010. Comparisons cannot be made with the Rest of the World as comparable data are not available for many nations.

Figure 7.1.4 **Debt service burden, the Tropics (% GNI)**



Source: World Bank (2013), State of the Tropics project.
Note: There are no data available for Oceania. The Caribbean only includes data for the Dominican Republic. Other large economies omitted from analysis due to data availability are Tanzania, Nigeria, Saudi Arabia, Hong Kong, and Singapore.

Figure 7.1.5 **Heavily indebted poor countries that have qualified for debt relief*.**



Source: Source: IMF (2013).
*As of September 2013

Central America, driven by Mexico had a debt service burden of almost 2% in 2010, the second highest in the Tropics. However this is a vast improvement since the 1980s and 1990s which saw debt service rise to 6% of GNI. Rapid improvement has followed the Mexican debt crisis in 1994 when the peso was devalued and a new debt agreement had to be negotiated with the United States and International Monetary Fund.

Central & Southern Africa, Northern Africa & Middle East, South East Asia and South America have shown similar patterns of high debt service during the 1980s and 1990s and rapid improvement since the turn of the century.

The decline in debt burden from 2000 to 2010 across the Tropics can be attributed to a number of factors including strong economic growth, a rise in export earnings, high international prices for primary commodities and a marked shift in external financing from debt to equity in a number of developing nations (World Bank 2013). Debt restructuring and outright debt relief from official and private creditors, due to programmes such as the Heavily Indebted Poor Nations (HIPC) Initiative and the Multilateral Debt Relief Initiative (MDRI) would have also had some impact (even though these initiatives are focused on very low income nations with relatively small contributions to regional GNI) (IMF 2013).

The shift from external debt to equity has been important particularly for middle income nations not eligible for debt relief. It represents investments being made in tropical nations where previously, those nations had to borrow to finance certain capital projects. It also means the risks associated with new capital and developments are shared more widely, increasing the resilience of the investment.

Although not detectable in aggregated time series data, the global economic and financial crisis (2008 and 2009) has had an impact on debt burden worldwide, but recent data for developing nations has shown an improvement to 2010.

Box 7.1.4 Debt relief for disasters – the 2004 Indian Ocean tsunami

In 2004, a massive undersea earthquake triggered a series of devastating tsunamis along most coastlines of the Indian Ocean, killing more than 230 000 people, and displacing nearly 2 million people. It is considered one of the deadliest natural disasters in recorded history. Indonesia suffered the most loss of life and property followed by Sri Lanka, India and Thailand.

In response to the disaster, the four most affected nations were offered a debt moratorium by some of the wealthiest economies in the world (The Paris Club – see Box 7.1.5), in addition to foreign grants and concessionary loans from multi-lateral organisations (Okoth 2012). India, Indonesia and Thailand refused to accept the debt moratorium. In this case, accepting debt relief had the potential to be counter-productive. The nations proposing the debt relief did not hold the debt, so there was potential damage to the debtor nations' credit ratings and future access to funding from private capital markets. The Paris Club would have had to convince commercial creditors to write off the debt. Sri Lanka accepted US$500 million worth of debt moratorium for one year (2005) (Saravananthan & Sanjeewanie 2008).

The nations which refused debt relief did accept concessionary (interest free or low cost) loans for the reconstruction of damaged infrastructure such as roads, bridges, telecommunications, transport systems, schools and hospitals. This proved to be an effective use of funds as it allowed the affected nations to develop public capital (an investment in the future) and still service their debts (Okoth 2012).

Rebuilding after the tsunami in Thailand. Image: Michael Sarver.

Debt relief programs

Debt service is a major issue affecting economic and human development prospects in many of the world's poorest nations. Since the late 20th century, there has been a strong focus by the international community on reducing the debt burdens of the world's poorest nations. A number of programs arising from G8 nations, the World Bank, Asian Development Bank, African Development Bank and International Monetary Fund are working to relieve debt in low income nations (IMF 2008).

The Heavily Indebted Poor Countries (HIPC) initiative was launched in 1996 by the World Bank and International Monetary Fund and aims to ensure that no poor nation faces a debt burden that it cannot manage. All but three of the 39 HIPCs are found in the Tropics, and most of those are in tropical Africa (see Figure 7.1.5). In order for nations to qualify for debt relief under this Initiative, they must meet certain criteria, commit to poverty reduction through policy changes, and demonstrate a good track record under programs supported by loans from the IMF and World Bank. During the initial stage, the International Monetary Fund and the World Bank provide interim debt relief and when a nation meets its commitments, full debt relief is available.

To help accelerate progress towards the United Nations Millennium Development Goal (MDGs) to deal comprehensively with developing country debt, the Multilateral Debt Relief Initiative (MDRI) was added to HIPC Initiative in 2005. This Initiative allows for 100% relief on eligible debts held by the IMF, World Bank and the African Development Fund (IMF 2013).

Although these programmes have reduced public debt in many nations, debt relief as an instrument to relieve poverty and promote development has received some criticism. Between 1989 and 1997, total debt forgiveness to poor nations totaled US$33 billion. During the same period, new borrowing by the same nations was estimated to US$41 billion (Easterley 2000). Without the necessary strong institutions and governance, debt relief may only succeed in transferring limited resources to corrupt governments with proven track records of misusing aid, potentially aggravating poverty among the world's most vulnerable populations (Easterley 2001, Chauvin & Kray 2010).

Despite a number of private creditors taking part in debt restructuring (e.g. The London Club, see Box 7.1.5), not all are willing to deliver debt relief under these initiatives. Some commercial creditors have been unwilling to extend relief under the HIPC initiative, leading to arrears accumulation, which can contribute to a rise in debt stock (Kutessa & Nabbumba 2004). Some creditors have even taken their debtors to court, suing for full payment of debt plus compensation.

There is evidence, however, where debt relief has had positive results in tropical nations. In Tanzania, savings from debt relief have been directed towards education; increasing school enrollments, building new classrooms, and recruiting more teachers. Debt relief in Mozambique led to 50 new HIV/AIDS testing and counseling offices being opened by 2007 (IMF 2013). The bulk of debt relief in Uganda has helped fund universal primary education, doubling school enrollment between 1997 and 1999 (Kutessa & Nabbumba 2004). An investigation across all HIPCs demonstrated that infant mortality rates decrease once nations receive debt relief through the initiative (Schmid 2009).

The challenge for multilateral organisations such as the World Bank and IMF is to ensure that debt relief and debt forgiveness programs really do lead to government reforms that enhance the economic and human development prospects of all people.

Debt-for-nature swaps

Nations under high debt stress often engage in economic activity with negative environmental outcomes such as deforestation (Torras 2003). Considered a win-win action for both the economy and the environment, debt-for-nature swaps are a financial instrument which exchange debt reduction or cancellation for prescribed conservation activities (Goekel & Gray 2011). Introduced in 1987 with an agreement between Bolivia and Conservation International, over the next ten years debt-for-nature swaps accounted for US$134 million worth of commercial developing nation debt. The majority of these projects were focused on tropical forests; improving protected area governance and promoting alternatives to deforestation (Raghabendra & Schartan 2001).

The significance of debt-for-nature swaps has declined since the mid-1990s due to the development of much larger debt relief programs (such as the HIPC Initiative and MDRI mentioned above). Additionally, concerns around the relatively small contribution to overall debt stock and whether they resulted in true economic and conservation outcomes, led to widespread criticism of these debt swaps (Knickley 2012). However, the vital role of tropical forests in limiting the likelihood of dangerous climate change has facilitated a renewed interest in debt-for-nature swaps in recent years, particularly for tropical nations such as Indonesia, Vietnam and Brazil which fall outside of the HIPC/MDRI framework (Cassimon et al. 2012). Although not a magic bullet, debt swaps could be considered one of a number of approaches for reducing deforestation and encouraging good environmental outcomes in the Tropics while alleviating debt service.

Looking Forward

Tropical nations will probably never be free of public debt. Indeed, in many cases, borrowing money is essential for ongoing development in the region. A challenge for all nations, particularly in the face of current economic instability, will be to manage this debt so that repayment does not trade off health, education and environmental development. Given tropical nations are amongst the poorest in the world, and carry high amounts of debt relative to income, this will be particularly important. Debt relief programs may alleviate debt problems temporarily but also have the potential

Box 7.1.5 Where does the money come from?

The international lending and borrowing environment is complex. Most debt operates through the sale of treasury bonds to the local or international private sector. However, in many tropical nations, large private enterprises capable of purchasing government bonds are rare. Those nations must borrow the bulk of needed funds from international lenders, both public and private.

The World Bank
The World Bank Group comprises two institutions: the International Bank for Reconstruction and Development (IBRD); and the International Development Association (IDA). The IBRD aims to reduce poverty in middle-income and credit worthy poorer nations, while the IDA focuses exclusively on the world's poorest nations. In the world of international finance, the World Bank provides low-interest loans, interest free credits, and grants to developing nations. They also facilitate financing through trust fund partnerships. The World Bank finances its activities through selling bonds in the world market; capital funds from shareholders (most nations in the world are shareholders) and sourcing grants from its 40 donor nations.

The International Monetary Fund
The International Monetary Fund (IMF) is an international organisation funded largely through its 188 member nations by quota payments and separate contribution-based trust funds. It provides advice on financial risks and fiscal policy and has the capability to provide loans to nations having trouble meeting their international payments and cannot otherwise find finance on affordable terms. This financial assistance is designed to help nations restore macroeconomic stability by rebuilding international reserves, stabilising their currencies, and paying for imports.

The Paris Club
The Paris Club is an informal group of official creditor nations (large economies) which facilitates coordinated and sustainable solutions to the payment difficulties experienced by debtor nations. Initially it was founded to make decisions around postponing payments to ease the debt burden, but rescheduling debt payments only served to pass the debt burden on to future generations. During the 1980s, amidst the Latin-American and African debt crises, the Paris Club moved more of their activities and funds towards debt relief including debt cancellation for low income nations. In order to receive debt relief, a debtor nation must satisfy a number of criteria approved by the IMF and the Paris Club.

The London Club
The London Club represents commercial creditors, generally banks, exposed to developing nation debt. On a case-by-case basis a sub-committee of bankers works with nations to restructure commercial debt. The London Club is most active in Latin-America and South East Asia. It also provides a variety of refinancing bonds and market-based instruments such as debt conversions and buy-backs.

World Bank headquarters, Washington DC. Deborah W Campos, World Bank.

to encourage governments to keep borrowing with the expectation that their debt will be forgiven. Debt relief should be considered as one source of financial resources, to be used in addition to several others.

Incentives and debt swaps, rather than debt forgiveness, for development and environmental programs might be a way forward, but ultimately, tropical nations will need strong policies and governance so borrowed money is invested responsibly, allowing for debt service as well as development.

References

Aiyar S, Mody A (2011) The demographic dividend: evidence from the Indian states. International Monetary Fund Working Paper, International Monetary Fund, Geneva.

Bloom DE, Canning D, Sevilla, J (2003) *The Demographic Dividend, a new perpective on the economic conseqences of population change.* RAND, Santa Monica.

Cassimon D, Prowse M, Essors D. (2011) The pitfalls and potential of debt-for-nature swaps: A US-Indonesian case study In: *Global Environmental Change* **21**.

Chauvin ND, Kraay, A. (2010) Who gets debt relief? In: *Journal of the European Economic Association* **5** (2-3).

Easterley W (2000) *The elusive quest for growth – economists' adventures and misadventures in the Tropics* The MIT Press, Cambridge, Massachusetts.

Easterley W. (2001) Debt Relief in: *Foreign Policy* **127**.

Gockel CK, Gray LC. (2011) Debt for nature swaps in action: two case studies in Peru in: *Ecology and Society* **16**(3).

IMF (2008) *Heavily Indebted Poor Nations Initiative and Multilateral Debt Relief Initiative – Status of Implementation* International Development Association and International Monetary Fund, Washington.

IMF (2013) *Debt relief under the Heavily Indebted Poor Nations (HIPC)* Initiative IMF Factsheet April 2013.

Kim M, Penm J (2007). India's Economic Prospects. In *Australian Commodities* **14** (4).

Knickley JE (2012) Debt, nature, and indigenous rights: twenty five years of debt-for-nature evolution. *Harvard Environmental Law Review* **36**.

Kuteesa FN, Nabbumba R. (2004) *HIPC Debt relief and poverty reduction strategies: Uganda's experience* in: Tuenissen JJ, Akkeman A (eds) HIPC Debt Relief, Myths and Reality. Forum on Debt and Development, The Hague, Netherlands.

Loayza N, Soto R. (2002). *Economic Growth: Sources, Trends, and Cycles.* Central Bank of Chile, Santiago.

Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, (eds). (2007). *Climate Change 2007: Mitigation of Climate Change.* Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press.

OECD (2003). *The Sources of Economic Growth in OECD Countries.* Organisation for Economic Co-operation and Development, Paris.

Okoth PG (2012) Disaster and emergency diplomacy with reference to the Indian Ocean tsunami crisis In: *International Journal of Disaster Management and Risk Reduction* **4**(2).

Sachs JD. (2001). *Tropical Underdevelopment.* National Bureau of Economic Research Working Paper Series. Working Paper 8119. National Bureau of Economic Research. Cambridge.

Saravananthan M, Sanjeewanie HMP. (2008) Recovering from the tsunami: people's experiences in Sri Lanka In: *Contemporary South Asia* **16**(3).

Schmid JP (2009) *Is debt relief good for the poor? The effects of the HIPC Initiative on infant mortality* in: Primo Braga CA, Dömeland D (eds). Debt Relief and Beyond, Lessons learned and challenges ahead. The World Bank, Washington DC, USA.

Sinding SW. (2009). Population, poverty and economic development. In: *Philosophical Transactions of the Royal Society* B **364**.

Sjaastad LA. (1983) International Debt Quagmire – to whom do we owe it? In: *The World Economy* 6(3): 305-324

Torras M. (2003) An ecological footprint approach to external debt relief In: *World Development* **31**(12).

UN (2012) *The Millennium Development Goals Report 2012* United Nations, New York.

UN (2013). *World Population Prospects: The 2012 Revision.* United Nations, New York.

Weil DN. (2009). *Economic Growth (second edition).* Pearson. Sydney.

World Bank. (2013) International Debt Statistics 2013. World Bank, Washington, DC.

Chapter 7.2

Economy | International trade and investment

YUS coffee, Papua New Guinea.
Image: Mark Ziembicki.

Summary of trade and investment indicators

Indicator	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Exports of Goods and Services % of GDP (1980-2010)	**26-47**	29-36	56-48	7-23	57-90	47-46	15-32	15-16	15-19	**18-25**	**19-25**
Imports of Goods and Services % of GDP (1980-2010)	**26-46**	29-38	28-36	12-27	55-83	54-51	17-35	14.6 – 15.1	16-21	**19-25**	**20-28**
Foreign Direct Investment In-flows % of GDP (1980-2010)	**0.7-3.5**	0.4-4.0	-1.5-6.1	0.1-1.5	1.6-5.7	1.0-2.4	1.1-2.4	0.6-2.4	1.0-2.4	**N/A**	**N/A**

Nations and their economies do not and cannot exist in isolation. Human communities have been trading with one another for millennia, and trade has been a vital contributor to the development of human societies and culture. Global markets ensure that no nation is isolated or remote from changes and developments in other nations. Ideally trade consists of one nation selling what it is best able to produce and buying what others produce better. It is generally considered to be better than aid as an engine of development. Similarly investments from one nation into another promote growth and share risk. However, unless open markets are combined with secure property rights and stable government, increased economic connectivity can cause instability.

Headline Indicator

Exports of goods and services provide an indication of a nation's integration with the global economy. Exports are an indicator of global demand for the commodities, goods and services created in an economy. Exports consist of transactions in goods and services from residents to non-residents.

Supplementary indictors

Imports of goods and services provide an indication of a nation's integration with the global economy and reflect a nation's demand for commodities, good and services from other nations. Imports consist of transactions in goods and services from non-residents to residents.

Foreign direct investment (FDI) can contribute to developing a nation's productive capacity and is a measure of the extent of economic globalisation. FDI is a measure of foreign ownership of productive assets such as factories, mines and land. It can be for the creation of new capital or can involve the transfer of ownership of existing capital.

Links to other dimensions

Gross capital formation, economic growth, research and development expenditure.

Is it getting better?

Exports:
Exports of goods and services as a percentage of GDP have grown rapidly in the Tropics over the 30 years to 2010, increasing from 25% to 47%. Export earnings however, were only 21% of global totals in 2010. South East Asia has the highest percentage of exports to GDP in the Tropics (90%) and South Asia showed the strongest growth. Export growth in other regions were mixed although generally positive except for Northern Africa and the Middle East and the Caribbean where small declines in exports relative to GDP was estimated.

Imports:
Imports of goods and services to tropical nations have increased rapidly in the 30 years to 2010 from 26% to 45% of GDP. The volume of imports to the Tropics grew by 210% during this period. Similar to exports, South East Asia imported the most relative to GDP (83%). South Asia reported strong growth in imports rising from 12%-27%. All other regions grew by smaller increments except for the Caribbean which showed a small decline.

Foreign direct investment:
Foreign investment increased in all regions of the Tropics in the 30 years to 2010. FDI to tropical nations increased more than tenfold between 1980 and 2010, from US$11 billion to US$157 billion. Foreign Investment is an important driver of economic growth in developing regions.

Timber market, Cameroon Image: Olivier Girard CIFOR.

Trade of goods and services

Trade can be considered a measure of how integrated a nation or region is with the global economy. Since World War II the value and volume of trade has continued to grow steadily. As a share of global output, in 2011 it was three times the level it was in the early 1950 (IMF 2011). This growth in global trade has been achieved by greater integration of global economies; a move to greater technological and skills specialisation; the rise of developing world trade driven by lower production costs; more efficient transport networks; and the rise in overall wealth world-wide.

Exporting is the sale of goods and services to another nation, and generates foreign currency revenue and economic development opportunities in the selling nation. Exports are generally driven by demand and market prices. Importing is the purchase of goods and services from other nations and is an essential element in economies. Very few nations can efficiently produce all the goods and services that societies require for investment and consumption purposes.

Goods that are traded include primary products like oil, minerals, timber and food stuffs, and manufactured goods. Services include traded skills, information, knowledge and tourism.

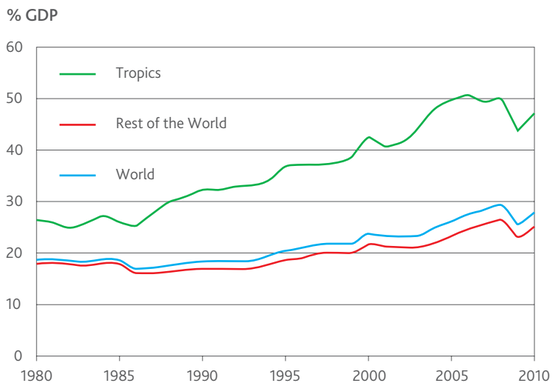
Imports have a fundamental economic relationship with exports, and together they determine a nation's balance of trade. When the value of imports is less than exports there is a trade surplus. When the value of imports is greater than exports a trade deficit will result. Persistent trade deficits can drain financial resources and affect national income and savings as well as investor confidence (The Economist 2011).

Exports can play an important role in economic activity, and in some nations export growth is instrumental in boosting GDP. In developing nations exports tend to be a higher proportion of GDP than in wealthier nations. A factor contributing to this is relatively low production costs for many primary and manufactured goods and for some services. Although commodities are traded throughout the world, nations in Europe and North America are the greatest importers. Increasingly however, emerging economies such as India, China and Brazil among others have growing import demands (Michalopolous & Ng 2013). This includes demand for inputs and skills to support economic and social development. Increased manufacturing activity in the Tropics has also required greater demand for technology commodities and intermediary inputs to the production process (such as minerals and energy), and growing wealth is increasing demand for imported consumer goods.

Regions that rely on food and agricultural imports for domestic consumption, such as sub-Saharan Africa and the Caribbean, are especially vulnerable to the impacts of exchange rate fluctuations and global supply and demand dynamics that affect prices for the basic commodities needed to sustain life (Valdes & Foster 2012). This can also have balance of trade impacts if there are no readily available and affordable substitutes when prices rise.

In recent decades trade growth has been a powerful mechanism for economic growth, and many nations are now committed to binding international trade agreements. This has supported foreign investment into low-cost developing nations – including those in the Tropics – putting downward pressure on prices for many internationally traded goods and services consumed in developing nations – further supporting increased demand. In developing nations, increased demand for the goods and services they produce supports financial inflows and investment for economic and social infrastructure. This has contributed to employment and income growth, skills development and opportunities to diversify the export base.

Figure 7.2.1 **Goods and services exports as a percentage of GDP**



Source: World Bank (2013), State of the Tropics project.
Note: Regional estimates include intra-regional trade, not just trade out of the region.

Export trends

Exports as a percentage of GDP increased rapidly in the Tropics in the 30 years to 2010 compared with the Rest of the World (see Table 7.2.1). In the Tropics exports increased from 26% to 47% of GDP between 1980 and 2010, while in the Rest of the World exports increased from 18% to 25% of GDP. Despite this growth, the value of exports from the Tropics was only 21% of global totals in 2010, up from 13% in 1980. Reflecting growing trade liberalisation, global exports as a percentage of GDP increased steadily between 1986 and the start of the global financial crisis (GFC) in 2008 (see Figure 7.2.1). The GFC affected global confidence and demand, with the direct impacts being greatest in large economies in North America and Europe. This had flow-on effects to economies that rely on nations in these regions for export revenue, with weaker demand resulting in falling export revenue. Export growth in the regions of the Tropics has been mixed since 1980. With the exception of Northern Africa & Middle East and the Caribbean, all regions recorded an increase in exports as a percentage of GDP between 1980 and 2010 (see Table 7.2.1). Nonetheless, the growth trajectories have not always been steady, and there have been periods of volatility.

In the Tropics, South East Asia has the highest rate of exports as a percentage of GDP, estimated at 90% in 2010 (though down from 98% in 2005). Even in 1980 though, exports were a major contributor to economic growth in South East Asia, and represented 57% of GDP. Exports from Hong Kong have increased most notably , up from 90% of GDP in 1980 to 219% in 2010, and this has been a large factor in export growth in the region (see Box 7.2.1). Exports from Singapore are also consistently high at between 150% and 230% of GDP. Growth in exports as a percentage of GDP in the region is driven by strong growth in China, Malaysia and Thailand.

South Asia recorded a strong increase in exports to GDP in the thirty years to 2010, from a low base of 7% of GDP in 1980. Strong growth in exports can be credited to the introduction of trade liberalisation policies in India and Bangladesh from the early 1990s. Exports were 23% of GDP in 2010 – still below the rate for the Tropics, but close to the rate for the Rest of the World.

Compared with other regions of the Tropics, South America and Oceania report relatively low exports as a percentage of GDP, and

Table 7.2.1 **Goods and services exports as a percentage of GDP**

	1980	1985	1990	1995	2000	2005	2010	PPT* Change 1980 - 2010
Tropics	26.4	**26.0**	**32.4**	**37.0**	**42.6**	**49.8**	**47.1**	**20.7**
Central & Southern Africa	29.3	27.6	32.0	36.9	40.5	40.5	35.7	6.4
Northern Africa & Middle East	56.2	27.5	35.3	33.3	38.2	51.7	48.5	-7.7
South Asia	7.4	6.3	8.0	11.9	14.1	19.7	22.6	15.2
South East Asia	57.4	55.7	68.8	73.6	86.4	97.8	90.2	32.8
Caribbean	46.6	45.9	50.9	50.3	51.6	55.0	45.5	-1.1
Central America	14.5	17.0	20.7	31.7	32.2	29.6	32.3	17.8
South America	14.5	15.3	15.4	12.0	14.5	20.0	15.8	1.3
Oceania	14.7	12.3	13.6	17.0	18.0	17.0	18.7	4.0
Rest of the World	**17.9**	**17.8**	**17.0**	**18.6**	**21.7**	**23.3**	**25.1**	**7.2**
World	**18.7**	**18.6**	**18.4**	**20.5**	**23.8**	**26.1**	**27.9**	**9.2**

Source: World Bank 2013, State of the Tropics project.
* Percentage point change. ** Estimate based on nations for which data are reported.
Note: Regional estimates include intra-regional trade, not just trade out of the region

only modest growth in the rate since 1980. Exports as a percentage of GDP have increased significantly in Central America, with rapid growth in the mid-1990s due to the North American Free Trade Agreement between the United States, Canada and Mexico coming into force in 1994 (see Box 7.2.2). Nonetheless, after the early promise of growth, the rate has remained around 30% of GDP for the past 15 years.

Exports as a percentage of GDP declined in Northern Africa & Middle East between 1980 and 2010, and varied between 28% and 56% over the period. This is largely due to fluctuating prices and demand for oil exports from Saudi Arabia – the dominant economy in the region. The Caribbean also recorded a modest decline in the rate of exports as a percentage of GDP, largely affected by Cuban exports falling from 33% of GDP in 1980 to 19% of GDP in 2010.

Import trends

As a percentage of GDP, imports of goods and services to nations in the Tropics increased at a faster rate than in the Rest of the World in the years to 2010. In the Tropics the value of imports increased from 26% of GDP in 1980 to 45% in 2010 (see Figure 7.2.2). The increase in the Rest of the World was more modest, up from 19% in 1980 to 25% in 2010.

As global trade is increasingly integrated, the flow of imports and exports tend to track closely. Goods that are imported can be either consumed in the importing nation, or transformed into new goods or services that can be either consumed in the domestic economy or exported. The global financial crisis in 2008 not only led to a worldwide decline in exports, but also imports, as reduced demand from developed nations had a flow-through to demand for imports to the production process from exporting nations.

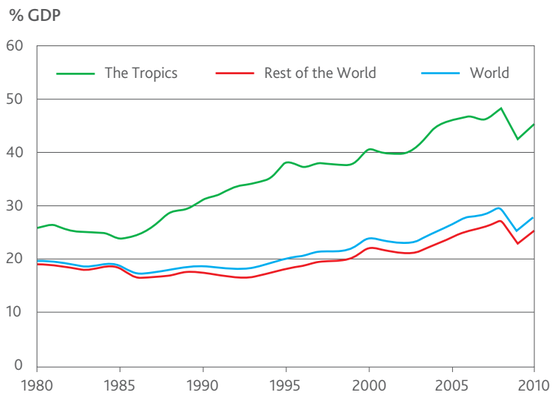
With the exception of the Caribbean, all regions of the Tropics reported an increase in imports as a percentage of GDP between 1980 and 2010 (See Table 7.2.2). In the Tropics, imports as a percentage of GDP are highest in South East Asia, at 83% in 2010, with Hong Kong, Singapore, Thailand, Malaysia and China being major importers. Other factors influencing strong import growth in the region include export growth in China and Thailand.

Imports in Central America increased from 17% of GDP to 35% in the 30 years to 2010. Mexico's involvement in NAFTA from 1994 drove most of this increase (see Box 7.2.2). South America reports only minor growth in imports as a percentage of GDP in the 30 years to 2010.

South Asia reported the lowest imports as a percentage of GDP in 1980 at 12.2%, but in the 30 years to 2010 it increased to 27%, higher than South America and Oceania. Strong import and trade growth in South Asia is attributable to the introduction of more liberal trade policies in India and Bangladesh from the early 1990s. However, even at 27% in 2010, imports as a percentage of GDP are well below the rate for the Tropics (though close to the rate for the Rest of the World).

The Caribbean was the only region in the Tropics to record a decline in imports as a percentage of GDP. Nonetheless, the fall was marginal, as reduced imports to Cuba and Barbados more than offset increased imports to Puerto Rica and the Dominican Republic.

Figure 7.2.2 **Goods and services imports as a percentage of GDP**



Source: World Bank (2013) State of the Tropics project.
Note: Regional estimates include intra-regional trade, not just imports to the region.

Trade agreements

Rapid growth in international trade has been assisted by creation of the World Trade Organisation (WTO) in 1995 to facilitate and formalise international trade agreements. These trade agreements have played an important role in strong growth in international trade in recent decades, and recent advances include more liberal agreements that encourage greater cross-border trade in services and intellectual property (WTO 2011a). China joined the WTO in 2001.

Box 7.2.1 The trade industry of Hong Kong

Hong Kong is the 10th largest trading economy in the world and is a signatory to three regional trade agreements – with China, New Zealand and Europe (through the Europe Free Trade Agreement, or EFTA) (WTO 2013). The trade sector employs around 500,000 people and accounts for almost 20% of Hong Kong's GDP (HKTDC 2012). Exports of goods and services have increased significantly to account for 219% of GDP in 2010, up from 90% of GDP in 1980.

Trade growth in Hong Kong has been influenced by its close proximity and historical and strategic links to China. This has made it a conduit for much of China's expanding global trade as its economy has opened up. Hong Kong is China's second largest export destination after the United States, and it receives 14% of Chinese exports. Over 50% of Hong Kong's exports are to China and 45% of Hong Kong's imports are from China. A large proportion of trade in and out of China passes through Hong Kong, and it re-exported over 60% of its Chinese imports in 2010 (HKTDC 2012).

Hong Kong has a growing trade-related service sector built on increased trade with China, and direct investment from China is increasing steadily, and now competes with investment inflows from Europe and the United States. Tourism is also a significant service export, accounting for around 4% of GDP and 6% of employment in 2010. More than 40 million people visit Hong Kong each year, and growth in visitors from mainland China is especially strong, increasing from 4.5 million in 2001 to 28 million in 2011 (Government of Hong Kong 2012).

Not surprisingly, with limited natural resources (including limited capacity to supply its own food), Hong Kong is highly dependent on international trade for economic growth. This means that Hong Kong's economic performance is closely linked to the global economy, and that it has limited capacity to manage volatility associated with the impact of external shocks that affects its major trading partners.

Hong Kong. Image: Mr Wang.

Trade agreements are important because they formalise trade arrangements between nations and aim to make trade less restrictive – creating opportunities for trade to expand across regions and industries. Up to 3,000 trade agreements were estimated to be in operation world-wide in 2010, with many other agreements still in negotiation phase (WTO 2011b).

The WTO is currently negotiating the Doha Development Round. Negotiations commenced in 2001 with a focus on addressing the trade needs of developing nations, including improved access to international trade and investment markets. The treatment of farm subsidies in developed nations, industrial tariffs and non-tariff barriers to trade are major obstacles hindering completion of the negotiation, and the long delay in reaching agreement is contributing to greater use of bilateral agreements between nations to encourage trade.

The Doha Round highlights the inherent difficulty in negotiating multilateral trade agreements between developing and developed nations. Trade agreements by their nature become more complex to negotiate as the number of signatory nations increases. For example, bilateral trade agreements tend to be less complex to negotiate as parties tend to have an understanding of each other, and the economic and social development opportunities and risks of entering an agreement. The North American Free Trade Agreement (NAFTA) and ASEAN Free Trade Agreement (AFTA) are examples of free trade agreements where some of the world's biggest developed economies have integrated with emerging and developing economies (see Box 7.2.2).

Export diversity

Exports as a percentage of GDP tend to be higher in developing nations than in developed nations. Additionally, primary goods represented at least 50% of commodity exports for two-thirds of developing nations in 2010 (UNDP 2011). This reliance on primary goods means that developing nations are at a relatively greater risk of adverse impacts from external shocks such as economic downturns and fluctuating commodity prices and exchange rates.

The increased risk of a volatile economic growth outlook can affect investor confidence in traded and non-traded sectors of the economy, with impacts on longer term prospects for economic and social development. This uncertainty can also contribute to under-investment in trade infrastructure in developing nations, including roads, railways, and ports – which is critical to developing efficient trade networks (USITC 2009).

Developed nations generally have a more diverse range of exports – including manufacturing and services – and do not rely as heavily on export revenue for economic growth (that is, a large proportion of production is actually consumed by the domestic population).

Looking forward

Imports and exports have played an important role in the ongoing economic development in the Tropics. Liberalisation policies combined with a region rich in natural resources have combined to increase exports, and rising affluence is driving import growth. Further development of manufacturing and services industries has diversified the export market in some areas of the Tropics.

Expanding the export base of both primary products and manufacturing as well as diversifying trading partners would benefit many tropical nations. This will require regional political stability, intra-regional trading, and building on current export bases by integrating them into existing and emerging markets. Emerging large economies will have a strong demand for raw materials and consumer goods. These emerging economic regions of the Tropics are becoming some of the world's largest trading nations and will rely on trade to maintain their rate of social and economic development.

Table 7.2.2 **Goods and services imports as a percentage of GDP**

	1980	1985	1990	1995	2000	2005	2010	PPT* Change 1980 - 2010
Tropics	25.8	**23.8**	**31.1**	**38.2**	**40.7**	**46.0**	**45.4**	**19.6**
Central & Southern Africa	28.7	26.6	28.4	37.6	35.2	37.3	38.0	9.3
Northern Africa & Middle East	28.1	35.2	29.6	27.1	24.8	29.8	36.2	8.1
South Asia	12.2	9.5	10.1	13.8	15.7	22.9	27.0	14.8
South East Asia	55.3	52.4	66.9	75.1	78.7	89.2	82.6	27.3
Caribbean	53.8	51.9	59.6	62.9	64.2	61.8	51.4	-2.4
Central America	17.0	12.8	22.4	30.3	35.0	32.6	34.6	17.6
South America	14.6	10.4	11.0	13.4	14.3	14.9	15.1	0.5
Oceania	15.7	15.3	15.7	17.6	20.3	21.1	20.8	5.1
Rest of the World	**19.0**	**18.2**	**17.4**	**18.2**	**22.2**	**24.0**	**25.3**	**6.3**
World	**19.7**	**18.7**	**18.7**	**20.2**	**24.0**	**26.4**	**27.8**	**8.1**

Source: World Bank 2013, State of the Tropics project.
* Percentage point change. ** Estimate based on nations for which data are reported.
Note: Regional estimates include intra-regional trade, not just imports to the region.

Box 7.2.2 North American Free Trade Agreement

The North American Free Trade Agreement (NAFTA) between the United States, Canada and Mexico was established in 1994, creating the world's largest free trade area in terms of GDP. The agreement introduced a range of measures which encouraged trade and investment flows by reducing trading costs, increasing business and infrastructure investment and competition, and establishing frameworks for regional co-operation. NAFTA was controversial when first proposed, mostly because it was the first free trade agreement involving developed and developing nations (Villarreal & Fergusson 2013).

NAFTA has contributed to strong increases in intraregional trade flows, which increased from around $290 billion in 1993 to more than $1.1 trillion in 2012. Cross-border investment and travel have also increased, with United States investments to Canada and Mexico estimated at almost $630 billion between 1994 and 2009. The United States also trades more with Mexico and Canada than with Japan, South Korea, Brazil, Russia, India, and China combined. Much of the growth in NAFTA trade has been between the United States and Mexico, where the trade balance went from a $2 billion United States surplus in 1993 to a $61 billion deficit in 2012 (Sergie 2014).

Rapid growth in trade in the early years of NAFTA has been tempered since 2001, affected by increased fears of terrorism following the 9/11 attack, and the impact of China joining the WTO, and the overall economic effects from increased trade through NAFTA are considered to be relatively modest, noting there have been adjustment costs as the three nations adjusted to more open trade and investment among their economies (Villarreal & Fergusson 2013).

Looking forward though, some commentators suggest the outlook for NAFTA to encourage regional trade is improving. For example, productivity improvements in Mexico are increasing its competitiveness with China, and the protection of intellectual property rights under NAFTA improves the likelihood of complex manufacturing processes occurring in the region (as opposed to, say, China). Abundant cheap shale-gas energy in the United States and a rapidly growing working age population in Mexico will also support economic activity and trade in the region (The Economist 2014).

The negotiation of other trade agreements such as the Trans-Pacific Partnership and the Transatlantic Trade and Investment Partnership highlights that there are many opportunities to encourage regional trade, development and greater economic integration.

Vehicles ready for export from Mexico. Image: Peanutian.

Foreign direct investment

Foreign direct investment is the physical investment from a firm or corporation of one nation to another nation and is a fundamental dynamic of global economics. In recent decades there has been an exponential increase in foreign direct investment in terms of both capital and geographic reach (Hufbaur & Draper 2013). Investments assist in developing physical infrastructure and acquiring capital goods and corporate assets (Trakman 2010). Foreign direct investment also contributes to technology dissemination, skills and management practices, and can increase productivity, employment and incomes in host nations. In developing nations foreign direct investment tends to dominate capital inflows.

Ideally foreign direct investment provides financial return to investors, and economic and social benefits to host nations. However, firms and corporations are vulnerable to political and financial risks, and host nations are at risk of dependent or restricted development. Strong governance frameworks and a robust financial sector can help to protect host nations from some of the key risks associated with large foreign direct investment flows – notably exchange rate volatility, inflation and current account imbalances.

Trends

Net foreign direct investment inflows as a percentage of GDP increased steadily in the Tropics in the 30 years to 2010, and at a significantly faster rate than the Rest of the World. Foreign direct investment in the Tropics increased from 0.7% of GDP in 1980 to 3.5% in 2010, while in the Rest of the World it increased from 0.5% of GDP to 1.6% over the same period (see Table 7.2.3).

Despite foreign direct investment inflows representing a higher proportion of GDP in the Tropics than in the Rest of the World, in 2010 the Tropics only accounted for around 22% of global foreign direct investment inflows (US160 billion), although this up from 12% in 1980 (US10 billion).

All regions in the Tropics recorded increases in net foreign direct investment inflows as a percentage of GDP between 1980 and 2010. Higher rates of foreign direct investment have corresponded with sustained economic growth. Northern Africa & Middle East reported the highest rate of net foreign direct investment inflows in the Tropics in 2010 at 6.1% – largely related to minerals and energy investment – although in 1980 the region was a net exporter of foreign direct investment. The privatisation of oil and gas assets in Saudi Arabia since 2002 is the major factor contributing to the rapid increase in Northern Africa & Middle East's net foreign direct investment inflows in the past decade (Ramady 2010), though there have also been significant increases in several other nations.

In South East Asia net foreign direct investment inflows increased from 1.6% of GDP in 1980 to 5.7% 2010. Given rapid economic growth in this region, this represents an increase of over 2,000% in dollar terms. There was a slight setback in growth in the late 1990s associated with the Asian Financial Crisis, but net foreign direct investment inflows have since recovered strongly. Hong Kong and Singapore in particular have high net inflows of foreign direct investment as a percentage of GDP.

As a percentage of GDP the net inflow of foreign direct investment in Central & Southern Africa was 4% in 2010, up from 0.4% in 1980, with Nigeria being a major contributor to growth, largely due to foreign investment in the oil sector. In the Caribbean, Central America, South America and Oceania net inflows of foreign direct investment as a percentage of GDP were all at 2.4% in 2010, and up from around 1% in 1980. Foreign direct investment peaked in these regions in 2000 and subsequently declined. Although this may be a result of poor macro-economic performance of investor nations, it is more likely to reflect a period of consolidation following the rampant cross-border investment in the late 1990s (Christiansen & Bertrand 2004). The global financial crisis in 2008 also had a greater impact in these regions (particularly South America) than in other tropical regions (UNCTAD 2010). South Asia recorded the lowest net inflows of foreign direct investment as a percentage of GDP in the Tropics in 2010 at 1.5%. Nonetheless, South Asia has experienced a large increase since 1980 as, prior to the liberalisation of capital flows in India in 1991, equity investment in the region was largely non-existent.

Table 7.2.3 **Foreign direct investment – net inflows as a percentage of GDP**

	1980	1985	1990	1995	2000	2005	2010	PPT* Change 1980 - 2010
Tropics	**0.7**	**0.8**	**1.3**	**2.2**	**3.2**	**3.1**	**3.5**	**2.7**
Central & Southern Africa	0.4	1.3	1.0	2.2	2.7	3.2	4.0	3.6
Northern Africa & Middle East	-1.5	0.4	1.3	-0.9	-0.1	4.6	6.1	7.6
South Asia	0.1	0.1	0.1	0.5	0.8	0.9	1.5	1.4
South East Asia	1.6	1.1	3.6	4.3	3.7	5.0	5.7	4.1
Caribbean	1.0	0.2	0.9	1.8	2.6	2.5	2.4	1.3
Central America	1.1	1.0	1.0	3.1	3.1	3.1	2.4	1.3
South America	0.6	0.8	0.4	1.1	4.3	2.5	2.4	1.7
Oceania	1.0	0.9	1.7	2.2	3.2	-0.6	2.4	1.4
Rest of the World	**0.5**	**0.4**	**0.9**	**1.0**	**4.1**	**2.4**	**1.6**	**1.1**
World	**0.5**	**0.5**	**0.9**	**1.1**	**4.0**	**2.5**	**1.8**	**1.3**

Source: World Bank (2013) State of the Tropics project.
* Percentage point change.
Note: Regional estimates include intra-regional investment

Box 7.2.3 International investment agreements and ASEAN

There is often debate about the most appropriate policy response to both attract foreign direct investment, and balance local concerns about foreign ownership and control (Nixon 2004). International investment agreements (IIAs) have emerged as an international legal framework for foreign investment. These agreements aim to ensure that nations adhere to specific standards on the treatment of foreign investments within their territory. They also define procedures for the resolutions of disputes if they were to occur. There are now more than 3,000 IIAs which include bilateral, regional and sectoral agreements (Malik 2011).

An example of a regional agreement with a strong influence on the Tropics is the ASEAN Comprehensive Investment Agreement (ACIA) which came into effect in early 2012. This agreement is designed to support a 'free, open, transparent and integrated investment regime in the Association of Southeast Asian Nations (ASEAN) region' (ASEAN 2013 p.V). Nations involved in this agreement include Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Burma/Myanmar, Philippines, Singapore, Thailand, and Vietnam. The ACIA covers almost all forms of investment, with liberalisation provisions covering manufacturing, agriculture, fisheries, mining and the services associated with these industries. It encourages cross-border investment within the region and protects investors from policy changes in individual nations.

International investment agreements are a multifaceted network of instruments, with agreements differing in regard to their geographical coverage, scope and the content of their obligations and commitments (UNCTAD 2005). Despite this complexity, they are a powerful tool that tropical nations with abundant natural resources can use to ensure foreign direct investment results in positive outcomes for both host nations and investors.

Bank of Indonesia, Yogyakarta. Image: Ridzki Noviansyah.

Investment and economic growth

Foreign direct investment contributes to the development of physical infrastructure and supports economic activity. Traditionally foreign direct investment has flowed from wealthy to less wealthy nations and, to a large extent, this is still the case today, especially as there has been a global trend toward reducing trade restrictions, including capital flows.

Foreign investors are usually multinational companies and investment firms pursuing opportunities, and developing nations can offer a relatively low-cost production base – often built on a large pool of labour and supportive regulatory frameworks. Improvements in political stability can also encourage foreign investment and economic growth through encouraging development of mineral and energy resources.

In South East Asia, government policies have increasingly opened national economies to foreign investment and encouraged the development of trading partnerships over the past 30 years (see Box 7.2.3). These policies have contributed to investment in economic and social infrastructure and the development of a highly skilled workforce. The region is now one of the fastest growing economic and trading bases in the Tropics and the world, and it continues to attract high levels of foreign direct investment (PWC 2012).

Developed nations are still the major source of outward foreign direct investment, but net outflows from developing nations are increasing. Developing nations' share of global foreign direct investment outflows increased from 6% in 1980 to 27% in 2011, and there are many intra-regional foreign direct investment flows in South East Asia, South Asia, Latin America and the Caribbean (Al-Sadig 2013). China is increasingly investing in international infrastructure projects, and supporting industries based around natural resources and primary commodities, notably in Africa. Chinese foreign direct investment in these nations has strengthened trading partnerships and contributed to economic and social development (Renard 2011).

Box 7.2.4 Aid and foreign direct investment

The 2002 Monterrey Consensus on International Financing and Development affirms that foreign aid and foreign direct investment are complementary sources of capital and aid is essential to encourage investment in nations that are least attractive to international investors (UN 2003). These nations are typically in Central and Southern Africa or small island states in the Tropics. Although some research suggests that aid and foreign investment are unrelated, there is strong evidence, especially in sub-Saharan Africa that higher foreign direct investment goes where higher aid does (Anyanwu 2012).

Aid improves the economic and social infrastructure which can raise the relative output value of capital in poor nations and facilitate the development of more stable financial systems thus encouraging foreign investment (Anyanwu 2012). However, other research demonstrates that the way that aid is invested can affect the influence it has on foreign investment, particularly in Africa. Aid invested directly into physical capital tends to crowd out foreign investors whereas if aid is invested into inputs complementary to physical capital, it is more likely to draw in foreign investment (Selaya & Sunesen 2012). In addition, aid has been shown to mitigate the negative effects of domestic terrorism on foreign investment (Sandler & Younas 2011).In post conflict nations, where reliable information is poor, aid can act as a signal to investors that the donors trust local officials and it is now a safe place to invest (Garriga & Phillips 2013).

International Red Cross, Central African Republic. Image: Juliette Humble, DFID.

Risks for the Tropics

Despite the potential for high returns, foreign direct investment is not without risk. Performance across the Tropics has been varied, and in some regions there is little empirical evidence that foreign direct investment has had a positive influence on sustainable development outcomes (Alfaro et al. 2010). Unregulated or poorly designed foreign direct investment can actually weaken the potential benefits of investment, including the opportunity for more stable and sustainable economic development. Macro-economic effects such as inflation and currency fluctuations can have direct and indirect effects on households and purchasing power, and the effects of a reversal of capital flows on host nations can be significant (UNDP 2011).

Host nations often face greater risk than investors, particularly if they rely on foreign direct investment for infrastructure and economic development. Exchange rate fluctuations can be especially detrimental to investments in developing nations, and foreign direct investment can 'crowd out' domestic investment opportunities for local businesses (Hayakawa et al. 2011). However, it is also a risk for developing nations not to support foreign direct investment, particularly those nations that lack capital or savings to invest in business development, industrial production, and skills development (Ghose 2004).

Central and Southern Africa is a region many investors consider risky because of political instability, conflict and corruption. This can impact investor confidence, even though the region has an abundance of natural resources such as oil, minerals and timber. (Interestingly, some recent research suggests that corruption may actually have a positive effect on foreign direct investment in resource endowed nations (Ezeoha & Cattaneo 2011). However, even if this were the case, improvement in human development is more positive when corruption is low (Anyawanu 2012). Ongoing political reform and greater economic stability in many nations in the region is encouraging foreign direct investment inflows, which can account for 30% to 70% of GDP in some Central & Southern African nations (UNDP 2011). Foreign aid also tends to encourage foreign direct investment (See Box 7.2.4).

Recent policy developments demonstrate that although nations are eager to attract foreign investment many have become more selective (UNCTAD 2013). Ideally domestic investment policies should target those investments that generate jobs, deliver poverty alleviation or help tackle environmental challenges. For example, the Philippines recently released an executive order putting new mining contracts on hold until new legislation, which modifies existing revenue-sharing schemes and mechanisms, has taken effect. To ensure compliance with environmental standards, the order also requires a review of the performance of existing mining operations (UNCTAD 2013).

Looking Forward

Trade and foreign investment will continue to be important drivers of economic and social development in the Tropics and throughout the world. However, future policies should enable an international investment regime that promotes sustainable development in the region. Tropical nations will need to strike the right balance between liberalisation and regulation and enhance the interfaces between investment and development such as those between investment and poverty (UNCTAD 2010) and those that provide adequate protection for the environment.

References

Al-Sadig A. (2013). *Outward Foreign Direct Investment and Domestic Investment: the Case of Developing Countries.* IMF Working Paper. Middle East and Central Asia Department. International Monetary Fund, Washington DC.

Alfaro L, Chanda A, Kalemli-Ozcan S, Sayek S. (2010). Does foreign direct investment promote growth? Exploring the role of financial markets on linkages. In: *Journal of Development Economics* **91**.

Anyanwu J. (2012). Why does foreign investment go where it goes? New evidence from African countries. In: *Annals of Economics and Finance* **13** (2).

ASEAN (2013) *ASEAN Comprehensive Investment Agreement (ACIA) – A Guidebook for Businesses and Investors.* ASEAN Secretariat, Jakarta.

Christiansen H, Bertrand A. (2004). *Trends and recent developments in foreign direct investment.* Organisation for Economic Cooperation and Development, Paris.

Ezeoha AE, Cattaneo N. (2011). *FDI Flows to Sub-Saharan Africa: The Impact of Finance, Institution, and Natural Resource Endowment.* Paper Submission for the CSAE Conference 2011: Economic Development in Africa.

Garriga AC, Phillips BJ. (2013). Foreign aid as a signal to investors: predicting FDI in post-conflict Countries. In: *Journal of Conflict Resolution.* January 2013.

Ghose AK. (2004). Capital inflows and investment in Developing Countries. Employment Strategies Papers No. 11. Employment Analysis Unit. Employment Strategy Department. http://www.ilo.int/wcmsp5/groups/public/---ed_emp/---emp_elm/documents/publication/wcms_114304.pdf (accessed on 02 April 2013).

Government of Hong Kong (2012). *Hong Kong: The Facts: Tourism.* Information Services Department, Hong Kong.

Hayakawa K, Kimura F, Lee H-H. (2011). *How Does Country Risk Matter for Foreign Direct Investment?* Discussion Paper No. 281. Institute of Developing Economies, Japan.

Hufbauer GC, Draper P. (2013). Facts and Figures in: *Foreign direct investment as a key driver of for trade, growth and prosperity: the case for a multilateral agreement on investment.* World Economic Forum, Geneva.

HKTDC (2012). Import and Export Trade Industry in Hong Kong. Hong Kong Trade Development Council Research http://hong-kong-economy-research.hktdc.com/business-news/article/Hong-Kong-Industry-Profiles/Import-and-Export-Trade-Industry-in-Hong-Kong/hkip/en/1/1X000000/1X006NJK.htm (accessed on 20 March 2013).

IMF (2011) *Changing patterns of global trade.* International Monetary Fund, Washington DC.

IMF (2012a). *World Economic Outlook: Coping with High Debt and Sluggish Growth.* IMF World Economic and Financial Surveys. International Monetary Fund, Washington DC.

Malik M. (2010). *Recent developments in international investment agreements: negotiations and disputes.* International Institute for Sustainable Development, Winnipeg.

Michalopoulos C, Ng F. (2013). *Trends in Developing Country Trade: 1980 – 2010.* Policy Research Working Paper, No. 6334. The World Bank, Washington DC.

Nixon R. (2004). *Transparency obligations in international investment agreements.* Australian Treasury, Canberra.

PWC (2012). *The Southeast Asian tigers roar again: this time for real.* Marketmap: How emerging markets change the global economy. Price Waterhouse Coopers, New York.

Ramady MA. (2010). *The Saudi Arabian Economy: Policies, Achievements, and Challenges* (2nd Edition). Springer, New York.

Renard M-F. (2011). *China's Trade and FDI in Africa.* Working Paper Series No. 126. African Development Bank Group, Tunisia.

Sandler T, Younas J. (2011). *Foreign direct investment, aid and terrorism: an analysis of developing countries.* Working Paper 2001 – 004A. Federal Reserve Bank of St. Louis. St Louis.

Sergie MA (2014). NAFTA's Economic Impact. Council on Foreign Relations http://www.cfr.org/trade/naftas-economic-impact/p15790 (accessed on 3 March 2014).

Selaya P, Sunesen ER. (2012). Does foreign aid increase foreign direct investment? *World Development* **40**(11).

The Economist (2011). *Guide to Economic Indicators: Making Sense of Economics.* Wiley, New Jersey.

The Economist (2014). *NAFTA at 20. Ready to take off again?* Print edition, 4 January 2014.

Trakman LE. (2010). Foreign Direct Investment: Hazard or Opportunity, in *George Washington International Law Review* **41**(1).

UN (2003). *Monterrey Consensus of the International Conference on Financing for Development.* United Nations, New York.

UNCTAD (2005). *South-South cooperation in international investment arrangements.* United Nations Conference on Trade and Development, Switzerland.

UNDP (2011). *Towards Human Resilience: Sustaining MDG Progress in an Age of Economic Uncertainty.* United Nations Development Program, New York.

UNCTAD (2010). *World Investment Report 2010.* United Nations Conference on Trade and Development, New York and Geneva.

UNCTAD (2013). *World Investment Report 2013* United Nations Conference on Trade and Development, New York and Geneva.

USITC (2009). *Sub-Saharan Africa: Effects of Infrastructure Conditions on Export Competitiveness*, Third Annual Report. United States International Trade Commission, Washington DC.

Valdes A, Foster W. (2012). *Net-Food Importing Developing Countries. Who They Are, and Policy Options for Global Price Volatility.* International Centre for Trade and Sustainable Development Issue Paper No. 43, Switzerland.

Villarreal MA, Fergusson IF. (2013). *NAFTA at 20: Overview and Trade Effects.* Congressional Research Service.

World Bank (2013). World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 11 January 2013).

WTO (2011a). *Understanding the WTO.* World Trade Organization, Switzerland.

WTO (2011b). *World Trade Report 2011.* The WTO and preferential trade agreements: From co-existence to coherence. World Trade Organization, Switzerland.

WTO (2013a). Regional Trade Agreements Information Systems (RTA-IS). World Trade Organization http://rtais.wto.org/UI/PublicSearchByMemberResult.aspx?MemberCode=344&lang=1&redirect=1 (accessed on 20 March 2013).

Mong Kok, Hong Kong.
Image Luke Chan.

Chapter 7.3

Economy | Science and Technology

'No nation that wants to shape informed polices and take effective action can afford to be without its own independent capacity in Science and Technology'

Kofi Annan

Solar panels, Cape Verde.
Image: Gerald R Ford Scholl of Public Policy.

Summary of of science and technology indicators

Indicator	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Research and Development Expenditure % GDP 2000-2008	**0.49 - 0.58**			0.74 - 0.73	0.62 – 0.97		0.37 – 0.35	1.47 – 1.93		**1.8 – 1.96**	**2.0 – 2.1**
Tertiary Enrollments per 100,000 population 2000-2010	**1190 – 2031**	318 – 780	735 - 1246	875 - 1675	1563 – 2476	1419 – 6168	2361 - 3025	1967 – 3491	4210 – 6136	**2085-3423**	**1743 - 2862**
Scientific and Technical Journal Articles per 100,000 population 1990-2009	**0.8 – 1.8**	0.4 – 0.3	0.6 – 0.4	1 – 2.3	0.5 – 2.5	0.8 – 1	1 – 2.6	1.2 – 4	19.6 – 18	**15.6 – 18.9**	**9.4 – 11.9**

Creating and using knowledge and innovation is an essential ingredient to human development. Technological innovation is a key driver of sustained economic growth and improved welfare. Investment in science and technology is a major input to this innovation process, providing the technical basis for improvements across all aspects of society and the natural environment. The effective development and application of technology requires sufficient and appropriate infrastructure and institutions and suitably trained personnel, as well as effective linkages within and between these groups.

Headline indicator

Research and Development Investment: Investment in research and development is a major contributor to innovation. Expenditures for research and development are current and capital expenditures on creative work undertaken to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. Research and development covers basic research, applied research and experimental development.

Supplementary indicators

Tertiary enrolments: The proportion of people enrolled in tertiary education is a representation of a nation's investment in higher education and innovation. People with appropriate skills are needed to create and apply knowledge and technology, leading to innovation and development.

Scientific and Technical Journal Articles: Scientists, engineers and researchers share knowledge through the publication of peer reviewed journal articles. They represent a key output of the scientific process.

Links to other dimensions

Education, Economic Output.

Is it getting better?

In the Tropics, available data suggest that measures of Science and Technology are improving. Investment in research and development is increasing modestly; numbers of published science and technical journal articles and enrollments in tertiary education are growing rapidly but from a low base. There is substantial regional variation in trends.

Despite these improvements, there is less investment in research and development, fewer tertiary enrolments per population and fewer scientific and technical journal articles produced in the Tropics than the Rest of the World. Investment in technology and innovation will be important for the tropical region as a whole to be competitive in future knowledge based economies.

Image: James Cook University.

Research and development expenditure

Science and technology are critical for improving social, environmental and economic outcomes. Nations and organisations drive science and technology by investing in research and development (R&D) programs. The primary function of R&D – which covers basic and applied research – is to discover and create new knowledge, products, processes and services. This includes making or improving tools, techniques and systems to solve problems or improve existing solutions. From an economic and human development perspective, the outputs of R&D activity contribute to technological innovation, which is a critical component of sustained economic growth and improved welfare (Grupp & Mogee 2004, Tijssen & Hollanders 2006).

The innovation process is not linear, and relies on an interconnected range of market and non-market institutions to work effectively (Sachs & McArthur 2002), as well as appropriate human capital and infrastructure to generate and apply knowledge. That is, the extent of technological innovation is affected by the strength of relevant institutions and systems, as well as the strength of linkages between them. Many economists believe the largest part of world-wide growth and development over the past ten years has been associated with greater and more efficient diffusion of technological change, and greater access to scientific and technological knowledge (Freeman & Soete 2009).

Science and technology is not always transferable across regions, ecosystems and cultures. In the Tropics, where R&D investment severely lags that of the Rest of the World, this non-transferability combined with a general lack of socially relevant, ecosystem specific, and time appropriate investment in critical areas such as health and agriculture are considered to be major factors contributing to relative underdevelopment in many parts of the Tropics (Sachs 2000). For instance, advances made in corn production in the United States will have little direct relevance for a cassava farmer in Vanuatu. Therefore the impact of R&D expenditure is likely to be maximised where it not only facilitates the adoption of science and technology developed elsewhere, but also invests in locally relevant innovations and solutions for the Tropics.

Table 7.3.1 **Research and development expenditure (% of GDP)**

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Tropics	**0.49**	**0.50**	**0.51**	**0.51**	**0.52**	**0.55**	**0.55**	**0.57**	**0.58**
Central & Southern Africa									
Northern Africa & Middle East									
South Asia	0.74	0.72	0.71	0.71	0.72	0.76	0.74	0.73	0.73
South East Asia	0.62	0.68	0.74	0.76	0.80	0.85	0.89	0.92	0.97
Caribbean									
Central America	0.37	0.39	0.43	0.39	0.39	0.39	0.37	0.35	0.35
South America	1.47	1.48	1.52	1.53	1.53	1.66	1.74	1.83	1.93
Oceania									
Rest of the World	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.1**
World	**2.1**	**2.2**	**2.1**	**2.1**	**2.0**	**2.0**	**2.0**	**2.0**	**2.1**

Source: World Bank (2013), State of the Tropics project.

Trends

Despite the contribution that expenditure on R&D makes to innovation, economic growth and development being well known (Freeman & Soete 2009), datasets reporting it tend to be quite poor. In the Tropics data are particularly limited for nations in Africa, the Middle East, the Caribbean and Oceania. Where data are not reported, it is likely that actual expenditure is low (Urama et al. 2010) (see Box 7.3.1).

Where sufficient data are available, it suggests that tropical nations commit a significantly smaller proportion of economic activity to R&D than in the Rest of the World (see Table 7.3.1), ranging from less than 0.04% of GDP in Honduras to 2.7% in the United States. In the decade to 2008, for the tropical nations which report data, R&D expenditure averaged 0.53% of GDP. In the Rest of the World expenditure as a percentage of GDP in 2008 ranged 0.02% in Bosnia and Herzegovina to nearly 5% in Israel, and averaged 2% of GDP in the decade to 2008.

As a proportion of GDP the Rest of the World invests almost four times as much in R&D than the Tropics but, given the difference in GDP levels, in expenditure terms the gap is even larger. In 2012 global R&D expenditure was estimated at around $US1.4 trillion, of which US$1.3 trillion was in the United State, China, Japan and Europe (Battelle & R&D Magazine 2012).

Although low, research and development expenditure in the Tropics has been increasing while the Rest of the World has remained constant. In the major economies of China,

Singapore, Hong Kong and, to a lesser extent, India and Brazil, R&D expenditure as a percentage of GDP increased between 1996 and 2007. In fact, over the past 15 years China's R&D as a proportion of GDP has consistently increased, and China is one of the few nations in the world where R&D spending has increased at a similar rate to GDP (Hollanders & Soete 2010). With this strong commitment to R&D activity, China is expected to overtake the United States in terms of total spending on R&D within the next ten years (Battelle & R&D Magazine 2012).

Although the reasons for relatively low levels of R&D investment in tropical nations vary, recent research suggests economic restrictions associated with credit and debt servicing constraints may be contributing to this outcome (Goni-Pacchioni et al. 2012). As the majority of R&D investment in developing nations is publicly funded (Mani 2010, Cruz & Chaimovich 2010), it is influenced by government debt, aid availability and political will, as well as myriad other interests competing for government investment.

Spillover and tropical innovations

Although the benefits of R&D activity may not be seamlessly transferable to all other locations, the benefits are by no means limited to those nations that undertake the investment. Spillovers' from research spending in other nations are likely to have positive impacts for tropical regions. In fact, spillovers from nations that are big R&D spenders are thought to be substantial (Coe et al. 1995). For example, research estimates that spillover effects from R&D in the United States and Japan in 1990 may have boosted output in developing nations by up to US$20 billion (Coe et al. 1995).

Taking advantage of spillover still requires some R&D capacity, and persons with the required skills, if technology and knowledge from another nation is to be absorbed and applied (Arnold & Bell 2001). Not all nations need to be at the cutting edge of global technological advances, but every nation needs the capacity to adapt and understand global technologies for local needs. It is suggested that tropical nations should prioritise R&D efforts towards 'creative imitation' rather than producing new knowledge (Arnold & Bell 2001). Some tropical regions have been extremely successful at this. The production of electronics and semiconductors throughout South East Asia is based on technology that came from Japan and the United States more than 30 years ago and has made a major contribution to the region's economic growth (Sachs & McArthur 2002).

There are, however, specific research and development questions which arise as a result of the climate, geography and history of the Tropics which cannot be answered by science and technology created outside the Tropics (Sachs 2000). Some products (e.g. cures for tropical diseases and pest-resistant tropical crops) could generate huge benefits for tropical nations, but have little impact in the Rest of the World (Arnold & Bell 2001). In the Tropics, where income per capita is well below that of the Rest of the World, limited 'capacity to pay' for regional-specific research can constrain the extent of regional R&D activity. In a study by the World Health Organisation, pharmaceutical companies reported they did not pursue research into new tuberculosis medications due to high investment costs and lack of commercial return (Blanc & Nunn 2000).

It is possible for developing nations to transition from simply being adopters of technology to become technology innovators (Sachs & McArthur 2002) The pharmaceutical industry in India, for example, has moved from one of duplicative imitation to being a world leader in pharmaceutical innovation (Kale & Little 2007). Recent legal changes have allowed India to move away from simply replicating medications for export, to widespread investment in new chemical entities and drug discovery with the potential for huge benefits for health and welfare.

Box 7.3.1 Science and technology indicators – data availability

Available data report that R&D expenditure in the Tropics is substantially less than the Rest of the World. While this is undoubtedly the case, research suggests that reported data for many developing nations is likely to underestimate the true level of spending (Urama et al. 2010). This is because, unlike in developed nations where there is a strong focus on collecting data for science and technology indicators, many developing nations do not routinely collect and manage this information. Contributing factors often include a lack of suitably trained personnel as well as organisational priorities and limitations. For example, many institutions, ministries and organisations in tropical nations – particularly in Africa, Oceania and the Caribbean – do not have a culture of recording these types of data.

Although the coverage of tropical nations for which R&D data are available may be poor, the nations that are reported account for around 80 to 85% of GDP in the Tropics. Further, as no time series data are available for most African, Middle East, Caribbean and Oceanic nations, trend analysis for these regions is not possible.

Data are available for some nations in these regions, though of the 75 nations in the above four regions, sufficient data for time series analysis are only available for 10, suggesting that any analysis based on the available data is unlikely to be representative of regional activity.

This lack of data is recognised as a constraint to effective policy development and, in many regions, initiatives are in place to improve reporting. For example, the African Union, the New Partnership for Africa's Development (NEPAD) and UNESCO have developed Africa's Science and Technology Consolidated Plan of Action as a critical step towards addressing this lack of data and information (see Box 7.3.2).

In Oceania data are only available for the two largest regional economies, tropical Australia and the United States (Hawaii) which, as developed nations, are not representative of the broader region. Despite the lack of data for Oceania there are a number of regional bodies providing scientific leadership and research capacity throughout the region (see Box 7.3.2).

Image: James Cook University.

Public and private expenditure

Trends in private R&D expenditure best illustrate the rapid geographical changes taking place worldwide in the distribution of R&D spending. In developing nations, R&D funding is dominated by public spending (Mani, 2010) but a growing share of R&D is being performed by the private sector. Increased private spending is considered desirable, as businesses tend to transform the results of research into products and processes more rapidly than government (Mani 2010). Multinational companies are decentralising research activities across the globe to both developed and developing nations (Zanatta & Queiroz 2007). The rationale for this strategy is that it can reduce labour costs and give companies access to local markets, human capital and natural resources. This shift has been rapid. In 1990, 95% of private R&D expenditure occurred in developed nations, but by 2002, this had dropped to 76% (Hollanders & Soete 2010).

In India, private R&D expenditure has increased from 18% to 28% of total R&D spending between 1991 and 2007 (Mani 2010). Even though public spending still dominates total R&D expenditure, it has remained somewhat constant (relative to GDP) during this period. Thus, increases in technology and development in India can largely be attributed to this increased level of private expenditure.

Public monies comprise most of the R&D expenditure (55%) in Brazil, despite private investment increasing marginally in the past 10 years (Cruz & Chaimovich 2010). In Cuba, the situation is the opposite; business investment in R&D has declined from 36% in 2001 to 18% in 2008. This has been attributed to greater science and technology capabilities emerging in other parts of Latin America, drawing private funding away from Cuba to other nations in the region such as Brazil and Mexico (Arxer 2010).

In China, private investment dominates R&D expenditure and its proportion increased from 60% in 2000 to 73% in 2008. Generous tax incentives for experimental development, technological equipment and infrastructure have contributed to this growth in private sector investment (Rongping 2010) alongside more liberal national policies to encourage international investments (Zanatta & Queiroz 2007).

There are several key factors which influence where private investment in R&D activities occurs with multi-national companies in particular seeking new resources, markets and efficiencies (Zanatta & Queiroz 2007). Adequate infrastructure, economic stability, fiscal incentives, an accessible and qualified workforce and appropriate intellectual property rights will all affect a nation's ability to attract private investment in R&D (Zanatta & Queiroz 2007, Naim 2010). Tropical nations lacking in R&D who wish to expand and develop science and technology capability, will need to undertake a wide range of measures to create an adequate environment to attract and promote business R&D investments.

Looking forward

There is no doubt that ongoing R&D investment in the Tropics is important for future development in this region. Partnerships between governments, the private sector and research universities will be essential for ongoing innovation in the Tropics. For poorer nations, regional approaches may be necessary to facilitate and manage R&D activities more effectively. Additionally, for increased R&D spending to be effective, investments in human capital and research infrastructure are essential.

Box 7.3.2 Regional approaches to research and development

Throughout the Tropics, regional approaches to R&D are helping to fill statistical gaps and develop research programs. Two such programs include "Africa's Science and Technology Consolidated Plan of Action" and the "Secretariat of the Pacific Community".

Africa

Many African nations have no record of the share of economic activity directed to R&D (Urama et al, 2010). Weak investment in R&D was identified as a potential risk to ongoing economic and social development and, to address this, the African Union (AU) and New Partnership for Africa's Development (NEPAD) have developed the Science and Technology Consolidated Plan of Action 2008-2013 (CPA) (African Union 2005). The CPA, adopted in January, 2007, articulates a commitment to collective actions to develop and use science and technology for the socio-economic transformation of Africa, and its integration with the global economy. Alongside the CPA, the African Ministerial Council on Science and Technology (AMCOST) was established as the overall governance structure for implementing the Plan. AMCOST is funded from donors and contributions from member nations.

A key objective of the CPA is to increase R&D expenditure to be at least 1% of GDP, as endorsed by the Executive Council of the African Union in the Khartoum Decision (EX.CL/Dec.254 (VIII)) in 2006.

Another initiative, arising from the CPA, the African Science, Technology and Innovation Indicators Initiative (ASTII) published the first African Innovation Outlook in 2010 which provides, in many cases the first record of many science and technology indicators for African nations (African Union 2010). According to the Outlook, only South Africa, Uganda and Malawi recorded research intensity above 1%. Other African nations ranged between 0.02% and 0.5%.

The CPA outlines flagship R&D programmes in four areas: biosciences; water; materials science and manufacturing; and information and communication technologies. The CPA also recommended coordinated funding for science, allowing nations to set their own research priorities, rather than donor organisations and nations. The African Union Research Grant Programme was established in 2008 and is responsible for coordinating research funding from a wide range of donors to answer key research and technology questions from member nations.

Although the CPA has been criticised for not achieving all of its objectives (Nordling 2010), it has brought science and technology to the attention of both donors (private organisations, NGOs and international aid organisations) and African politicians, and has led to the development of other new programs and given individual science ministries guidance and direction to further science and technology in Africa. The CPA expired in 2013 but many programs which have arisen from the plan (e.g. AMCOST, ASTII and the African Union Research Grant Programme) will continue into the future.

The Pacific

Small island nations in the Pacific face a number of unique challenges, including how to manage rising sea-levels, saltwater intrusion, destructive storms and limited land resources. Solutions to these problems will require appropriate policy development, investment in R&D, and local capacity building.

Available data (or lack of it) suggests there is little to no investment in R&D in these nations, even though a number of organisations are known to be coordinating and funding a range of activities which small nations may not be able to afford (Turpin et al. 2010). Among these, the SPC plays a key role in developing science and technology in the region.

The SPC was the first regional scientific and development organisation in the Pacific. Established in 1947, its key objective is to deliver priority work programs to a number of member nations and territories to develop professional, scientific, technical, research and management capacity (SPC 2007). Funded largely through international aid from Australia, New Zealand and the European Union, the SPC model has been successful in the region, with a number of positive outcomes in agricultural research, marine fisheries, and social research focussing on women, youth and culture.

This regional approach to R&D may be effective in addressing knowledge and technology needs as well as fostering collaboration across the region. To achieve regional collaboration and developmental outcomes however, wide consultation with governments and other stakeholders is necessary to truly understand the R&D needs of each nation (Perera & Lamberts 2012). As a first step, basic science and technology statistics need to be generated so this region can become more visible to global science.

South Pacific.
Image: Pierre Lesage.

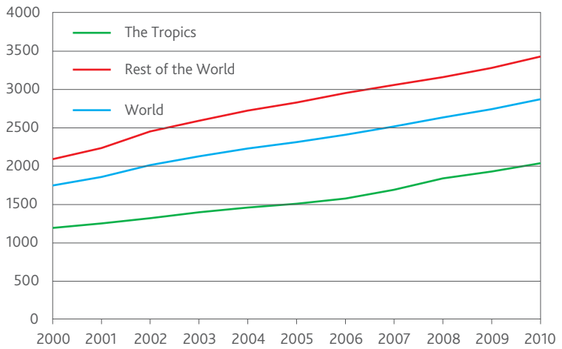
Tertiary enrolments and graduates in science and engineering

Innovation, research and technology require more than just funding to drive development. People with appropriate skills are needed to create, adapt and use technology and knowledge. Higher (tertiary) education is vital for equipping people with the necessary skills and knowledge to contribute to advancement of science and technology in the Tropics.

Higher education produces skilled graduates who will contribute to a competitive workforce and develop the research capability necessary for innovation and consequently, development. Enrolments in tertiary education represent inputs to the research, development and innovation process. Not all students will go on to be involved in science and technology but they provide an indicator of growth in the knowledge and innovation capacity of an economy.

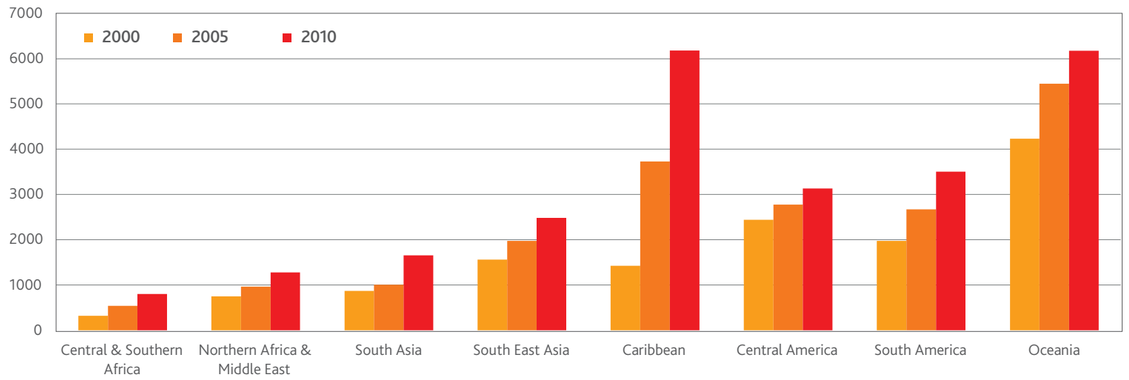
The number of people pursuing higher education has increased substantially. In 1970, there were less than 30 million students enrolled in tertiary education worldwide. This number increased to more than 150 million by 2007. Learning and innovation are seen as key to the development of nations and economies. Given the Tropics is home to a number of developing economies, investment in higher education will be important for future progress in this region.

Figure 7.3.1 **Tertiary education enrolments per 100 000 population**



Source: UNESCO (2013), State of the Tropics project.

Figure 7.3.2 **Tertiary enrolments per 100 000 population, the Tropics**



Source: UNESCO (2013), State of the Tropics project.
Note: These estimates do not include India, China or Hong Kong.

Trends

Enrolments in tertiary education have increased in the Tropics and the Rest of the World over the past 10 years (see Figure 7.3.1). However, fewer people attend universities in the Tropics than the Rest of the World and the average rate of increase of enrolments in the decade to 2010 has been slightly lower in the Tropics (5%) than the Rest of the World (6%).

The number of people enrolled in tertiary education has increased across all regions of the Tropics in the past decade (see Figure 7.3.2). This global pattern is considered to be a result of the elimination of legal and economic barriers (e.g. gender, race and cost) (Shin & Harman 2009) and indicates that a wider group of socio-economic classes are now accessing higher education.

Central & Southern Africa has the lowest rate of university enrolment in the Tropics. However, enrolments in this region increased by 150% in the decade to 2010. Multiple factors have contributed to student increases in Africa, including rapid population growth, rising levels of secondary education completion (Kritz 2013) as well as a vast increase in the number of public and private universities (Kingsley 2010). This rate of increase is second only to the Caribbean where data is reflecting low total population growth rather than large increases in tertiary enrolments. Population growth in Cuba in particular has been declining since 2002 and has shown negative growth since 2008.

A more direct measure of human capital for science and technology development is the proportion students graduating with qualifications in science and engineering. Data on graduates from tropical universities are sparse, however some trends emerge. An average of 24% of all reported tertiary graduates from the Tropics between 2000 and 2010 studied in the science and engineering fields. However, only 10% of all science and engineering graduates worldwide came from institutions in the Tropics. Graduates from the Tropics studying science and engineering increased in the decade to 2010 from less than 100,000 to almost one million. Evidence also suggests that not only the total numbers but also the rate of increase are underestimated due to some data not being available (Gereffi et al. 2008). The rate of increase in the Rest of the World has been lower, even though total tertiary enrolments has grown faster, with total reported science and engineering graduates per annum increasing from 1.8 million to 3.1 million in the ten years to 2010.

Transition to a knowledge based economy

There is no doubt that participation in higher education has been increasing worldwide. Additionally, there is broad consensus that human capital is an important determinate of productivity, improved living standards and other economic and social outcomes (De la Fuente & Ciccone 2002). In an increasingly globalised world, with an emerging knowledge-driven economy, university graduates represent a significant investment into human capital (Asian Development Bank, 2007). Economic advantage is coming less from abundant natural resources or cheap labour and more from technical innovations and the competitive use of knowledge (Salmi 2001).

According to the OECD, "knowledge based economy" is an expression to describe trends in advanced economies towards greater dependence on knowledge, information and high skills, and the increasing need for ready access to all of these things by the business and public sector (OECD 2005). Some of the key characteristics of a knowledge based economy are that learning is increasingly central for both people and organisations; learning organisations are increasingly networked; and initiative, creativity, problem solving and openness to change are increasingly important skills (Houghton & Sheehan 2000).

Many tropical nations are investing in initiatives to bring about a knowledge based economy. For example, Malaysia has increased government spending in tertiary education resulting in a 25% improvement in tertiary enrolments. They have re-orientated training and education systems to prioritise the sciences and have encouraged university-industry partnerships (Asian Development Bank 2007).

The increasing number of tertiary enrolments in institutions in the Tropics is a strong indication that this region can move towards a more knowledge based economy. By raising the level of education and its quality, and increasing graduate numbers, tropical nations may be able to stimulate innovation, broaden the diversity of products and services, and increase returns from capital assets through more efficient allocation and management (The World Bank 2008). However, even though investment in information technology is increasing in tropical regions (e.g. most recently Africa: The Economist 2013) many tropical nations are still a long way from relying on knowledge and technology for income and growth.

Student mobility, brain drain and the tropical diaspora

Students and graduates are highly mobile, particularly from the Tropics. In 2000, 19 of the 20 nations with the highest rate of skilled migration were in the Tropics[3]. In 2010, 3.6 million students were enrolled abroad. East Asia and Oceania provide the largest source of international students

with the largest number (17%) originating from China. Around 6% of all students in central Asia and 5% of all students from sub-Saharan Africa study outside of the region (UNESCO 2013). Half of all of Colombia's science PhDs work abroad and an estimated 47% of Ghanaian doctors work in other nations (Kearney 2009).

Since the 1960s, there has been concern about rising levels of "Brain drain", initially in developed nations like the United Kingdom but more recently, the concern has been from lower and middle income nations (Docquier & Rapoport 2011) where it is a much bigger issue in a relative sense. Brain drain refers to well educated, highly skilled people leaving areas of low income to seek higher incomes and standards of living elsewhere, and students who move abroad to study but do not return upon achieving their qualification (Chien & Chiteng Kot 2011).

In sub-Saharan Africa, brain drain is a large problem and many nations lack the human capital required for progress. In 2007 the African Union established the Mwalimu Nyerere African Union Scholarship Scheme which is designed to enable African students to study science and technology at higher education institutions on the continent[4]. This program facilitates mobility of students while also supporting human capital to stay in the region.

Brain drain may not always be negative. Technology and knowledge can move both outward and inward. Since 1990 the diaspora[5] of developing nations has doubled in size and, as more highly skilled individuals migrate than low skilled individuals, the diaspora is generally well educated. This group of people can provide an important technological resource for their home region. Migrants returning to a nation with assets such as entrepreneurship, technology, marketing knowledge and investment capital can have large economic and technological benefits (World Bank 2008).

Looking forward

A key challenge for nations and higher education institutions in the Tropics will be the balance between developing high quality, world class universities and improving access to higher education. In rich, developed economies, policymakers are able to facilitate funding for both quality and quantity in their higher education systems. The USA for example, can fund world-leading universities as well as support thousands of smaller, cheaper, community colleges. Middle to low-income nations in tropical regions face a trade-off between widening access and maintaining quality (Healy 2013).

[3] The top 20 countries with the highest emigration rates of university graduates as a percentage of the national high skilled labour force in 2000: Haiti (83.4); Sierra Leone (49.2); Ghana (44.7); Kenya (38.5); Laos (37.2); Uganda(36); Eritrea (35.2); Somalia (34.5); El Salvador (31.7); Rwanda (31.7); Nicaragua (30.2); Hong Kong (29.6); Cuba (28.8); Sri Lanka (28.2); Papua New Guinea (27.8); Vietnam (27); Honduras (24.8); Croatia (24.6); Guatamala (23.9) from Docquier F, Rapoport H (2011)

[4] The Accra Declaration on GATS and the Internationalization of Higher Education in Africa can be found at http://www.che.ac.za/documents/d000060/AccraDeclaration-Final.pdf.

[5] In this case, "diaspora" refers to the segment of people who live and work outside their homeland but maintain cultural connections

University students, Malaysia.
Image: Nafise Motlaq World Bank.

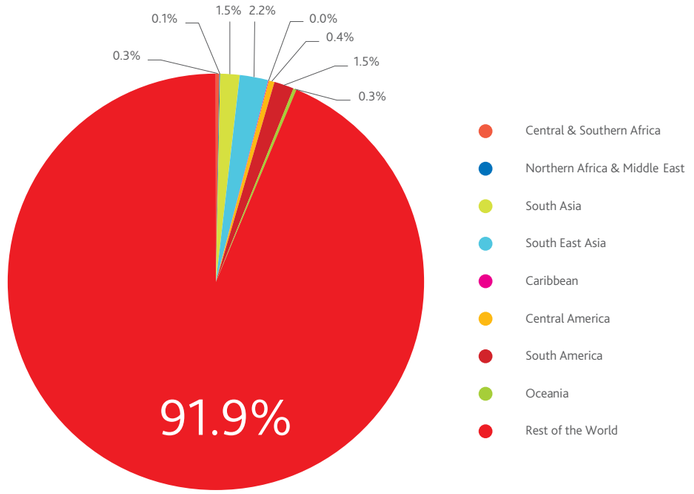
Scientific and technical journal articles

Economic growth, social development, and environmental management are closely linked to the application of scientific knowledge. Articles published in scientific and technical journals represent the latest theoretical research and experimental results in their field. Journal articles are the principal way that scientists and researchers communicate with one another and share their research findings. As such, the number of articles published is an output indicator of research and technology activity being undertaken in an economy, and represents new contributions to knowledge. Research activity represents an investment in the future, whether it is for environmental, social, or economic purposes.

It is widely acknowledged there is an unbalanced distribution of scientific activity between the developing and developed world (Annan 2003). Geographic disparity between the Tropics and the Rest of the World is common in both health and ecological research (Jentsch & Pilley 2003, Stocks et al. 2008). Recently however, governments in the developing world, including many in the Tropics, have set out to develop more knowledge intensive economies by investing in education, science, technology and innovation, information and communication infrastructure, and adapting the policy and regulatory environment (Asian Development Bank 2007).

Global patterns of scientific progress and quality, and how they affect the tropical world can be important indicators of scientific, economic and social development (Gálvez et al. 2000).

Figure 7.3.3 **Total number of scientific and technical journal articles, 2009**



Source: NSF (2011), State of the Tropics project.

Trends

Scientific and technical journal articles refer to the number of scientific and engineering articles published in the fields of physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. These data are not representative of all scientific and technological outputs from work conducted in the Tropics; they are publications where one or more authors are affiliated with an institution located in the Tropics.

Where time series exist, tropical nations account for only 5% of scientific and technical journal articles published worldwide since 1990. This proportion has been increasing, with research from the Tropics responsible for more than 6% of all scientific and technical publications in 2009 (see Figure 7.3.3) compared with 3.3% in 1990. Nearly 45% all articles authored in tropical institutions are attributed to Brazil and India.

Article output worldwide between 1990 and 2009 grew at an average rate of 2.7% per annum. Growth of articles from the Tropics was more than double the Rest of the World (2.4%) at 6% per annum. This steady improvement is being driven by South Asia, South East Asia, South America and Central America which have all shown dramatic increases in science and technology journal article output, even relative to population increases in those regions (see Table 7.3.2). The rate of outputs from Central & Southern Africa and Northern Africa & Middle East has actually declined.

The number of articles from South East Asia and South America has more than tripled in the past two decades. These trends have been driven largely by individual countries such as China (including Hong Kong), Singapore and Brazil, which have increased their output during this time substantially (see Figure 7.3.4). These regional patterns, driven by strong and growing economies represent an investment by those nations in science and technology, research and the tertiary education sector.

In Brazil, the increase in journal article output has been correlated with a growing number of doctoral graduates (Cruz & Chaimovich 2010). China has also been investing in higher education, research and technology development. China's total article output is now third only to the USA and Japan and likely to surpass both in the near future (Rongping 2010). India's recent rise in journal article output is fuelled by increased investment in pharmaceutical research as well as a sharp rise in international collaborations, particularly with South Korea and Japan (Mani 2010).

The disparity between the Tropics and the Rest of the World in terms of output in journal articles may also be exacerbated by the way scientific journals are measured and reported. There is a bias towards English language journals and those published in North America and Europe. Small, low impact, local journals published in local languages are unlikely to be included in worldwide databases. Conversely, it is these journals which are likely to publish work most relevant to the Tropics, addressing local issues (Galvez et al. 2000).

Table 7.3.2 **Scientific and technical journal articles published per 100,000 population**

	1990	1995	2000	2005	2009
Tropics	**0.81 (16,053)**	**0.83 (18,157)**	**1.05 (25 182)**	**1.40 (36,708)**	**1.75 (48,942)**
Central & Southern Africa	0.44 (1,762)	0.33 (1,535)	0.29 (1,539)	0.26 (1,584)	0.30 (2,035)
Northern Africa & Middle East	0.59 (474)	0.52 (487)	0.38 (413)	0.36 (446)	0.35 (488)
South Asia	0.98 (5,683)	0.90 (5,697)	0.91 (6,152)	1.20 (8,669)	1.54 (11,663)
South East Asia	0.51 (2,831)	0.52 (3,170)	0.91 (6,068)	1.53 (10,886)	2.29 (17,160)
Caribbean	0.82 (236)	1.01 (311)	1.21 (395)	1.13 (386)	0.98 (347)
Central America	0.99 (955)	1.54 (1,659)	2.12 (2,483)	2.61 (3,281)	2.59 (3,433)
South America	1.17 (2,574)	1.52 (3,654)	2.47 (6,459)	3.42 (9,624)	3.99 (11,771)
Oceania	19.55 (1,538)	19.02 (1,644)	17.59 (1,673)	17.46 (1,833)	17.98 (2,045)
Rest of the World	**15.62 (484,391)**	**16.19 (541,224)**	**16.89 (597,529)**	**17.88 (661,870)**	**18.88 (724,193)**
World	**9.37 (475,365)**	**10.21 (564,137)**	**10.61 (629,903)**	**11.23 (709,431)**	**11.89 (788,333)**

Source: NSF (2012), State of the Tropics project.

Collaborative science in the Tropics

The world has become more connected. Knowledge and research, like economies and markets, have become global. According to the National Science Foundation, co-authorship worldwide rose from 40% of articles published in 1988 to 67% in 2010, with international co-authorship increasing from 8% to 24%. This move to international collaboration is driven by factors such as lower cost communication and air-travel, increased use of information technology, national policies encouraging international collaboration and the increased mobility of students (Ware & Mabe 2009).

Research collaboration plays a central role in the generation of knowledge as these partnerships will share scientific goals and exchange ideas and expertise to address specific problems. International collaboration can help address those challenges which transcend national borders such as climate change, global health, food security, biodiversity, water security, energy security, and population growth. The increase in international collaboration will have positive outcomes for research and development in the Tropics. It removes the need for "fly in fly out" researchers from non-tropical areas and encourages greater integration with local scientists and institutions and therefore, more likely adoption of new technologies and advancements (Eddleston 1999).

Previously, collaborations between poorer tropical nations and wealthier nations in higher latitudes have been characterised by an imbalance in terms of access to information, funding, training, conferences and publishing opportunities, as well as the disproportionate influence of non-tropical partners in project administration and budget management (Jones & Blunt 1999). However, many tropical countries are now home to exceptional research institutions that are not only well resourced and staffed but also politically influential.

Building science and technology capacity in the Tropics

Many scientific and technical challenges facing the Tropics are unique. To meet these challenges, nations and institutions in the Tropics will need to continue to build capacity and invest in science and technology.

Traditional capacity building activities conducted by international organisations can be counterproductive to the development of a sustainable research program in terms of inappropriate research priorities, inhibiting knowledge transfer between scientists, and not facilitating the necessary communication pathways to policy development (Wolffers et al. 1998). Aid and donor programs often favour "seed" funding initiatives which fail to provide the long term, reliable funding required to develop and sustain research communities in terms of infrastructure and personnel in the Tropics (Ware & Mabe 2009).

Establishing and maintaining centres of scientific excellence in key tropical areas and "twinning" organisations between the developed and developing world are two techniques which have been used and are considered more successful than simply providing one-off capacity building support (Eddleston 1999, Jones & Blunt 1999).

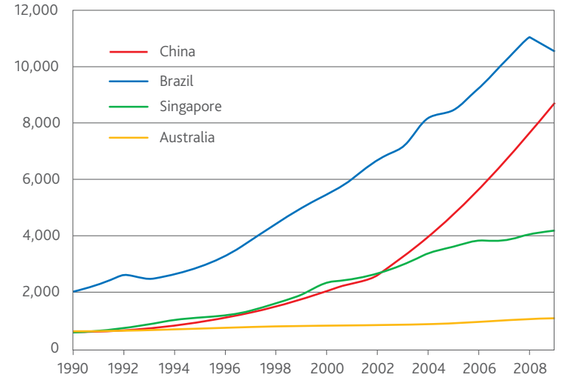
Information flow – to, from, and between tropical nations

Nations in the Tropics face many problems including poverty, inadequate drinking water, high illiteracy, high foreign debt and a heavy disease burden. In order for science and technology to play a role in alleviating some of these stressors access to knowledge and information must be maintained and improved.

Improving access to information technology and online journal archives is a technique used to bridge the divide between developing nations and the more scientifically prolific economies in the Rest of the World (Nchinda 2002). Two programs: the Health InterNetwork Access to Research Initiative (HINARI)[7] ; and the Global Online Research in Agriculture (AGORA)[8] have been developed to provide free or highly discounted subscription access to major online journals for developing countries. These programs have been successful in improving access to published information for some countries, however exclude countries like India, China and Brazil so are unlikely to have a major impact on the total number of articles published from tropical regions (Chan & Costa 2005).

The above initiatives improve information flow to the Tropics, but do not necessarily facilitate or assist tropical researchers to share and publish research arising in the Tropics. Unlike most of the Tropics, the tropical regions of Africa and the Middle East have shown no improvement in scientific output over the past two decades. Several reasons have been proposed for why Africa makes such a small contribution to the scientific and technical literature including: perceived poor quality by world standards; communication barriers, brain drain; inadequate access to publication media; and poor management of some smaller less well known journals (Britz & Lor 2003).

Figure 7.3.4 **Number of scientific and technical journal articles published for key tropical countries***



Source: NSF (2012), State of the Tropics project.
*Corrected for tropical population

[7] Health InterNetwork Access to Research Initiative - http://www.who.int/hinari/en/ HINARI Programme set up by WHO together with major publishers, enables developing countries to gain access to one of the world's largest collections of biomedical and health literature. More than 8,500 journals and 7000 e-books (in 30 different languages) are now available to health institutions in more than 100 countries, areas and territories benefiting many thousands of health workers and researchers, and in turn, contributing to improve world health.

[8] Access to Global Online Research in Agriculture - http://www.aginternetwork.org/en/ The AGORA program, set up by the Food and Agriculture Organization of the UN (FAO) together with major publishers, enables developing countries to gain access to an outstanding digital library collection in the fields of food, agriculture, environmental science and related social sciences.

[9] Thomson Rueters Institute of Scientific Information Web of KnowledgeSM Essential Science IndicatorsSM http://apps.webofknowledge.com

Scientists, health workers and engineers in the Tropics would benefit from information generated in their own country or region. Future development in this area will require international databases to include local publications – currently they are dominated by research from Europe and North America, much of which has little relevance to the Tropics.

Looking Forward

The growing contribution of tropical institutions to the global scientific literature and recognition of tropical institutions as leaders in various fields will ensure that science and technological challenges particular to the Tropics continue to be met. This will require significant capacity building and investment in science and technology in tropical regions from both public and private sectors. Partnerships between tropical and non-tropical institutions will continue to be beneficial and greater investment in and awareness of peer reviewed journals which focus on tropical regions and nations will be needed. Incentives for qualified scientists to live and work in the Tropics will also be important for sustained growth in science and technology.

Box 7.3.3 Citations – quality and quantity of scientific and technical journal articles

The quality of scientific research is measured in a number of ways; the most widely used method being citation rates (Coryn 2004). Citations occur when a researcher refers to another researcher's work in a publication. Highly cited research is considered meritorious or significant.

The Tropics produces relatively low numbers of scientific and technical journal articles but research authored in tropical regions has a citation rate (number of citations per paper) on par with the Rest of the World. According to the Thomson Reuters Institute for Scientific Information (ISI)[9], in the decade to 2012, tropical nations had a citation rate of 13 citations per article published, slightly higher than the Rest of the World (12 citations per paper). There is some debate as to the usefulness of citations as an indicator of scientific quality due to the ISI's bias towards US journals, as well as only recording publications written in English (Coryn 2004, Aksnes 2003). Additionally, papers might be highly cited because they have been discredited (Galvez et al. 2000), or due to some authors' over-citing their own work (Aksnes 2003). Additionally, only peer reviewed, published articles are included in this index. It does not include 'grey literature' such as reports from governments and non-government organisations.

Citation rate is considered the best measure of research quality available, and the data indicates that although the bulk of scientific and technical journal articles are produced in non-tropical regions, the quality of research from the Tropics is as good as the Rest of the World.

Scientific journals. Image: Robert Cudmore.

References

African Union–New Partnership for Africa's Development (2005) *Africa's science and technology consolidated plan of action* African Ministerial Council on Science and Technology, Johannesburg, South Africa.

African Union–New Partnership for Africa's Development (2010) *African Innovation Outlook 2010*, AU–NEPAD, Pretoria.

Aksnes DW. (2003) A macro study of self-citation *Scientometrics* **56**(2).

Annan K. (2003) A challenge to the world's scientists *Science* **299** (5612).

Arnold E, Bell M. (2001) Some new Ideas about Research for Development In: *Partnership at the leading edge: a Danish vision for knowledge, research and development.* Danish Ministry of Foreign Affairs: Copenhagen, Denmark.

Arxer I. (2010) Cuba in: *UNESCO Science Report 2010* United National Educational, Scientific and Cultural Organization, Paris France.

Asian Development Bank (2007) *Moving towards knowledge based economies: Asian experiences* Technical Note, Regional and Sustainable Development, Asian Development Bank, Philippines.

Battelle and R&D Magazine (2012) 2013 Global R&D Funding Forecast R&D Magazine, New Jersey, USA.

Blanc, DC and Nunn P (2000) *Incentives and disincentives for new anti-tuberculosis drug development* World Health Organization, Switzerland.

Britz JJ, Lor PJ. (2003) A moral reflection on the information flow from south to north: an African perspective. *Libri.* **53**(3).

Chan L, Costa S. (2005) Participation in the global knowledge commons: challenges and opportunities for research dissemination in developing countries *New Library World* **16**(3).

Chien C-L, Chiteng Kot F (2011) *New patterns in student mobility in the Southern Africa Development* Community UIS Information Bulletin No. 7. UNESCO, Canada.

Coe DT, Helpman E, and Hoffmaister AW. (1995) *North-South R&D Spillovers* Working paper no 5048 National Bureau of Economic Research, Massachusetts, USA.

Coryn CLS. (2004) The use and abuse of citations as indicators of research quality *Journal of Multidisciplinary Evaluation* **4**.

Cruz CHB, Chaimovich H (2010) Brazil in: *UNESCO Science Report 2010* United Nation Educational, Scientific and Cultural Organization, Paris France.

De la Fuente A, Ciccone A (2002) *Human capital in a global and knowledge-based economy Final Report,* Employment and European Social Fund, European Commission, Spain.

Docquier F, Rapoport H (2011) *Globalization, Brain Drain and Development* Working paper 5590 Institute for the Study of Labor, Bonn, Germany.

The Economist (2013) Information technology in Africa – the next frontier, in: *The Economist* 16 February 2013.

Eddleston, M (1999) Encouraging high-quality clinical research in the tropics *The Lancet* **353**(9159).

Freeman C, Soete, L (2009) Developing science, technology and innovation indicators: what we can learn from the past *Research Policy* **38**.

Gálvez A, Maqueda M, Martínez-Bueno M, Valdivia E. (2000) Scientific publication trends and the developing world: what can the volume and authorship of scientific articles tell us about scientific progress in various regions? *Scientific American* **88**(6).

Gereffi G, Wadhwa V, Rissing B, Ong R. (2008) Getting the numbers right: international engineering education in the United States, *China and India Journal of Engineering Education* January 2008: **13-25**.

Goñi-Pacchioni EA, Lederman D, Malony WF (2012) *Why don't poor countries do R&D?* World Bank, Washington DC.

Grupp H, Mogee ME. (2004) Indicators for national science and technology policy: how robust are composite indicators? *Research Policy* **33**.

Healy N. (2013) Building world-class universities and widening access to higher education: are these policy goals mutually exclusive? In: Sim J (ed) QS *Showcase – Asia, Middle East & Africa 2013*, QS Asia Quacquarelli Symonds Pty Ltd. Singapore.

Hollanders H, Soete L. (2010) The growing role of the knowledge in the global economy in: *UNESCO Science Report 2010* United National Educational, Scientific and Cultural Organization, Paris France.

Houghton J, Sheehan, P (2000) *A Primer on the Knowledge Economy* Centre for Strategic Economic Studies, Victoria University, Australia.

Jentsch B, Pilley P. (2003) Research relationships between the South and the North: Cinderella and the ugly sisters *Social Science and Medicine* **5**.

Jones ML, Blunt P. (1999) 'Twinning' as a method of sustainable institutional capacity building *Public Administration and Development* **19**.

Kale D, Little S (2007) From imitation to innovation: the evolution of innovative R&D capabilities in the Indian pharmaceutical industry. *Technology Analysis and Strategic Management* **19(5).**

Kearney M-L (2009) Higher Education, Research and Innovation: charting the course of the changing dynamics of the knowledge society in: Meek VL, Teichler U and Kearney ML (eds) *Higher Education, research and innovation: changing dynamics – Report on the UNESCO Forum on Higher Education, Research and Knowledge 2001-2009* International Centre for Higher Education Research, University of Kassel, Germany.

Kingsley B (2010) Globalization and higher education in sub-saharan Africa: A mixed blessing? *World Studies in Education* **11**(2).

Kritz M (2013) International student mobility in tertiary education capacity in Africa In: *International Migration* International Organization for Migration, Oxford, UK.

References | Continued

Mani S (2010) India in: *UNESCO Science Report 2010* United National Educational, Scientific and Cultural Organization, Paris France.

Naim T (2010) South Asia in: *UNESCO Science Report 2010* United National Educational, Scientific and Cultural Organization, Paris France.

Nchinda, TC. (2002) Research capacity strengthening in the South *Social Science and Medicine* **54**.

Nordling L. (2010) Africa Analysis: Continent's science plan needs refocus *SciDev Net*. 26 Feb 2010.

NSF (2012) *Science and Engineering Indicators* 2012: http://www.nsf.gov/statistics/seind12/ (accessed 7 February 2013) National Science Foundation, Arlington, Virginia.

OECD, 2005, *The Measurement of Scientific and Technological Activities: Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual, Third Edition* prepared by the Working Party of National Experts on Scientific and Technology Indicators, OECD, Paris.

Perera S, Lamberts R (2012) *Review of formal science policy in the Pacific Islands: a project for the UNESCO Apia programme on science policy development in the Pacific Islands*. The Australian National University, Canberra.

Rongping M (2010) China in: *UNESCO Science Report 2010* United National Educational, Scientific and Cultural Organization.

Sachs JD. (2000) *Tropical Underdevelopment Center* for International Development Working Paper 57. Harvard University, Boston, USA.

Sachs JD, McArthur JW. (2002). Technological Advance and Long-Term Economic Growth in Asia, in Bai C-E and Yuen C-W (eds) *Technology and the New Economy* MIT Press, Cambridge.

Salmi J (2001) Tertiary education in the 21st century: Challenges and Opportunities. *Journal of the Programme on Institutional Management in Higher Education* **13**(2).

SPC (2007) *Meeting house of the Pacific – the story of SPC 1947-2007*. Secretariat of the Pacific Community, Nouméa, New Caledonia.

Stocks G, Seales L, Paniagua F, Maehr E, Bruna, EM. (2008) The geographical and institutional distribution of ecological research in the Tropics *Biotropica* **40**(4).

Tijssen R, Hollanders H. (2006) *Using Science and Technology Indicators to support knowledge based economies* United Nations University Policy Brief 11, Netherlands.

Turpin T, Woolley R, Intarakumnerd P, Amaradasa W (2010) Southeast Asia and Oceania in: *UNESCO Science Report 2010* United Nations Educational, Scientific and Cultural Organization, Paris France.

UNESCO (2013) Global Flow of Tertiary Level Students: http://www.uis.unesco.org/Education/Pages/international-student-flow-viz.aspx (accessed March 2013).

Urama KC, Ozor N, Kane O, Hassan M. (2010) Sub-Saharan Africa in: *UNESCO Science Report 2010* United Nation Educational, Scientific and Cultural Organization, Paris.

Ware M, Mabe M, (2009) *The STM Report: An overview of scientific and scholarly journal publishing* International Association of Scientific, Technical and Medical Publishers, London.

Wolffers I, Adjei S, ver der Drift R (1998) Health research in the tropics *The Lancet* **351**.

World Bank (2008) Accelerating catch up: Tertiary education for growth in Sub-Saharan Africa *Directions in Development – Human Development*. The World Bank, Washington DC.

World Bank (2008) *Global Economic Prospects: technology diffusion in the developing world*. The World Bank, Washington DC.

World Bank (2013) World Bank Development Indicators http://data.worldbank.org/ (accessed 7 February 2013).

Zanatta M, Queiroz S. (2007) The role of national policies on the attraction and promotion of MNEs' R&D activities in developing countries *International Review of Applied Economics* **21**(3).

Engineering Students, Thailand.
Image: Gerhard Jörén, World Bank.

Urbanisation, Vietnam.
Image: Tran Veit Duc, World Bank.

Essay 4

Tropical underdevelopment – is it a thing of the past?

Dennis Trewin, AO.

Dennis Trewin was the Australian Statistician and head of the Australian Bureau of Statistics from July 2000 until January 2007. Prior to that he was Deputy Australian Statistician and, from 1992 to 1995, Deputy Government Statistician in New Zealand. He has recently been working as a statistical consultant on assignment with a range of countries and with the UN, OECD and World Bank. His most recent assignments have been in Indonesia, Fiji and Sweden.

Dennis has held a number of other positions such as an Australian Electoral Commissioner, an Associate Commissioner at the Productivity Commission for the study into the Not for Profit Sector, and a Trustee and Board member for the Australian Reward and Investment Alliance. He has been Chairman of the Advisory Board of the ARC Centre of Excellence for Coral Reef Studies. He has been Chairman of the Policy and Advocacy Committee of the Academy of Social Sciences of Australia. He is also an Adjunct Professor at Swinburne and Curtin Universities, a Council Member of the University of Canberra, and a Director of the Australian Mathematics Trust. He has been recognised as an Officer in the Order of Australia and received a Centenary Medal for his contribution to statistics.

Internationally, Dennis has been President of the International Statistical Institute. He was Chairman of the Global Executive Board for the 2005 round of the World Bank's International Comparison Program.

Tropical underdevelopment – Is it a thing of the past?

Dennis Trewin

Introduction

In his 2000 paper on Tropical Underdevelopment, Jeffrey D. Sachs (Sachs 2000) concluded that there was a significant historical difference between temperate and tropical regions in terms of economic growth rates and per capita incomes. His hypotheses were based on a range of quantitative models and he suggested this historical divide would persist into the near and far future. 'The income gap has also been amplified because poor public health and weak agricultural technology in the tropics have combined to slow the demographic transition from high fertility and mortality rates to low fertility and mortality rates. The analysis suggests that economic development in tropical ecozones would benefit from a concerted international effort to develop health and agricultural technologies specific to the needs of the tropical economies' (Sachs 2000).
The time period used for much of his analysis ended at 1995 and correctly represented the situation at that time. He noted that tropical countries had grown more rapidly in the years leading immediately up to 1995 (per capita GDP both temperate and non-temperate regions had grown at 2.3%)[1]. He thought, however, that this growth should have been greater, given the natural tendency of per capita incomes to converge as a consequence of global trade, technology diffusion and capital flows from richer countries. You would expect the tropical countries to grow faster than the temperate zone but he believes 'this tendency towards convergence is muted, if not eliminated altogether' (Sachs 2000, pg. 9). He also highlighted the relatively poor performance of many African and Latin American countries.
I have used 1995 as the starting point for my analysis wherever possible. That period has not always been available in the data used for the State of the Tropics Report so I have used a similar period in these cases. Sometimes, I have also referred to data from more distant periods to emphasise the changes to tropical countries. It should be noted that I am a statistician not an economist and I have taken a statistician's perspective to this analytical essay.

The economic growth rates for the Tropics have greatly exceeded those for the Rest of the World since 1995, probably more so than expected by Sachs. Improvements have also occurred in a range of other progress indicators. The main purpose of this paper is to provide some explanation of the arguably surprising strength of this economic growth. I have primarily used the indicators in the State of the Tropics Report to illustrate my points.

[1] All references to GDP in the text and tables are to real GDP ie nominal GDP adjusted for the impact of price increases

Table E4.1 **Average annual change in real GDP (%)***

	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010	*1980-2010*	*1995-2010*	*2000-2010*
Tropics	2.1%	3.9%	4.6%	3.6%	4.8%	5.8%	*4.1%*	*4.7%*	*5.3%*
Central & Southern Africa	0.9%	3.3%	1.1%	3.8%	5.5%	6.5%	*3.5%*	*5.3%*	*6.0%*
Northern Africa & Middle East	-3.2%	3.4%	2.6%	3.3%	4.3%	3.6%	*2.3%*	*3.7%*	*4.0%*
South Asia	4.9%	5.7%	5.9%	5.6%	7.1%	8.3%	*6.3%*	*7.0%*	*7.7%*
South East Asia	4.5%	7.5%	8.2%	3.4%	6.1%	6.5%	*6.0%*	*5.3%*	*6.3%*
Caribbean	0.3%	2.3%	3.7%	4.7%	4.0%	4.6%	*3.3%*	*4.4%*	*4.3%*
Central America	1.7%	1.4%	1.5%	4.9%	1.8%	2.6%	*2.3%*	*3.1%*	*2.2%*
South America	0.9%	2.1%	3.3%	1.7%	3.1%	4.5%	*2.6%*	*3.1%*	*3.8%*
Oceania	4.1%	3.7%	3.2%	3.9%	3.3%	2.1%	*3.4%*	*3.1%*	*2.7%*
Rest of the World	3.4%	3.6%	2.7%	3.7%	3.1%	2.7%	*3.2%*	*3.2%*	*2.9%*
World	3.2%	3.6%	3.0%	3.7%	3.4%	3.3%	*3.4%*	*3.5%*	*3.4%*

Source: World Bank (2013), State of the Tropics project
*Measured at purchasing prices parity in constant 2005 international dollars.

To be clear, the objective of the essay is not to criticise Sachs' significant paper; rather, it is to use Sachs' paper as a base and to provide some analysis of the main driving forces for the relatively strong improvements in the Tropics since the publication of that paper. In particular I will analyse Sachs' hypotheses to explain the lower growth rates in the Tropics to assess whether changes in the areas addressed by the hypotheses have led to better economic performance. I will also look at other indicators we think may be important to explain the extraordinary economic performance of the Tropics.

A review of Sachs' main findings

Sachs' quantitative analysis showed that the growth rates for the Tropics were much lower than the temperate region over the period 1820 to 1995. Per capita incomes in the Tropics were correspondingly lower than the Rest of the World and the ratio decreased over time.

Sachs provided five hypotheses as to why this might be the case. These five factors related to technology development, technology productivity, innovation, societal dynamics and geopolitical factors.

(1) Technologies in critical areas are ecologically specific, especially in the areas of health and agriculture, but also construction, energy use, and some manufacturing processes. Such technologies do not easily transfer across ecological zones.

(2) Temperate zone technologies were more productive than tropical zone technologies in crucial areas of health, agriculture, energy utilisation, and military technology. It is likely these differences could not be overcome by altering existing temperate zone technologies.

Table E4.2 **Annualised change in per capita GDP for selected period***

	1995 - 2010	2005 - 2010
Tropics	3.0%	4.1%
Central & Southern Africa	2.6%	3.8%
Northern Africa & Middle East	0.8%	0.3%
South Asia	5.6%	6.9%
South East Asia	3.9%	5.2%
Caribbean	3.2%	3.6%
Central America	1.6%	1.2%
South America	1.7%	3.3%
Oceania	0.6%	0.1%
Rest of the World	2.2%	1.8%

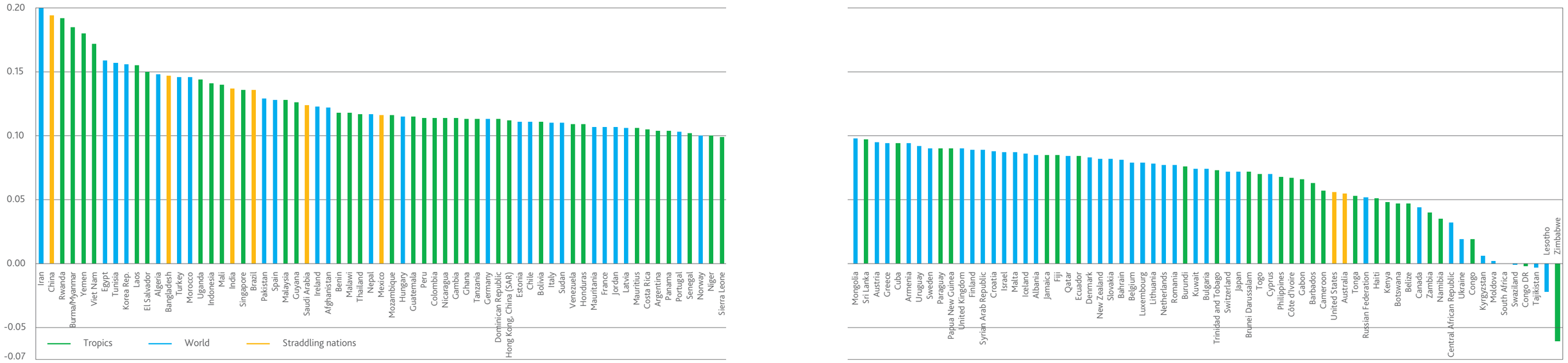
Source: World Bank (2013), State of the Tropics project
*Measured at purchasing prices parity in constant 2005 international dollars.

Table E4.3 **Change in Human Development Index between 1990 and 2010***

	Average of 1990 HDI	Average of 2010 HDI	Difference 1990-2010
Tropics (excluding straddling nations**)	0.48	0.58	0.10
Central & Southern Africa	0.38	0.45	0.07
Northern Africa & Middle East	0.37	0.50	0.13
South Asia	0.46	0.59	0.13
South East Asia	0.57	0.70	0.13
Caribbean	0.63	0.71	0.08
Central America	0.58	0.69	0.11
South America	0.60	0.71	0.11
Oceania	0.68	0.75	0.07
Oceania (Australia & USA omitted)	0.55	0.62	0.08
Rest of the World	0.69	0.76	0.08
Rest of World (including Australia and USA)	0.69	0.77	0.07
World	0.59	0.68	0.09
Straddling nations**	0.62	0.74	0.12

Source: UNDP (2014), State of the Tropics project
*Values are the average for nations with available data using State of the Tropics regions.
**Straddling nations include: Mexico, Brazil, Saudi Arabia, India, Bangladesh, China, Australia and United States (Hawaii).

Figure E4.1 **Magnitude of change in Human Development Index between 1990 – 2010**



Source: UNDP (2014), State of the Tropics project

(3) Temperate zone innovation has been favoured strongly by larger and richer populations. Technological innovation has an increasing return to scale. Therefore, the larger, richer population in the temperate zone, which has been integrated in a global market since 1800, has strongly favoured innovation. This has probably amplified the gap between the temperate and tropical zones over the past 200 years.

(4) Societal dynamics are different. The processes of urbanisation and demographic transition, among other societal dynamics, further amplify discrepancies in the development process. Tropical regions have long lagged behind fast growing temperature regions.

(5) Geopolitical factors. Temperate zone imperial domination of tropical regions on the basis of superior military technology, and rich-country control of the institutions of globalisation – are further amplifiers. However Sachs believed their role was often exaggerated when not considered alongside the underlying technological, demographic, and urbanisation processes.

According to Sachs, 'If these hypotheses are broadly correct, then policy solutions for tropical underdevelopment will require a much greater national and international focus on technological innovation directed at the problems of tropical ecology' (Sachs 2000 pg.4).

Overview of economic performance since 1995

How have the Tropics performed economically in more recent years? Over the period from 1995 to 2010, GDP in tropical nations grew at an annual rate of 4.7% compared with 3.2% for the Rest of the World (see Table E4.1). The fastest growing regions have been South Asia (7.0%), Central and Southern Africa (5.3%) and South East Asia (5.3%).

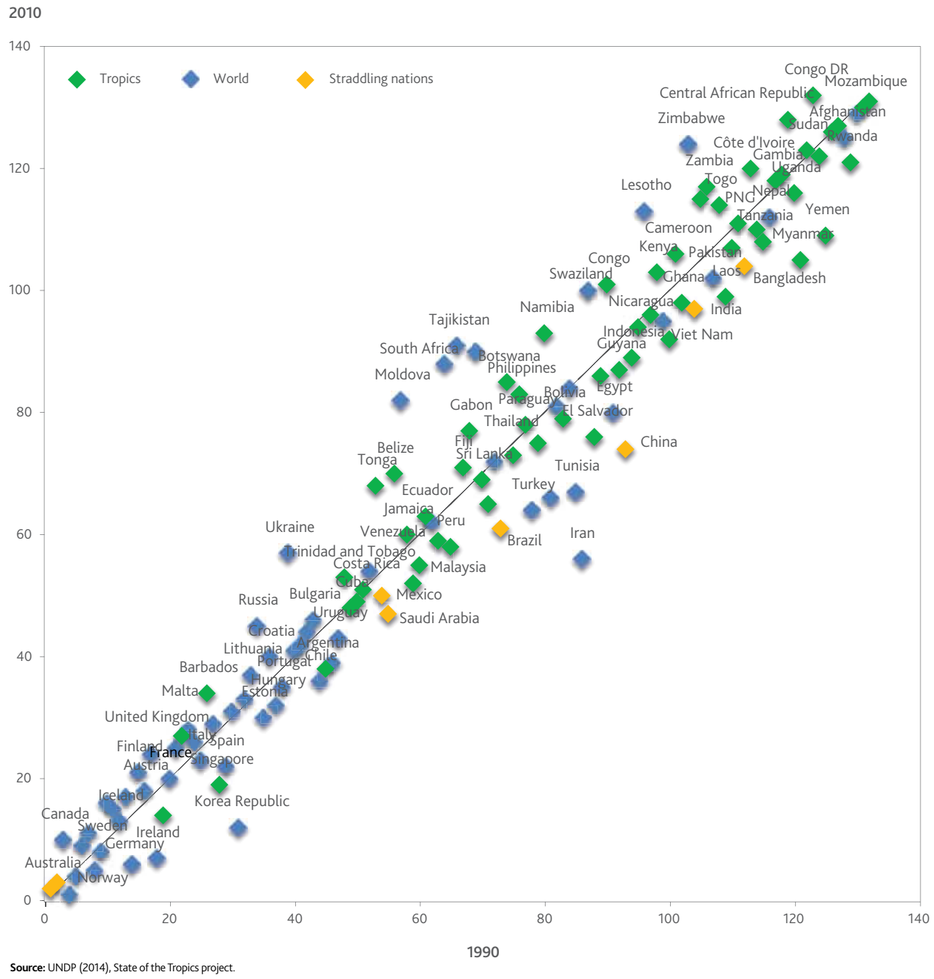
In fact, the rate of growth for these regions has accelerated in recent periods. This is also true for Latin America. Looking at the more recent 2005-10 period, it can be seen that the growth has been 5.8%, much higher than the 2.7% experienced by the Rest of the World (see Table E4.1). Of course, per capita incomes remain much lower – it will take many decades of higher growth to catch up.

How does this compare with Sachs' analysis of earlier periods? His definitions of regions are not identical but are close enough to make comparisons valid. During the long period from 1820 to 1992, the per capita GDP of the temperate region grew at an annual average rate of 1.4 percent per year, compared with 0.9 percent per year in the non-temperate region (dominated by tropical countries). Note that these are per capita measures so they will be lower than growth in GDP measures if there has been positive population growth. He also points out that the ratio of per capita GDP measures for temperate to non-temperate countries changed from 1.4 in 1820 to 4.5 in 1995.

Table E4.2 shows the comparisons for annualised growth rates for per capita GDP. On this measure, the Tropics are also growing much faster than the Rest of the World. Over the 1995 to 2010 period, the Tropics grew at 3.0% compared with 2.2% for the Rest of the World.

In more recent times, the growth in the Tropics has accelerated whereas it has gone in the opposite direction for the Rest of the World. Over the 2005 to 2010 period, the annualised growth in per capita GDP for the Tropics was 4.1% compared with 1.8% for the Rest of the World. This is much greater than the 0.9% annualised growth estimated by Sachs for the non-temperate region (which will be dominated by countries in the Tropics). Things have clearly changed although the performance by region is quite mixed. Differences between regions are explored later in the paper.

Figure E4.2 **Human Development Index, 1990 rankings versus 2010 rankings**



Source: UNDP (2014), State of the Tropics project.

This relative improvement for tropical countries is also true for a range of other progress indicators, some of which are summarised by the UNDP's Human Development Index (HDI) (UNDP 2014).[2] As can be seen from Table E4.3, the change in the HDI between 1990 and 2010 has been 0.10 (21%) for tropical countries (excluding those large countries straddling the tropical and temperate regions) compared with 0.07 (10%) for the Rest of the World.[3] If you include the straddling countries, such as China, India and Brazil, the improvement would be 0.11. The regions showing the greatest improvement are South East Asia, South Asia and Northern Africa and the Middle East. The regional estimates in Table E4.3 include the straddling countries.

These findings are reinforced by the following two figures. In Figure E4.1, the countries with the greatest improvement in HDI scores are shown on the left. The tropical countries are shown in green and countries which straddle the Tropics are shown in yellow. There is a definite preponderance of tropical countries on the left hand side of the graph especially if the straddling countries are included (which have performed better on average). There is also some clustering on the right hand side. This latter group is dominated by poor performing African countries. The performance has been quite mixed in African countries – some have shown significant improvements, others have not. Figure E4.2 shows rankings rather than HDI scores. Countries falling below or to the right of the diagonal line improved their ranking. It is not as easy to see but the tropical and straddling countries are more likely to have improved their ranking.

Then and now: a comparison, a viewpoint, a changing landscape?

I will look now at the economic growth and development in the Tropics with specific attention to each of Sachs' five hypotheses. A number of indicators have been used to illustrate the way the tropical landscape has changed economically, socially and environmentally. I will look first at hypotheses (1), (2) and (3); it is convenient to look at these hypotheses concurrently as they all relate to technology and transfer of technology. The relevant indicators are shown in italics and, for the first three hypotheses, they are as follows: foreign direct investment, research and development expenditure, mobile technology, internet, tertiary enrolments and scientific and technical journal articles.

The expectation is that *foreign direct investment (inflows)* should have increased as it is an effective way to transfer knowledge. Likewise, *research and development* activity should have increased in tropical countries. *Mobile technology* and the *Internet* have been powerful technologies for developing countries including those in the Tropics. The extent of the take-up of mobile technology is of interest. Likewise, an increase in tertiary education enrolments is a good proxy indicator to understand the development of knowledge in the Tropics. Within the tertiary sector, the number of scientific and technical journal articles also provides an indicator of research capability and output. I will look at each of these indicators in turn but the figures for each of these indicators suggest that there has been "a much greater national and international focus on technological innovation directed at the problems of tropical ecology" since the time period on which Sachs' paper was based. Perhaps his proposed policy solution has occurred, at least to some extent.

Foreign direct investment (inflows) increased substantially in all regions of the Tropics over the 30 years to 2010. Foreign direct investment to tropical nations increased more than tenfold between 1980 and 2010, from US$11 billion to US$157 billion. As a percentage of GDP, it has increased from 0.7% of GDP in 1980 to 2.2% in 1995 to 3.5% in 2010. This ratio was highest in the Northern Africa and Middle East (6.1%) and South East Asia (5.7%) regions. It also increased fastest in these two regions. However, the ratio declined in Central America between 1995 and 2010.

Research and development expenditure (as % of GDP) remained much lower than the Rest of the World (0.58% compared with 1.96%) in the late 1990s, but grew much faster at 18% between 2000 and 2008 compared with 9% for the Rest of the World. The fastest growing regions have been South East Asia and South America.

Mobile technology has emerged as one of the fastest growing consumer technologies ever introduced. In the Tropics mobile telephony has become the dominant means of communication and the principal gateway to increased ICT access and use, with penetration rates reaching 68% in 2010 up from 3.7% in 2000 and 0.1% in 1993 although somewhat less than the Rest of the World at 83%. The penetration is highest for South America, Central America and South East Asia all of which have higher penetrations than the Rest of the World on average.

Diffusion of the Internet in the Tropics has happened quickly in terms of both users and penetration, although access is considerably less widespread than mobile communications. Growth rates of 30% per annum between 2000 and 2010 (twice that of the Rest of the World) enabled the number of Internet users in the Tropics to reach 471 million in 2010 and achieve a penetration rate of 16.5%. All regions have grown rapidly, although Central and Southern Africa, Northern Africa and the Middle East, and South Asia lag behind the other regions.

With respect to *tertiary education enrolments per 100,000 population,* growth has been rapid from 1190 to 2031 over the 2000 to 2010 period. Although still considerably less than the ratio of 3423 students in the Rest of the World, there has been considerable catch-up. The proportional growth in Central and Southern Africa has been stronger than most other regions although the number of enrolments is still relatively low.

[2] The Human Development Index combines indicators of life-expectancy, educational attainment and income into a composite index. It is designed to serve as a frame of reference for both social and economic development.

[3] Data for 1990 are used as the base period as data for 1995 could not be sourced. This in unlikely to have a major impact on the analysis, noting that the improvement in the performance of the tropical countries has been accelerating.

The *number of scientific and technical journal articles per 100,000 population* originating from authors in the Tropics has more than doubled over the 1990 to 2009 period, but this figure remains very low at 1.8 when compared with for the Rest of the World at 18.9. Consistent with research and development expenditure, the regions with the most rapid growth were South East Asia and South America.

Sachs' policy solution to develop technology in the Tropics was to have a much greater national and international focus on technological innovation directed at the problems of tropical ecology. The indicators discussed above suggest there has been considerable progress in this direction, perhaps because newer technologies are not so ecology dependent (e.g. a lower reliance on agriculture). The impressive increase in foreign direct investment implies that there has been significant technology transfer. The advent of air conditioning and additional protections from tropical diseases has also made it easier for people from temperate climates to work in the Tropics and transfer their knowledge. Furthermore, the large increase in tertiary enrolments suggests that there is growing capacity within the tropical regions to adopt new technologies. The other indicators suggest important increases in home-grown technical capability even though still considerably less than the Rest of the World. All these factors are likely to have contributed to the higher economic growth in the tropical regions.

I turn now to hypothesis (4), which relates to societal dynamics such as urbanisation and demographic transition. Have there been many changes since 1995? The indicators I will look at are as follows: *urban population, life expectancy, maternal mortality, child (under 5) mortality and youth literacy*. Although not one of the indicators in the State of Tropics Report, I will also look at *fertility* because it is an important part of the demographic transition.

Urban population (as a percentage of the total population has increased considerably over the past 30 years, much greater than Sachs would have envisaged when writing his paper, I think. It has been growing steadily at an annual rate of 3.3% and was 45% of the population in 2010 compared with 38% in 1995 and 30.5% in 1980. This is still less than the 56.2% for the Rest of the World. In relative terms, the biggest growth has been in South East Asia. The process of urbanisation has supported economic development by providing the labour needed for industrial activity, but has also been a factor in the expansion of slums.

With respect to life expectancy, there have been significant improvements in the tropical countries. Over the past 50 years, life expectancy has improved from 41.3 years to 65.2 years. Although this represents a considerable catch-up to the Rest of the World, it remains 7.7 years lower. Over the past 15 years, the improvement for the tropical regions has been about five years, showing some acceleration. The relatively larger increase in life expectancy in the Tropics reflects greater access to vaccines and major improvements in many of the social determinants of health, including increased access to potable water and sanitation facilities, and enhanced public health infrastructure. There are two important exceptions. Whilst deaths from most of the so-called neglected tropical diseases (NTDs) have declined, this is not the case for dengue fever. Also obesity and non-communicable diseases such as diabetes are growing concerns. The rates have been growing steadily, although they are still well below those for the Rest of the World.

Sachs noted the significant improvements in public health in a number of tropical countries (mostly Asian) that preceded their economic take-offs. These improvements in public health have also now occurred in a number of other tropical countries and might have similar impacts. Reduction of maternal and child mortality has also been an important contributor to the improvement in life expectancy. All regions experienced significant decreases in both indicators with some regions now experiencing rates lower than the average for the Rest of the World.

Fertility has decreased significantly in the tropical regions and is continuing to fall. For the 1950-55 period, the fertility rate was 6.2 which had fallen to 3.2 by 2005-10. Much of the reduction occurred prior to 1990-95 when it had already dropped to 4.1. For the South America, Central America and South East Asia regions the fertility rate is now only slightly above that for the Rest of the World. It remains high for the Northern Africa & Middle East and Southern & Central Africa regions but, in Africa at least, it is expected to fall with reductions in child mortality and improvements in the education levels of girls.

Youth literacy has improved steadily over the period from 1989-93 to 2005-10, from 79.8% of youth to 86.2%. Whilst the rate is still lower than the Rest of the World, the South East Asia, South America and Central America regions have rates higher than the Rest of the World on average. Also, the South Asia region is experiencing the most significant increase in youth literacy. This is a consequence of a significant increase in mean years of schooling over this period.

It can be seen that the societal dynamics of the tropical regions have changed in that they now represent more closely the conditions that exist in non-tropical countries. Urbanisation has definitely increased and a demographic transition is occurring because of lower mortality and fertility rates, as discussed above. The tropical countries are experiencing the so called demographic dividend to their economic growth as relatively high proportions of their populations are of working age. The improvements in youth and adult literacy mean t there is a more skilled workforce and a greater range of job opportunities for this workforce.

Societal dynamics have changed more rapidly in some regions than others with South East Asia being the most notable example. However, there are other regions such as South Asia and Central and Southern Africa where the transition has started. If Sachs' hypothesis (4) is correct, then it could be concluded that changes in societal dynamics have contributed to the faster economic growth in the tropical regions.

Sachs' hypothesis (5) is about geopolitical factors but I will not comment on this aspect of Sachs' theory because the State of the Tropics Report does not contain any relevant indicators except to note improved governance in many countries. Furthermore, Sachs' assessment is that "their role is often exaggerated when not considered alongside the underlying technological, demographic, and urbanisation processes".

Other factors

Sachs also mentions the importance of agriculture productivity to growth in the tropical regions, and notes that productivity had been much lower than the Rest of the World for a number of reasons including the lack of technology specific to the tropical ecological regions. Significant improvement appears to have been made in agriculture productivity in more recent years. Although there has been little increase in the use of land in the Tropics, output has increased dramatically because of improved productivity. Two of the important contributions have been increased irrigation and use of inorganic fertilisers both of which have their own environmental problems.

Over the past 30 years, livestock productivity has increased by 89% for cattle/buffalo (South America being the main contributor) and 44% for sheep/goats (Central and Southern Africa being the main contributor) compared with much more modest growth for the Rest of the World (3% and 4% respectively). Total cereal production has more than doubled (South America and South East Asia being the main contributors) but still lags the Rest of the World in yield even though it has improved by 67% over the past 30 years. The increase in agriculture productivity has been important because it has corresponded with an increase in demand (and prices) for agriculture commodities. Africa has generally lagged the other regions in the use of technology and improved techniques to improve agriculture productivity. However, the analysis above suggests there is some catch-up.

On the other hand, there are some warning signs with respect to future agriculture productivity. Nearly one-third of land in the Tropics suffered degradation between 1981 and 2003. This is more than the global average of 20%. South East Asia had the greatest area of land degradation at 53% but it is now much less reliant on agriculture for economic activity. Deforestation followed by poor agricultural practices were the major causes of land degradation.

Water is also an issue. The Tropics have just over half the world's renewable resources (54%). Despite this, half the tropical population was considered vulnerable to water stress in 2010 and current water use patterns are still considered unsustainable in many parts of the Tropics. Agriculture accounts for 81% of water withdrawals so is especially vulnerable.

Despite these improvements in agriculture productivity and increase in agriculture production, agriculture has become a relatively less important part of the economy in the Tropics. It was 18% of GDP in 1980, down to 15% in 1995 and further down to 12% by 2010.[4]

Sachs also referred to the ability to mobilise energy resources and suggested that tropical countries were disadvantaged because they had relatively fewer coal resources. However, electricity generation has grown much faster in the Tropics than the Rest of the World. Tropical regions accounted for 7% of electricity generation in 1980 and grew to 15% by 2010. On a per capita basis, it is still much faster with energy production increasing by 4% per annum in the Tropics over the past 30 years compared with 1.7% per annum in the Rest of the World. Furthermore, electricity generation from renewable resources (mostly hydroelectricity) has also increased much faster in the Tropics from 15% of world usage in 1980 to 23% in 2010. Imports of energy sources such as coal would have been an important contributor but the tropical regions are also richer in oil and renewable resources.

To summarise, there appears to be considerable progress in the Tropics in all the factors that Sachs regarded as pre-conditions for improved growth, namely the "underlying technological, demographic, and urbanisation processes" as well as substantially improved agriculture productivity even though agriculture has become relatively less important as the economies have diversified. Furthermore, the "ability to mobilise energy resources" seems to have improved. Consistent with his hypotheses, these are likely to be significant factors in the greatly improved economic performance of the tropical regions. However, these may not be the only factors that matter. This issue is explored in the following section.

What other factors might be driving the improved performance of the tropical regions?

Apart from the South East Asia and South Asia regions, the tropical regions had relatively low growth compared with the Rest of the World up until the mid-1990s, i.e. the end point of Sachs' analysis. For the other regions, the improved growth started about then or shortly afterwards. Improved political stability has been one important factor that has influenced the sudden improvement in many circumstances in the Tropics. This does not hold for every tropical country and, where it does not exist, poor economic performance is one of the outcomes. Institutional strengthening and good governance are also important, which includes arrangements for collecting taxes and other revenues due to government. This applies particularly to the financial system and its supervision. Also, there needs to be a favourable policy environment that includes flexible capital and labour markets. The performance of tropical countries is mixed but generally there have been significant improvements in those countries where the economic performance is best.

One of the comparative advantages of most tropical countries is relatively low labour costs. This has facilitated a shift in manufacturing and

[4] Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production

certain services from developed countries to a number of tropical countries. This has been an important factor in South Asia, for example.

There are other important factors which are covered by the State of the Tropics indicators such as (i) education (mean years of schooling of adults), (ii) openness through international trade and investment (exports of goods as %of GDP, foreign direct investment, net inflows), (iii) infrastructure development (gross capital formation) and (iv) corruption.

The mean years of schooling as an adult almost doubled in the Tropics between 1980 and 2010 from 2.9 years to 5.9 years. This is still less than the Rest of the World (8.5 years). The regions with the highest mean years of schooling are the Caribbean (8.2 years) and Central America (7.8 years). It is important that these improvements continue as it has been shown that there is a strong relationship between mean years of schooling and per capita incomes.

Growth in exports of goods as a % of GDP has been very strong from 26.4% in 1980 to 37.0% in 1995 to 47.1% in 2010. This is much faster than the growth in exports in the Rest of the World, where the ratio was 25.1% in 2010. GDP growth has also been slower in the Rest of the World. Exports of goods as a % of GDP for the Tropics were actually more than 50% prior to the Global Financial Crisis. The ratio for exports (47.1%) is higher than that for imports (45.8%) so the Tropics are a net exporter, and trade in goods contributes positively to economic growth. Unfortunately there is no similar data for trade in services.

South East Asia has the highest proportion of exports to goods as a % of GDP (90.2%) but this large number may be due in part to re-exports from places like Hong Kong and Singapore. South Asia has the strongest growth in exports driven by the trade liberalisation policies of India and Bangladesh. These regions in particular have more mixed economies and have significant exports from industries other than agriculture. Services are also becoming increasingly important.

Foreign direct investment, net inflows increased substantially in all regions of the Tropics in the 30 years to 2010 assisted in part by liberalisation policies in many countries. Foreign direct investment to tropical nations increased more than tenfold between 1980 and 2010, from US$11 billion to US$157 billion. As a percentage of GDP, it has increased from 0.7% of GDP in 1980 to 3.5% in 2010. The petroleum industry was an important contributor. When consideration is given to this increase in foreign investment together with the story on exports, tropical countries have clearly become more open. Developed countries have traditionally been the source of funds for foreign investment but in recent years, developing countries such as China have also become important investors.

With respect to gross capital formation, there has been sound performance in the Tropics which has contributed to both current and future economic growth. This indicator includes both private and public outlays. As a proportion of GDP, gross capital formation has been growing at about 0.5% per annum over the last 30 years and the ratio is now 25%. In the Rest of the World, the ratio has declined at a rate of 0.1% per annum to 22%, and is now lower than for the Tropics. The ratio is highest in South Asia (35%) and South East Asia (30%) with the highest growth in South Asia where there have been active policies in place in India to encourage investment. The growth in South East Asia was affected somewhat by the Asian Financial Crisis in 1997 but has since recovered.

Corruption, according to the World Bank's World Governance Indicators (World Bank 2013), is more prevalent in the Tropics than in the Rest of the World, and the gap has not changed significantly since 2000. Corruption tends to be more prevalent in resource rich developing countries, especially where there is weak rule of law and state ownership of resources.

It is difficult to assess the influence of corruption on economic growth. Studies have shown that it will have a negative impact and the World Bank is trying to address it for that reason. Certainly the most corrupt countries are among those that performed the worst economically. It would be interesting to look at whether there is correlation between those countries that have reduced corruption (unfortunately this number is small) and economic growth.

To summarise, apart from the pre-conditions implied by Sachs' hypotheses and the other factors mentioned in the opening paragraphs of this section, it appears that there is a relationship between economic growth and education, openness through international trade and investment, and infrastructure development. It could be argued that Sachs' pre-conditions are necessary but not sufficient, as other factors are also important.

What has been the industry breakdown of economic growth?

It is illuminating to look at how various sectors of the economy contribute to growth. As shown in Table E4.4, the trend for the Tropics has been the decline in the relative importance of agriculture4 (even though it has increased substantially in actual size), and the increased importance of both industry[5] and services[6]. Industry has increased from 29% of GDP to 32% between 1995 and 2010. The increase for services is slightly greater from 49% of GDP to 53%. This is not unexpected. As countries develop, there is generally relatively less reliance on agriculture.

The ability to adapt the industry structure of economies is important. To quote Sachs, 'these (more successful) economies were able to establish new productive sectors (e.g. textiles, electronic machinery, semiconductors and electronic components) where tropical production was not burdened by climatic or ecological factors' (Sachs 2000 pg. 31).

The story is quite mixed across the regions as is the relative importance each sector. For agriculture the biggest decreases between 1995 and 2010 were in Southern and Central Africa, Northern Africa and the Middle East and South Asia. For South East Asia, the decrease in the relative importance of agriculture occurred earlier.

The relative increase in the importance of industry started from the mid-1990s. For this grouping, the biggest increases have been in Southern and Central Africa, and Northern Africa and the Middle East. There were actually decreases in the relative importance of industry in the Caribbean and Central America.

On the other hand, for services, the Caribbean and Central America were among the regions with the biggest increases along with South East Asia from 1995 to 2010. The trend towards services started even earlier in South East Asia. There was a significant fall in the relative importance of services over this period in Northern Africa and the Middle East.

Differences between regions

In this section I rely mostly on information in the State of the Tropics Report. The approach I have taken is to arrange the regions by their annualised growth over the 1995 – 2010 period and then look at where the regions are relatively strong or weak, mostly in terms of the indicators in the Report (see Table E4.5). The economic performance of the regions is quite mixed and will use Table E4.5 to see whether there are any patterns that help explain this mixed performance.

It is worth noting the following pen pictures of the nature of the growth for each of the regions.

- South Asia: Very strong growth well before 1995, accelerating through the 2000s
- South East Asia: Very strong growth started well before 1995 and has continued with a slight setback during the 1997 Asian Financial Crisis
- Central and Southern Africa: Very strong growth only started during the 2000s but has been accelerating
- Caribbean: Strong but steady growth since 1995

[5] Industry includes mining, manufacturing, construction, electricity, water, and gas.

[6] Services include wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services.

Table E4.4 **Contribution of different sectors to GDP (%)**

	1980			1995			2010		
	Agriculture	Industry	Services	Agriculture	Industry	Services	Agriculture	Industry	Services
Tropics	**18%**	**29%**	**48%**	**15%**	**29%**	**49%**	**12%**	**32%**	**53%**
Central & Southern Africa	32%	27%	42%	30%	27%	44%	24%	34%	43%
Northern Africa & Middle East	26%	25%	42%	32%	22%	36%	20%	37%	32%
South Asia	35%	21%	48%	26%	25%	49%	19%	28%	53%
South East Asia	24%	30%	43%	16%	32%	48%	12%	34%	54%
Caribbean	13%	23%	55%	8%	25%	60%	5%	18%	71%
Central America	9%	25%	53%	6%	30%	50%	4%	26%	62%
South America	11%	35%	48%	8%	32%	51%	6%	36%	53%
Oceania	10%	36%	53%	7%	29%	64%	6%	29%	64%
Rest of the World	**6%**	**38%**	**50%**	**5%**	**32%**	**55%**	**4%**	**30%**	**63%**
World (estimated)	**8%**	**36%**	**50%**	**7%**	**31%**	**54%**	**6%**	**31%**	**61%**

Source: World Bank (2013), State of the Tropics project.

- Northern Africa and the Middle East: Growth has been steady since 1995 but there has been significant population increases so per capita growth has been quite small

- South America: Strong growth only really started in the 2000s after many decades of weak growth

- Central America: Apart from the late 1990s relatively low growth during this period, with per capita GDP hardly growing at all

- Oceania: Relatively weak growth that has been declining in magnitude with virtually no growth in per capita GDP

It is difficult to see a clear pattern from Table E4.5. Exports are clearly important for the stronger growing regions but the nature of the exports vary quite a bit from one region to another. South Asia seems to be taking advantage of relatively low labour costs but with improvements in education and youth literacy. Their economy has had significant increase in both industry and services. This increase has been supported by capital formation although foreign investment remains surprisingly low.

The strong performance of South East Asia is not surprising. There has been an excellent performance on the full range of economic, scientific and social indicators. Exports have clearly been a big part of the story. In the past there would have been a comparative advantage through relatively low labour costs, however their costs would no longer be low compared with South Asia for example. They have needed to add value through improved labour productivity or a switch to less labour intensive industry. The indicators suggest this may be happening. Also, services are playing a much larger role in the economy than previously.

Although Southern & Central Africa remains low on a range of science, education and other social indicators, there has been an increase in foreign investment. This may be due to foreign investors taking advantage of low labour costs, even though most industry in the region is based around commodities such as oil. Also, there have been important improvements in agriculture productivity. Export performance has grown steadily as a percentage of GDP but nowhere near as strongly as South Asia which also has relatively low labour costs. The Southern & Central Africa region is large and diverse: culturally, historically and politically. It is therefore not surprising that there is a great deal of variation in the performance of nations within the region.

The Caribbean has high and improving education indicators, especially tertiary education. The labour costs for the region are relatively high. There has been a big switch from industry to services possibly as a consequence. Also, exports (and economic growth) have been limited because Cuba does not have as much access to open markets and investment as many other countries.

Oceania is the worst performing region especially when you look at growth in per capita GDP. Their tertiary education levels are high, mostly because of the contribution of tropical Australia and Hawaii, but other education levels are declining. The labour costs of the region are relatively high compared with the high performing regions so the comparative advantage of the smaller countries is not clear.

The influence of China and India is important both because of their own contribution to economic growth and the contagion effect on other economies in the region. Only parts of both countries are in the Tropics so this diminishes their impact, especially China. In India, we have estimated 57% of the population live in the Tropics and contribute to 68% of India's GDP. In China, only 12% of the population live in tropical regions producing 12% of national GDP. However, even after removing the direct contributions of China and India, the regions still show strong growth, although at a lower level. China and India, although important, are only part of the story.

The Future

The World Bank's Global Economic Prospect (World Bank 2014) provides a positive picture for economic growth for the Tropics driven primarily by strong global demand for their commodities and services. However, the predicted performance is mixed across the regions as it is at present. South Asia is seen as growing strongly and getting back to near previous levels of very high growth. South East Asia is seen as growing at high but slowly reducing levels. Central and Southern Africa is shown as having increasingly high economic growth at relatively high levels. The Caribbean is shown as having steady growth at reasonably high levels. Northern Africa and the Middle East is shown as having improving but relatively weak growth. Both South America and Central America are shown as having steadily improving economic growth prospects although growth will not be as high as most other regions. For Oceania, growth is shown as steady at relatively low levels but could do better depending on the performance of Papua New Guinea.

There will be a range of challenges if the Tropics are to continue their current and projected strong performance. One such challenge is climate change and the climate change essay suggests that global warming will be an ongoing issue for the Tropics despite acknowledged uncertainty about other climate outcomes. Although it is unclear how rising temperatures and changing weather conditions will affect highly variable weather patterns such as rainfall and tropical cyclones, small changes in a region with reasonably constant temperatures are likely to have a larger impact than in areas with a more variable temperature range.

Tropical countries will need to invest in infrastructure development through private and public capital formation, expenditure on research and development relevant to the needs of the Tropics, improved access to the Internet and other relevant technologies, and continue to strengthen institutions and governance to reduce corruption and similar constraints on business activity.

Table E4.5 **Analysis of the relative strengths and weaknesses of regions**

	Relative Strengths	Relative Weaknesses
South Asia (7.0%)	• Large increase in exports • Low labour costs • Large increase in capital formation • Switch from Agriculture to Industry & Services • Increases in life expectancy and youth literacy	• Low level of Internet usage • Low level and relatively smallincrease in foreign investment
South East Asia (5.3%)	• High level and growth in foreign investment • Increase in R&D and technology indicators • High level and growth in capital formation • Increase in a range of social indicators • Increased urbanization • High level of exports • Switch to Services	• High (and increasing) income inequality
Central & Southern Africa (5.3%)	• Increase in foreign investment • Switch from Agriculture to Industry • Low labour costs • Improvement in Agriculture productivity	• Technology still at low level • Tertiary education at low level but growing quickly • Fertility is high
Caribbean (4.4%)	• High level and growth in tertiary education • High level for mean years of schooling • Switch from Industry to Services	• Net importer of goods
Northern Africa & Middle East (3.7%)	• Large increase in foreign investment • Switch from Agriculture to Industry • Significant net exporter	• Technology indicators are relatively low • Fertility is high • Decline in exports as % of GDP
South America (3.1%)	• Increase in a range of technology indicators • Increase in youth literacy • Large increase in agriculture productivity • Relatively high commodity prices	• High income inequality
Central America (3.1%)	• Increase in a range of technology indicators • Increase in youth literacy • Increase in mean years of schooling • Switch from industry to services	• Decline in foreign investment as % of GDP
Oceania (3.1%)	• High level of tertiary education	• Poor performance on a range of economic indicators • Imports growing faster than exports

Source: State of the Tropics project

Conclusions

My conclusion is the pre-conditions for growth as outlined by Sachs paper are necessary, but not sufficient to guarantee that the Tropics will match or exceed growth in the Rest of the World. One of the most important conditions is having appropriate institutional and policy settings. This is seen not so much by the information in this report but the very different performance of countries within a region.

Returning to the Sachs pre-conditions, significant factors have been the improvement in agriculture productivity coupled with improvements in health and public stability. These have increased the workforce available for productive activities and enabled tropical countries to take advantage of available technologies.

Once these essential conditions have been met, economic growth will be improved further through education, openness to trade and investment, and infrastructure development, among other things. GDP depends on the factors of production (e.g. labour and capital) and how you use these factors (e.g. technology). As the essay shows, there have been improvements in all these areas in the tropical regions. In particular, trade and investment have facilitated the transfer of technology and knowledge and enabled countries to focus on activities where they have a comparative advantage. Furthermore, the transfer of technology and knowledge has reduced the need for countries to undertake these types of innovative activities themselves.

Is tropical underdevelopment a thing of the past? Clearly the answer is no. However, unprecedented growth and change in recent years has closed the gap between the Tropics and the Rest of the World, and within an appropriate policy framework can continue to do so into the future.

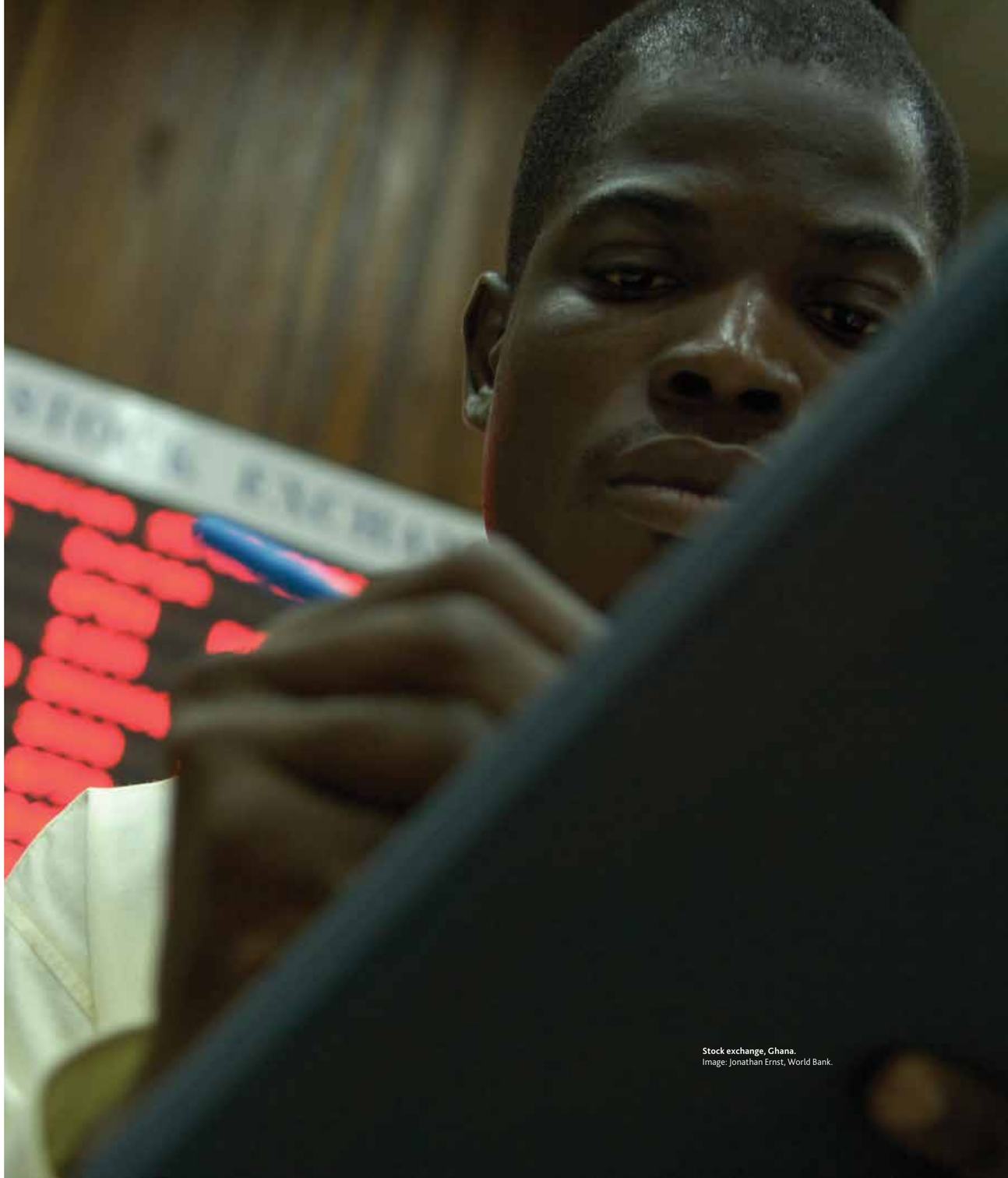
References

Sachs JD. (2000), "Tropical Underdevelopment", CID Working Paper No 57, Centre for International Development at Harvard University, Boston.

UNDP (2014), Human Development Index. United Nations Development Programme. http://hdr.undp.org/en/statistics/hdi (accessed 01 February 2014).

World Bank (2013) World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 11 January 2013).

World Bank (2014) Global Economic Prospects. http://www.worldbank.org/en/publication/global-economic-prospects (accessed 01 February 2014).



Stock exchange, Ghana.
Image: Jonathan Ernst, World Bank.

Chapter 8

Governance

Jakarta.
Image: Jerry Kurniawan.

Chapter 8.1

Governance | Human security, crime and corruption

Dadaab refugee camp, Kenya.
Image: B Bannon UNHCR.

Summary of human security, crime and corruption indicators

Indicator		Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Refugees 1990 – 2010 ('000)		6,790 - 4,258	4,427 - 1,317	209-155	207-155	695-822	16-36	131 – 19	8 – 411	0 – 2	7,999 - 6,107	14,790 - 10,365
Homicide rate per 100 000 population, 2004		15	22	11	5	9	15	17	33	9	6	9
Corruption (World Governance Indicators - 2011)	Control of Corruption*	-0.35	-0.58	-0.89	-0.65	-0.13	0.45	-0.33	-0.48	0.05	0.30	N/A
	Rule of Law*	-0.41	-0.70	-1.01	-0.32	-0.11	0.20	-0.50	-0.65	0.26	0.33	N/A
	Regulatory Quality*	-0.39	-0.63	-0.98	-0.41	0.17	0.12	0.07	-0.44	-0.42	0.38	N/A

*The World Governance Indicators are calculated using data reporting the perceptions of governance from a wide variety of sources, and organising them into clusters corresponding to six dimensions of governance, namely Voice and Accountability, Political Stability & Absence of Violence/ Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption. WGI values range from -2.5 to 2.5, with higher values representing better performance (see Box 8.1.4).

Conflict, corruption and violence have a direct and often traumatic impact on the wellbeing of individuals, families and communities. The security of individuals is an important determinate for national, regional and global stability and progress.

Human insecurity can be the result of factors at multiple levels. National and regional level factors such as persecution, genocide, human right's abuses, civil war, and invasion can result in widespread insecurity. Additionally, high levels of crime at a community level can lead to people feeling unsafe and unsecure. Corrupt governments, organisations and individuals can affect development at its very core by skewing decision making, budgets and policy implementation.

People displaced by insecurity (refugees) are particularly isolated from society, often emotionally traumatised, unable to work and face language barriers. Similarly, serious crime and corruption can affect a person's ability to find stable employment and move around with freedom. Corruption by those in power denies the participation of people in society by diverting public funding into private hands and denying state support, usually to those who need it the most. Additionally, a nation with weak governance and 'rule of law' may find it difficult to attract legitimate investors.

Crime and corruption have long been obstacles for nations trying to bring about the political, economic and social changes desired for development.

Indicators:

Refugees – the number of residents fleeing a country for reasons of fear or persecution is an indicator of the standard of governance and level of violence (or risk of violence) in society.

Homicide rate – the homicide rate provides an indication of the prevalence of crime in a society. While representing only a small fraction of overall crime, homicide is an offence which has a relatively consistent definition, and is also a crime that tends to be reported.

Corruption – corruption affects all levels of society, but tends to have the greatest impacts on the poor. It increases the cost and lowers the quality of public services, and can restrict access to water, education, health care and other key services. It also distorts people's relationships with and trust for public officials, the police and people in authority.

Is it getting better?

Refugees – Globally the number of refugees has fallen 30% over the past two decades, from 14.8 million in 1990 to 10.4 million in 2010. Refugee numbers in the Tropics declined significantly between 1994 and 1997, but numbers have stabilised at around 4 million over the past decade. The decline in refugee numbers between 1990 and 1999 was driven by the repatriation of significant numbers of refugees to Mozambique and Ethiopia in the Tropics, and Afghanistan in the Rest of the World, as conditions in these nations improved after extended periods of unrest. The proportion of the population who are refugees is similar in the Tropics and the Rest of the World (0.15%). Although not reflected in the latest data, refugee numbers in the Middle East have increased rapidly in recent years.

Homicide rate – Although time series data are not available, in 2004 the homicide rate in the Tropics was much higher than the Rest of the World. The Tropics reported a homicide rate of 14.5 per 100,000 population or around 375,000 murders. This was considerably higher than the homicide rate of 5.6 per 100,000 in the Rest of the World. South America, Central & Southern Africa, and Central America reported the highest homicide rates, at 32.9, 21.6 and 17.0 per 100,000 population respectively. South America's rate is more than treble the global rate.

Corruption - In 2011 the Tropics achieved lower scores than the Rest of the World for the assessed governance indicators, indicating higher rates of corruption. For 'Control of Corruption', 74% of nations in the Tropics had a rating of less than zero, compared to 45% in the Rest of the World. For 'Rule of Law', 75% of nations in the Tropics had a rating of less than zero, compared to 41% in the Rest of the World. Although the Tropics performs marginally better with respect to the 'Regulatory Quality' indicator, the story is similar.

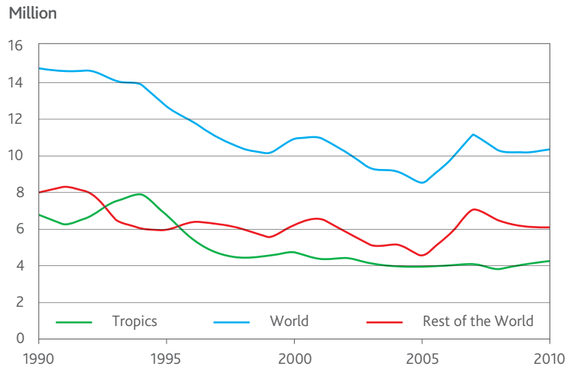
Darfur. Image: Albert Gonzalez, UNAMID.

Refugees

The concept of human security is broader than safety, and also takes into consideration humanitarian, economic and social issues such as human rights, governance and access to economic opportunity, education and health care (UNDP 1994). The number of displaced persons is an indicator of human security, which includes internally displaced persons (IDPs), asylum seekers and refugees[1].

Displaced persons have abandoned their homes because of threats to their life and liberty – often as a result of religious persecution, cultural discrimination, ethnicity, political belief, human rights abuse or armed conflict and violence – and the number of refugees is an indicator of international human security (that is, people who do not feel safe in their own country) (UNHCR 2006). Nonetheless, in any given year, internally displaced persons typically outnumber refugees.

Figure 8.1.1 Refugee population by place of origin



Source: World Bank (2012), UNHCR (2012), State of the Tropics project.

Trends

Globally the number of refugees has fallen 30% over the past two decades, from 14.8 million in 1990 to 10.4 million in 2010[2], though there was an increase in 2000 and a spike in refugee numbers in 2006 and 2007 which has since stabilised at around 2 million additional refugees compared to 2005 (see Table 8.1.1).

The decline in numbers between 1990 and 1999 was driven by the repatriation of refugees to Mozambique and Ethiopia in the Tropics, and to Afghanistan in the Rest of the World, as conditions in these nations improved after extended periods of unrest. Renewed conflict in Afghanistan was the major contributor to the increase in refugee numbers in 2000, and the spike in 2006 was largely due to civil war in Iraq which saw the outflow of 1.2 million people. The further deterioration in conditions in Afghanistan (Dani 2013) has accounted for the balance of the increase in refugee numbers from 2006.

Refugee numbers in the Tropics declined significantly between 1994 and 1997, but have since stabilised at around 4 million over the past decade. Globally, changes in the total number of refugees since 1998 have been driven by factors in the Rest of the World, most notably in Iraq and Afghanistan.

The decline in refugee numbers globally reflects a reduction in the number of armed conflicts and civil wars since the 1990s and the end of many longstanding disputes within troubled nations (UNHCR 2006). As a result, human rights conditions have improved in many nations and this has enabled several large scale refugee repatriations.

The data in this report do not include the large numbers of refugees fleeing recent conflicts in the Middle East, particularly Syria. The UNHCR estimates more than 2 million people were living in refugee camps in September 2013 as a result of this conflict (UNHCR 2013).

In the Tropics, Central & Southern Africa, South Asia and Central America report a decrease in refugee numbers since 1990 (see Table 8.1.1). The most significant improvement has been in Central & Southern Africa where refugee numbers fell by 3.1 million (70%) to 1.3 million in the two decades to 2010. Several nations in Central & Southern Africa were affected by long running civil wars which weakened civil institutions and the rule of law and, subsequently, the confidence of citizens to be treated fairly and justly. There have been large refugee flows in nine of the region's 37 nations which have accounted for the vast majority of regional refugee movements. However, in most instances there have subsequently been significant repatriations, notably between 1990 and 1998 as security improved. Central & Southern Africa accounted for 31% of refugees from the Tropics' in 2010 compared to 65% in 1990. The major improvements have been in Ethiopia, Liberia and Mozambique (see Box 8.1.1).

South America, Northern Africa & Middle East and South East Asia have had the largest increase in refugee numbers in the 20 years to 2010, up by 400,000, 190,000 and 125,000 respectively. In South America refugee numbers increased 50 fold to 411,000 in 2010, with the vast majority coming from Colombia due to instability associated with conflict between the government and guerrilla forces and violence associated with narcotics and trafficking (UNHCR 2011). In 2009, and for the first time, Northern African & Middle East reported the highest number of refugees of the tropical regions. In 2010 Northern Africa & Middle East accounted for 35% of refugees from the Tropics, up from 19% in 1990, driven by increased refugee numbers from Somalia.

Refugees and host nations

Refugees impose a variety of economic, environmental, social and security burdens on host nations, but can also deliver benefits in the form of humanitarian assistance, economic assets and human capital. The dynamic will vary across nations, and will depend on a range of factors such as the political and economic position of the host nation and the nature of host-refugee relations (World Bank 2011a).

For host nations, a large number of refugees can place strain on food and water supplies as well as social and economic infrastructure such as housing, medical and education services and labour markets (UNHCR 1997). Security threats can include bilateral tensions with the source refugee nation and animosities between refugees and the local community (World Bank 2011a). Such threats can have a destabilising effect on host nations. A better understanding of the environmental impacts of large refugee camps is also emerging, including their longer term effects of land degradation, deforestation and water pollution (UNHCR 2002).

The majority of refugees are hosted in nations sharing land or maritime borders with the nation of origin. As the vast majority of refugees are from developing nations and regions, it follows that the majority of refugees are hosted in nations that are also developing. Developing nations provide

[1] Displaced persons include internally displaced persons, asylum seekers and refugees. Internally displaced persons are people who leave their homes owing to a well-founded fear but have not crossed a border to another nation. An asylum seeker is a person who has crossed a national border seeking protection as a refugee, but who is awaiting an assessment of the validity of their claim. A refugee is an asylum seeker who has had their claim assessed and confirmed. The definition of a refugee is narrower than that of an IDP owing to the exclusion of generalised violence, and natural/human made disasters as accepted reasons for displacement. The rights of refugees to participate in economic and social activities in host nations varies from nation to nation.

[2] This excludes Palestinian refugees, which come under the jurisdiction of United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) as opposed to the United Nations High Commissioner for Refugees (UNHCR). The number of Palestinian refugees is estimated at 4.8 million in 2010, up from 2.4 million in 1990.

Table 8.1.1 Refugee numbers by place of origin

	1990	2000	2005	2010	% change 1990 to 2010	PPT* contribution to change
Tropics	**6,790,824**	**4,740,469**	**3,953,157**	**4,257,610**	**-37**	**-37**
Central & Southern Africa	4,427,169	2,325,546	1,772,978	1,317,243	-70	-46
Northern Africa & Middle East	1,305,040	1,447,583	1,325,039	1,495,016	15	3
South Asia	208,574	132,861	120,139	154,929	-26	-1
South East Asia	695,035	752,515	618,521	821,677	18	2
Caribbean	15,616	27,823	33,621	36,328	133	0
Central America	131,272	35,589	11,686	19,166	-85	-2
South America	8,118	18,101	69,701	411,179	4,965	6
Oceania	1	451	1,473	2,071	206,124	0
Rest of the World	**7,998,719**	**6,233,408**	**4,509,177**	**6,107,006**	**-24**	**-28**
World	**14,789,543**	**10,973,877**	**8,462,334**	**10,364,616**	**-30**	**-65**

Source: World Bank (2012), UNHCR (2012), State of the Tropics project.
*Percentage point.

Box 8.1.1 Mozambique

The return of 1.45 million people to Mozambique in the 1990s is one of the most successful refugee repatriation stories in recent times. For 15 years Mozambique was wracked by civil war, its people were subject to torture and execution, and a large proportion of civil and economic infrastructure was destroyed. More than one third of Mozambique's population of 17 million was displaced, around 4 million internally and 2 million as refugees in neighbouring nations (Wilkinson 1998).

When the 1992 peace agreement was finalised Mozambique was considered a broken nation, and there were few incentives for displaced people to return home (Wilkinson 1998). A year after the hostilities ended there were still around 1.2 million refugees, but by 1996 there were only 34,000.

In addition to UNHCR initiatives to assist with the provision of food, shelter and equipment and to rebuild infrastructure, the successful repatriation was assisted by the fact that many family groups had remained together or reunited quickly after the conflict, there were few orphaned children, property disputes were uncommon as land was plentiful and political and military differences were resolved quickly. Favourable weather conditions also provided good harvests. These factors acted to speed up the political reconciliation and reintegration processes.

The situation in Mozambique is considered unusual, and there are many examples of refugees remaining in asylum camps and refusing to return to their homeland after civil conflicts have ended.

In 2010, refugee numbers from Mozambique are low (130), and although it is a poor nation, it is now a place of asylum for refugees, primarily from other African nations.

Red Cross Workers, Mozambique. Image: EU Humanitarian Aid and Civil Protection.

asylum for around 80% of the world's refugees (UNHCR 2010). Of the 48 least developed nations in the world, 35 are refugee hosts, and 31 of these nations are in the Tropics (nine in Northern Africa & Middle East, 20 in Central & Southern Africa and one in each of the South Asia and South East Asia regions) (UNHCR 2010).

The refugee burden in the Tropics is significant. In 1990, tropical nations hosted 47% of the world's refugees, falling to 37% in 2010.

Host nations carry a significant burden in the initial stages of a refugee influx. Nonetheless, where permitted, refugee populations have shown that they can contribute to economic activity in host nations. For example, refugees have been able to supply labour to expand output from labour intensive industries such as agriculture, and to stimulate local economies by increasing demand for goods and services. The allocation of financial aid to develop infrastructure in host nations also provides flow-on benefits to local communities (World Bank, 2011a).

Protracted refugee situations

Although the number of refugees has been trending down over the past two decades, each year there can be significant changes in the number of people that are either becoming refugees or being repatriated. This ebb and flow is influenced by factors in the refugee home nation, and the reality is that any refugee situation can range in duration from being short term to very protracted.

Refugee numbers can decrease as a result of repatriation, resettlement or integration into the host nation. Only a small number of nations offer resettlement programs. Resettlement numbers were down to 99,000 in 2010 (compared with 112,000 in 2009) and there were 197,600 repatriations, the lowest number in 20 years. While data on local integration are limited, it appears to have been less effective in recent years in reducing refugee numbers (UNHCR 2010).

Protracted refugee situations[3] are therefore an ongoing challenge for the international community, with 69% of the 10.4 million refugees in 2010 classified as being in protracted situations, and with many having limited prospects for durable solutions.

Protracted situations stem from a combination of factors, including ongoing risk conditions in home nations, policy responses and conditions in host nations, and a lack of engagement by the international community. Ongoing conflict, fear of persecution and a lack of basic infrastructure in home nations are common reasons for refugees not returning home. At the same time, host nations have to manage the often long term nature of the refugee situation, responding by closing borders to new arrivals, confining refugees to overcrowded camps or restricting the movement and rights of refugees (UNHCR 2002). This can have significant implications for refugees, and impact access to a safe environment as well as opportunities for employment, education, health services and other basic necessities.

Latest data (for 2004) report that 61% of the refugees from tropical nations were in a protracted situation. The majority of the affected refugees were from Central & Southern Africa (1.2 million) and Northern Africa & Middle East regions (786,000). Since 2004 there has been a sharp decline in the number of refugees from three of the four Central & Southern Africa nations that reported a significant number of protracted refugees, suggesting the number of protracted refugees has also fallen. The situation in Northern Africa & Middle East is less encouraging with refugee numbers almost doubling in two out of four protracted refugee nations, and static in a third.

The Rest of the World has not been immune to the protracted refugee situation. Afghanistan has been the leading source of refugees since 1990, though numbers declined from 6.3 million to 3.1 million in 2010. Pakistan and Iran host 96% of refugees from Afghanistan (UNHCR 2010). Around 80% of refugees from Afghanistan were living in a protracted situation in 2004.

Historically, protracted refugee crises have been resolved through the combined efforts of humanitarian organisations and political and security stakeholders. This integrated approach has been missing from more recent protracted refugee situations. The problem has been compounded by international donors influencing the direction of their financial aid to short-term, high profile refugee situations, and by 'donor fatigue'.

Looking forward

The unique circumstances of each displaced person and refugee situation can mean that finding sustainable solutions is not easy. Especially for refugees, there is a need for improved international cooperation and an international commitment to ensure their safety and rights in both home and host nations. An increase in the number of protracted refugees suggests that durable solutions in home nations are becoming harder to achieve, putting greater pressure on host nations and the international community to find solutions that don't involve repatriation.

Looking forward, climate (or environmental) refugee numbers are likely to increase as extreme weather events become more common and displace large numbers of people. At the same time, more gradual impacts of climate change such as rising sea levels have the potential to fundamentally change international relationships as part, or whole, nations are lost, and large populations need to be relocated (see Box 8.1.2).

[3] In 2004 the UNHCR identified a protracted refugee situation as one where 25,000 or more refugees of the same nationality have been in exile for more than five years in a given host nation.

Box 8.1.2 Climate refugees

Climate refugees are people who have had to move due to sudden or gradual changes to their natural environment caused by climate change. Climate change has been linked to a host of negative environmental impacts including rising sea levels and increased occurrences of flooding, drought and water scarcity and extreme weather conditions such as cyclones. These events can lead to short or long term displacement of individuals either within or across national borders, and increase international security issues and risks.

The most vulnerable nations to rising sea levels in the Tropics are Kiribati, Vanuatu, the Marshall Islands, the Maldives, Tuvalu and Bangladesh. In the most extreme climate change scenarios it is likely that a number of nations will disappear as a result of climate change, leaving their inhabitants stateless. While island nations such as Kiribati and Tuvalu have small populations (at 98,000 and 10,000 respectively in 2010) relocating these populations in a way where culture is maintained and people are able to continue living lives they value is a challenge for the future.

In Bangladesh around 500,000 people have been displaced with the permanent submersion of parts of Bhola Island since 2005. Rising sea levels coupled with intensifying storm surges put a significant proportion of Bangladesh's population at risk of future displacement, with major consequences for economic and social dynamics in Bangladesh and neighbouring nations as people look for more secure areas to live.

Despite millions of people being at risk of becoming climate refugees there is a lack of government and international agency recognition of their specific circumstances as they don't satisfy the traditional refugee criteria. As such, there are currently no international laws to protect the rights of climate refugees – a situation that warrants attention by the international community.

Kiribati. Image: Johanna Mustelin.

Homicide rate

The intensity and organisation of violent crime can take many forms, and can have a major impact on the wellbeing of victims and communities. Victims of crime may suffer financially, physically, psychologically and emotionally, and the fear of crime can affect a population's sense of security and willingness to engage in civil society. Violent activities of organised criminal groups can also have broad political consequences. Crime also incurs direct financial costs on communities for the provision of law enforcement services by the police, as well as court, legal and correctional services (ABS 2004).

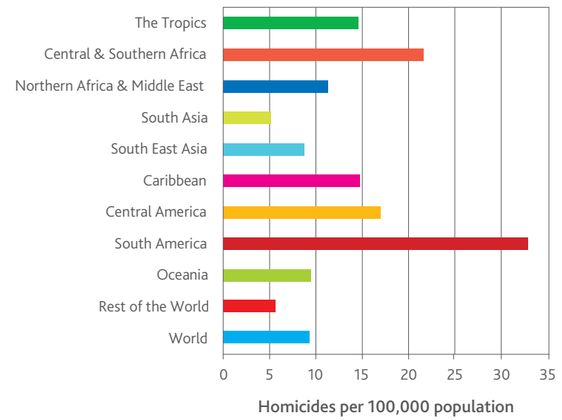
While representing only a small fraction of overall crime, intentional homicide[4] is one of the most serious offences in civil society. Killing is treated seriously in all societies, and homicide tends to be recorded more effectively and in a more consistent manner than other crimes.

The relationship between higher rates of violence and homicide and fragile institutional capacities is widely accepted, and nations with higher respect for the rule of law and effective criminal justice systems tend to have lower homicide rates. There is also a strong association between insecurity engendered by the risk of violence and underdevelopment (Geneva Declaration on Armed Violence and Development 2011). Without security, human, social, and economic development suffers.

A range of social factors are associated with high rates of violence and homicide. For example, most violent crime is committed by and against males aged between 15 and 30. High youth unemployment, limited educational opportunities, weak judicial systems and easy access to weapons all influence homicide rates. Robbery-related homicide rates also tend to be higher in nations with greater income disparities (ECOSOC 2012).

Violent crime and homicide also have significant economic costs. High homicide rates are a sign of social instability; can influence decision making by both domestic and foreign investors; increase security and other costs of doing business; discourage the accumulation of assets; and deplete the skilled labour force – primarily through the flow of human capital to safer nations. These factors erode business confidence and constrain a nation's longer term growth prospects.

Figure 8.1.2 Homicide rate



Source: World Bank (2012) - International Public Health Sources, State of the Tropics project.

Trends

A number of homicide datasets are available, though each is characterised by a short time series, and with data missing for many nations and years. These issues make trend analysis difficult. For 2004, international public health data are used for analysis here, primarily because it has almost complete coverage of nations. The United Nations Office on Drugs and Crime (UNODC) also reports a time series dataset but it has limited national coverage, particularly for African and Oceania nations. Nonetheless, this dataset is useful for trend analysis of the regions for which it has a good coverage of nations.

In 2004 the Tropics reported a homicide rate of 15 per 100,000 population (see Figure 8.1.2), or around 375,000 murders. This was considerably higher than the homicide rate of 6 per 100,000 in the Rest of the World. In the Tropics, South America, Central & Southern Africa and Central America reported the highest homicide rates at 33, 22 and 17 per 100,000 population respectively. South America's rate is more than treble the global rate.

Looking at 2004 data, homicide rates in South Asia, South East Asia and Oceania are the lowest of the tropical regions, with each reporting less than 10 homicides per 100,000 population. South Asia had the lowest homicide rate at 5.1 per 100,000

[4] Intentional homicide is the unlawful death purposefully inflicted on a person by another person, and captures a wide range of acts from domestic disputes that result in killing; interpersonal violence; violent conflicts over land, or resources; inter-gang clashes; and predatory violence and killing by armed groups.

population, making it the only tropical region with a homicide rate comparable to the Rest of the World. In 2004 South America and Central & Southern Africa reported homicide rates around seven and five times higher respectively than in South Asia.

The wide range of results across regions suggests that homicide rates are sensitive to local factors. This is hardly surprising given each nation's unique cultural, historical, political, economic, and social context. Some regions show common patterns across nations while others exhibit a wide disparity. Even within nations homicide rates can vary markedly.

Looking at time series data, homicide rates are consistently high in the three tropical regions for which data are available (see Figure 8.1.3). While rates in South America have been static, they have been trending up in the Caribbean and Central America in the decade to 2010 (see Box 8.1.3). The significant presence of organised crime groups and high levels of income inequality in these regions contribute to high homicide rates. Guatamala, Honduruas and Panama all had Gini co-efficients[5] greater than 60 in 2010, indicating high income inequality (World Bank 2012).

For other tropical regions there are insufficient data for trend analysis, but for many of those nations for which some data are available homicide rates have tended to fall. Also, and notably in many non-tropical regions, significant advances in medical technology and services have led to a decrease in the lethality of assaults and contributed to lower homicide rates.

Economic and social factors

Income inequality is recognised as a factor influencing homicide rates (UNODC 2011). In the Tropics, Central & Southern Africa, the Caribbean, Central America and South America each report a high degree of income inequality, with straight average Gini coefficients ranging from 44 to 52 in the 2005-2009 period compared to 38 for the Rest of the World. In fact, using latest available data for the period 2005 to 2009, nine of the ten nations in the world reporting the highest Gini coefficients are in these four tropical regions.

High levels of income equality in these regions are often exacerbated by ethnic class divisions, as well as exclusionary factors such as unequal access to employment, education, health and basic infrastructure. These issues can limit opportunities for those at the bottom of the social and economic scale to earn a living through non-violent means (UN-HABITAT 2007).

In a similar vein, there is a strong inverse relationship between homicide rates and human and economic development. This is fairly striking when GDP per capita and homicide rates are compared. In 2004 GDP per capita in the Rest of the World was around three times higher than in the Tropics, and it had a homicide rate around one-third that of the Tropics. Central & Southern Africa reported the lowest GDP per capita of the tropical regions in 2004 and, with a Gini coefficient of 45, a high degree of income inequality. Perhaps not surprisingly, at 22.8 homicides per 100,000 population, Central & Southern Africa reported the second highest homicide rate of the tropical regions.

The United Nations Human Development Index (HDI) takes a broader view of wellbeing than income and, in addition to GDP per capita, includes measures of life expectancy, literacy and education in its calculation. Using this measure, the link between human development and homicide rates is also evident. In 2004 and 2005 the 22 nations with the lowest HDI scores reported a population-weighted homicide rate of 23.2 per 100,000. Twenty-one of the 22 nations are in the Tropics, with the majority in the Central & Southern Africa region. Of interest, two nations in the Central & Southern Africa region reported HDI scores of more than 0.7 in 2004, and both of these nations reported less than four homicides per 100,000 population. However, both nations are small, and combined they represent less than 0.2% of the regional population.

The relationship between human development and homicide rates however is not consistent across regions, suggesting that other factors are also at play. For example, in 2004 South Asia reported relatively low GDP per capita of $2,438 and yet, by a large margin, had the lowest homicide rate in the Tropics at 5.1 per 100,000. While there is no clear explanation for this, it is likely that cultural factors may contribute to the low homicide rate, as nations in this region are typified by a supportive communal life with strong family and religious values, and a cultural ethos which contributes to relatively compliant and cohesive communities (Currie 1985).

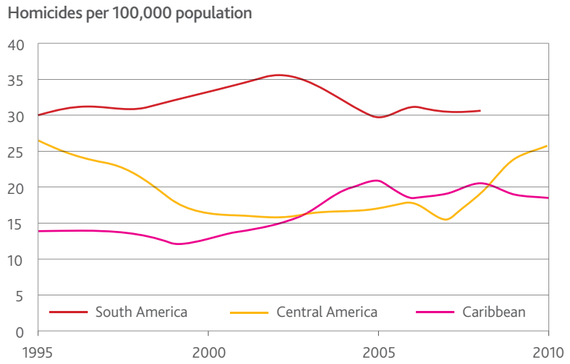
South America is another example and, to a lesser extent, Central America. Socio-economic conditions in these regions vastly exceed those in the African and Asian regions, yet high homicide rates prevail. This suggests different sets of factors are at play in these regions, including the presence and influence of major organised crime groups.

Organised crime and gangs

A youthful population can be a great asset for a nation, but it can also be a source of social instability. Most crime is committed by and against males between the ages of 15 and 30, and this demographic is more likely to be associated with gangs and organised criminal groups.

Globally, many of the nations with the highest homicide rates are also primary drug source or transit nations. The large majority of these nations are in the Tropics – in the Caribbean, Central America and South America. Since the mid-1990s Central America has been the major transit corridor for drugs entering the United States from South America. The United States Government estimates that 90% of cocaine arrives through the Central American corridor (World Bank 2011b).

Figure 8.1.3 Homicide rates – Caribbean, Central America and South America



Source: World Bank (2012) - Criminal Justice & International Public Health Sources, State of the Tropics project
Note: Due to insufficient time series data the Caribbean does not include Antigua & Barbuda, Barbados, Haiti and Saint Lucia; Central America does not include Belize or Honduras; and South America does not include Bolivia or Suriname.

[5] The Gini coefficient is a measure of statistical dispersion, measuring inequality among values of a frequency distribution. A Gini coefficient of zero expresses perfect equality where all values are the same (for example, where everyone has equal income) and a coefficient of 100 expresses maximum inequality (where one person has all the income).

Box 8.1.3 Homicide rates in tropical Latin America

The nations of tropical South America report significant variation in homicide rates, and in 2008 ranged from 2.9 per 100,000 in Peru to 52 per 100,000 in Venezuela.

In Colombia, the homicide rate fell from 69.7 per 100,000 population in 1995 to 33 in 2010. With support from the United States, Plan Colombia was implemented in the early 2000s to address, amongst other things, drug-related organised crime through better resourcing of anti-drug activities and stricter law enforcement. The area under coca cultivation fell from 163,300 hectares in 2000 to 81,800 hectares in 2008 and cocaine production declined by 35% (UNODC 2003). Homicide rates fell dramatically in this period. Colombia recorded a sharp fall in its homicide rate in 2003, and it has fallen steadily since then.

At the other end of the scale, homicide rates have increased markedly in Venezuela. The increase in both conventional and drug-related homicide is believed to be influenced by a corrupt, inefficient and politicised judiciary, an ineffective prison system due to violence and overcrowding, a corrupt and poorly paid police force, the presence of up to 15 million illegal weapons, and an official discourse that supports class warfare (The Economist 2010). Prior to 1999 the homicide rate was steady at around 20 per 100,000 population, but has increased to 49 per 100,000 in 2009.

Homicide rates in Brazil have increased more modestly, up from 27 per 100,000 in 1995 to 31 per 100,000 in 2008. Combined, these factors have seen South America's homicide rate range between 30 and 35 per 100,000 population between 1995 and 2008.

The crackdown on drug-related crime in Colombia has seen a transfer of these criminal operations to Central America (Insight Crime 2011) where homicide rates have been trending up since 2003. For most nations in Central America the late 1990s was a period of declining homicide rates. Since then, although the timing has varied, most nations in the region have experienced a turning point, with homicide rates starting to trend up. Four of the eight nations in Central America region report a homicide rate above 40 per 100,000 population in 2010. Nonetheless, Central America's homicide rate, at 26 per 100,000 in 2010, was relatively low given Mexico's weighting of almost 75% in regional calculations, with its homicide rate at 22 per 100,000. Excluding Mexico, Central America's regional homicide rate increased by nine, to 35 per 100,000.

Institute for Peace Promotion and Injury Violence Prevention, Universidad del Valle. Image: Ian Britton.

Along the transit corridor the value of illicit drugs increases as they get closer to the United States, and this higher value tends to correlate with higher homicide rates. In the first Central American city on the trafficking route the homicide rate was 12 per 100,000 persons in 2004. By the time drugs reach the final Central American city before entering the United States the price has increased by a factor of five and the homicide rate by a factor of three, to 41 per 100,000 (UNODC 2011). The greater financial stake for organised and violent crime groups contributes to higher homicide rates closer to the United States. Competition and disagreements between criminal groups, seizures by authorities and the threat of greater enforcement activity have historically been a root cause of lethal violence on the transit corridor.

Globally, drugs are a key focus of organised criminal activity. Nonetheless, other forms of inherently violent transnational organised crime also exist, notably people trafficking, though data on these activities are not as readily available.

Firearms

The availability of firearms is another factor that influences homicide rates. UNODC data for 108 nations (covering 50% of global homicides) reports that in 2010, 42% of homicides involved a firearm, with 74% of homicides in the Americas involving a firearm and 21% in Europe (UNODC 2011). In Africa, an estimated 35% of homicides involved a firearm in 2003 (UNODC 2005). Firearm-related homicide was considerably lower in other regions.

The recent history of armed conflict in many African and Latin American nations has increased the availability of firearms. The combination of a large number of guns in the civilian population, the demobilisation of ex-combatants into civil society (often with limited employment prospects), and a legacy of scores to be settled and reduced inhibitions about the use of violence can all contribute to higher homicide rates (Cole & Marroquín Gramajo 2009).

Rule of law

A nation's capacity to enforce the rule of law can affect homicide rates. Nations with strong and effective legal systems that are enforced and adjudicated independently and equally tend to have lower homicide rates. Conversely, factors such as corruption, an inability to prosecute offenders and a lack of prison facilities can foster a perception of impunity and contribute to high rates of homicide.

Effective law enforcement is resource-intensive, and this can lead to lower than desirable deployment in these activities, especially in developing nations. Where resources are scarce, low numbers of police officers can be exacerbated by inadequate training, high rates of illiteracy, substandard equipment and police corruption. In six Central & Southern African nations for which data are available, the ratio of police per 100,000 population ranges from 42 to 160, significantly lower than in developed nations which tend to have 400 to 500 police per 100,000 people (Barker 2010). These six nations have relatively high homicide rates, ranging from 17 to 37 per 100,000 in the 2004. A similar story emerges in some parts of Central America, though there is greater variability in the relationship as there are nations that, despite relatively high numbers of police per capita, report exceptionally high homicide rates.

In the Tropics, the three regions with homicide rates less than 10 per 100,000 in 2004 had more than 300 police per 100,000 people population (UNODC 2011).

Similarly, there is a link between the resourcing and effectiveness of the criminal justice system and homicide rates. Developed nations tend to have 10 to 18 judges per 100,000 population, while in Africa and Latin America/Caribbean the range tends to be three and eight per 100,000 respectively (UNODC 2011). Fewer judges mean there is a lower chance of conviction, especially as witnesses can disappear when cases progress slowly. The chance of a homicide resulting in a conviction is around 11% in Africa, compared to 56% in the United States, 66% in Oceania and 63% in Asia (UNODC 2005). Conviction rates are as low as 2% in some parts of Central America (UNODC 2007).

Homicide and development

Homicide undeniably affects individuals and societies. The human costs, particularly in nations with limited social safety nets, can be significant for both the victim and perpetrator (if convicted) and their dependents, especially where they are a family's sole breadwinner. At a societal level, a greater risk of homicide can cause individuals to withdraw from social and commercial activities which can affect education, health and economic outcomes. High homicide rates can also influence a nation's skilled labour pool, with major consequences for growth prospects. The highest emigration rates for educated workers are from Central America and Africa, and both regions report high homicide rates (UNODC 2007). High crime and homicide rates can also influence investment in a region, which can have long term economic and employment impacts.

Looking forward

In the main, crime is the outcome of a limited range of choice and inequality of opportunity. As such, integrated policy frameworks that address social and economic dimensions of crime are likely to be more effective in reducing rates of violent crime and homicide in the long run. This could include policies aimed at employment growth, poverty eradication, and equitable income distribution in the future. Policies that improve the circumstances of those in society that are most vulnerable to becoming involved in violent crime are likely to have a positive impact on homicide rates.

Nonetheless, such policies need to be partnered with efforts to improve the effectiveness of police and judicial systems to ensure citizens are adequately protected, including from organised crime groups and gangs.

Corruption

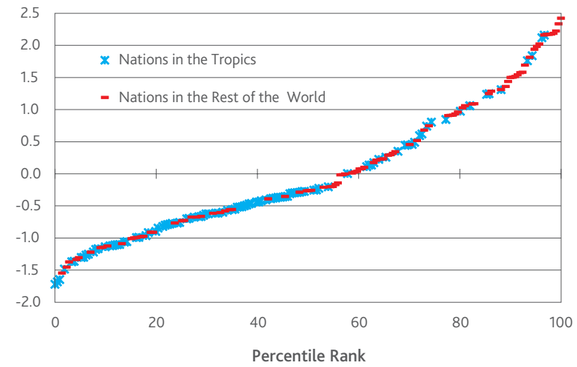
The concept of governance relates to the manner in which public and private sector officials and institutions acquire and exercise authority to shape policy and provide goods and services. Good governance promotes equity, transparency, accountability and the rule of law, and can contribute to sustainable development outcomes (UNESCAP 2012). Poor governance systems increase the risk of power being misused for private gain (that is, corruption), in both the public and private sectors (World Bank 2006).

Corruption undermines political stability and, especially in developing nations, this can have impacts beyond national borders (Lewis 2007). The interpretation of what constitutes corruption varies across cultures and nations, but it commonly includes bribery, embezzlement, nepotism and conflict of interest (Slater 2011). Corruption tends to be more prevalent in nations where government is centralised, legislative and judicial institutions are weak, the rule of law is not strictly enforced, public service education requirements and wages are low, and where there is limited capacity to hold offenders to account (Furphy 2010).

The biggest obstacle to combating corruption is the difficulty measuring it, due to its clandestine nature. Victims' fear of retaliation and the perpetrators vested interest in secrecy generally result in non-disclosure. This has led to 'perceptions' being the most common measure of corruption. Despite criticisms regarding its subjective nature, perceptions have proved to be a reasonable indicator of the extent of corruption. Measuring scandals, investigations or prosecutions tend to reflect other factors such as freedom of the press, or efficiency of the judicial system rather than corruption (Transparency International 2011).

A number of corruption perception datasets are available, with the World Governance Indicators (WGI) 'Control of Corruption', 'Rule of Law' and 'Regulatory Quality' assessed here as measures of corruption and governance. WGI values range from -2.5 to 2.5, with higher values representing better performance with respect to the indicator.

Figure 8.1.4 World Governance Indicator, Control of Corruption, 2011



Source: World Bank (2012), State of the Tropics project.

The WGI are recognised as being among the most carefully constructed and widely used governance indicators (see Box 8.1.4). Nonetheless, the indicators have limitations, and care needs to be taken in interpreting reported estimates and how they are used in decision making. Transparency International's public sector-focussed Corruption Perceptions Index (CPI) is another commonly cited measure of corruption[7].

Governance indicators are often used by decision-makers in distributing aid, although this is often against the intentions of the creators of these indicators. The use of corruption indicators for the distribution of aid can also be resented, as many developing nations perceive them to have a private-sector and 'western' bias, with narrow, legal interpretations of governance. The argument is that this can obscure subtle but costly manifestations of poor governance which affect both developing and developed nations, particularly where there is an element of state capture by powerful vested interests (for example, financial and media organisations) which impacts government decision-making (Arndt & Oman 2006).

Trends

Looking at 'Control of Corruption', in 2011 74% of nations in the Tropics had a rating of less than zero, compared to 45% in the Rest of the World suggesting that mechanisms to control corruption are less progressed in the Tropics. Figure 8.1.4 reports the 'Control of Corruption' ratings for 2011. The 2011 ratings

[7] Transparency International's Corruption Perceptions Index is probably the most widely recognised governance indicator, but is not used in the assessment here due to its limitations with respect to time series analysis.

[8] Regional estimates are calculated as the straight average of national scores in the region.

are largely unchanged since 2000, suggesting that perceptions of the control of corruption are relatively static. Globally, between 2000 and 2011 only seven nations reported statistically significant improvements in the 'Control of Corruption' indicator, two of which were in the Tropics and both in Central & Southern Africa.

For 'Rule of Law', in 2011 75% of nations in the Tropics had a rating of less than zero, compared to 41% in the Rest of the World. Globally, between 2000 and 2011 only ten nations reported statistically significant improvements in the 'Rule of Law' indicator, four of which were in the Tropics, across three regions. Although the Tropics' performs marginally better with respect to the WGI 'Regulatory Quality' indicator, the story is similar in that very few nations report statistically significant changes over time.

Of note, almost 90% of tropical nations in the dataset are classified as developing, compared to around 55% in the Rest of the World. Nations scoring poorly on perceptions of corruption are mainly poor or failed states affected by extended periods of conflict, ex-communist states or nations run on communist lines (The Economist 2011). In contrast, nations with the highest scores tend to be high income, developed nations.

At the regional level[8] there were no statistically significant changes in the 'Control of Corruption', 'Rule of Law' and 'Regulatory Quality' indicators over the period 2000 to 2011 and, as such, only regional ratings for 2011 are reported in Table 8.1.6. In the Tropics the Caribbean performs best with respect to the 'Control of Corruption' indicator, with a rating in 2011 of 0.45 and eight of its 12 nations having a rating greater than zero, followed by Oceania and South East Asia. For the other regions in the Tropics, less than 20% of their nations have a 'Control of Corruption' rating greater than zero.

Oceania performs best with respect to 'Rule of Law' and, along with the Caribbean, has more than half of its nations reporting a positive rating. South East Asia is the next best performed, and for each of the other tropical regions less than 15% of their nations have a rating greater than zero. South East Asia reports the highest 'Regulatory Quality' rating followed by the Caribbean and Central America. However, the Caribbean and Central America are the only regions to report at least 50% of nations with a 'Regulatory Quality' rating greater than zero.

Low ratings in many African nations reflects weak political and administrative institutions – often associated with prolonged periods of conflict – which contribute to poor governance systems, widespread nepotism and abuse of power. The influence of tribal, religious and geographic interests in public decision making processes have also negatively impacted governance and anti-corruption measures in these regions (Uwimana 2011). Nonetheless, several nations report good results, including Rwanda and Botswana (see Boxes 8.15 & 8.1.6)

Relatively high perceptions of corruption in many nations of Central and South America can reflect weak democratic institutions (often associated with a lack of independence), or being at an early stage of civic and institutional transition following years of authoritarian rule (Salas 2011). Weak institutions provide opportunities for corruption, and for organised crime to gain influence. It is not clear whether organised crime weakens the state through corruption or if corruption allows organised crime to flourish, but as long as both coexist the integrity of democratic institutions is at threat (Salas 2011).

Although Oceania performs relatively well, many developing nations in the region are characterised by poor governance and geographically dispersed populations. Vast distances combined with complex relationships between traditional and modern systems can affect the state's capacity to influence day-to-day decision making, and the effectiveness of accountability institutions in addressing corruption. This is especially the case in remote areas. For example, the traditional practice of gift-giving can be problematic, though whether it is corruption or culturally sanctioned will depend on the intent, scale and the public or private nature of the gift (Barcham 2007).

Box 8.1.4 World Governance Indicators

The World Governance Indicators (WGI) framework defines governance as "the traditions and institutions by which authority in a country is exercised (Kaufmann et al. 2010). This includes (a) the process by which governments are selected, monitored and replaced; (b) the capacity of the government to effectively formulate and implement sound policies; and (c) the respect of citizens and the state for the institutions that govern economic and social interactions among them." For each of the three areas, two measures of governance are constructed.

The WGI are among the most widely used governance indicators, and are constructed using data reporting the perceptions of governance from a wide variety of sources, and organising them into clusters corresponding to six dimensions of governance, namely Voice and Accountability, Political Stability & Absence of Violence/ Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption (Arnt & Oman 2006).

The WGI also report margins of error to reflect the unavoidable imprecision in measuring governance, and which assist the user in interpreting and comparing results across nations and over time. WGI values range from -2.5 to 2.5, with higher values representing better performance with respect to the indicator.

Image: James Cook University.

Table 8.1.2 **Selected World Governance Indicators, 2011**

	Control of Corruption	Rule of Law	Regulatory Quality
Tropics	**-0.35**	**-0.41**	**-0.39**
Central & Southern Africa	-0.58	-0.70	-0.63
Northern Africa & Middle East	-0.89	-1.01	-0.98
South Asia	-0.65	-0.32	-0.41
South East Asia	-0.13	-0.11	0.17
Caribbean	0.45	0.20	0.12
Central America	-0.33	-0.50	0.07
South America	-0.48	-0.65	-0.44
Oceania	0.05	0.26	-0.42
Rest of the World	**0.30**	**0.33**	**0.38**

Source: World Bank (2012), UNHCR (2012), State of the Tropics project.
*Percentage point.

Natural resources & foreign aid

Corruption is more prevalent in developing nations and tends to be exacerbated when there are large financial inflows from natural resource development or foreign aid. Of 27 tropical, developing nations identified as being resource-rich (Baunsgaard 2012), 22 (81%) scored 35 or lower on Transparency International's 2012 CPI[9] , compared with 52% for non-resource rich developing nations in the Tropics. With a CPI score of 65 however, diamond-rich Botswana stands out as an exception (see Box 8.1.6).

A large proportion of global resource extraction occurs in developing nations, and host governments receive considerable revenue from license fees, royalties and taxes. Nonetheless, many of these nations perform poorly on a range of social and economic indicators, suggesting the majority of the benefits from resource extraction accrue to a small elite, rather than the broader population. In the absence of a culture of transparency and institutions to combat corruption, extractive windfalls can easily be misappropriated for personal gain rather than being used to support nation-wide growth and development (Lewis 2007). For example, many developing nations in Africa with significant resource wealth and extraction revenues perform poorly in the United Nations Human Development Index.

The propensity for corruption appears most evident in oil producing nations with weak rule of law and state ownership of resources. This environment can foster a culture of rent-seeking by political leaders for personal gain, and lead to perverse social and economic outcomes due to structures and incentives that oil dependence creates (Karl 2004). As oil rents increase, so does corruption, while political rights tend to deteriorate, especially where there is a high degree of state participation in oil production (Arezki & Brückner 2009). In many instances resource companies are complicit in corrupt activities through a lack of transparency in reporting production levels and payments to government.

Foreign aid, much like natural resources, can result in significant financial inflows and opportunities for large-scale personal gain by corrupt officials if governance is weak, at the expense of those most in need of assistance. In fact, without effective institutions aid is likely to have a detrimental impact on the quality of governance (Abuzeid 2009). This suggests that aid should first be directed to improving governance (e.g. supporting international agreements and initiatives on governance, or providing funding and technical support for governance reforms). Benefits will be maximised if the projects supported are limited to those where sound governance arrangements are in place. Research suggests that before 1997 increases in foreign aid were associated with higher levels of corruption or no change, and that, encouragingly, since 1997 the 'anti-corruption movement' has had some success, with increases in multilateral aid often associated with lower levels of corruption (Charron 2011).

Looking forward

As economic activity is increasingly globalised, so too is the transnational nature of bribery and corruption. Its eradication therefore requires international solutions through co-operation and shared responsibility. The World Bank and other major international institutions now target corruption as a major cause of underdevelopment, and provide assistance to affected nations to address factors underlying corruption. This includes

[8] Regional estimates are calculated as the straight average of national scores in the region.

[9] The CPI ranks nations on a scale from 100 (very clean) to 0 (highly corrupt). A score of 35 is chosen arbitrarily, but is intended to reflect a relatively low CPI score. The median CPI score in 2012 was 37.

introducing measures to combat fraud and black-listing companies that breach procurement guidelines. There is also evidence that donor nations have begun to give more importance to recipient nations' actions to curb corruption when deciding how to allocate multilateral aid (UNDP 2007), though the impact with respect to bilateral, strategic aid is less evident.

The Extractive Industries Transparency Initiative (EITI), implemented in 2003, is another example of a global scheme designed to improve transparency and accountability. This public-private sector initiative requires subscribing nations to publish all payments from extractive industry operators, and aims to ensure that these revenues contribute to long term economic and social development. The EITI has become the global standard in the extractives industry, and a model for international co-operation to other sectors (USIP 2010).

Box 8.1.5 Rwanda

Rwanda is one of the least corrupt nations in Central & Southern Africa, and is an example of what can be achieved with a commitment to strengthening political, judicial and administrative institutions and governance. Major anti-corruption reforms undertaken in Rwanda since 1997 include the introduction of the National Decentralisation Policy and the establishment of the Office of the Ombudsman, the Anti-Corruption Unit in the Rwanda Revenue Authority, the Auditor General and the National Tender Board (Chene 2008). Accepting bribes is now a criminal act.

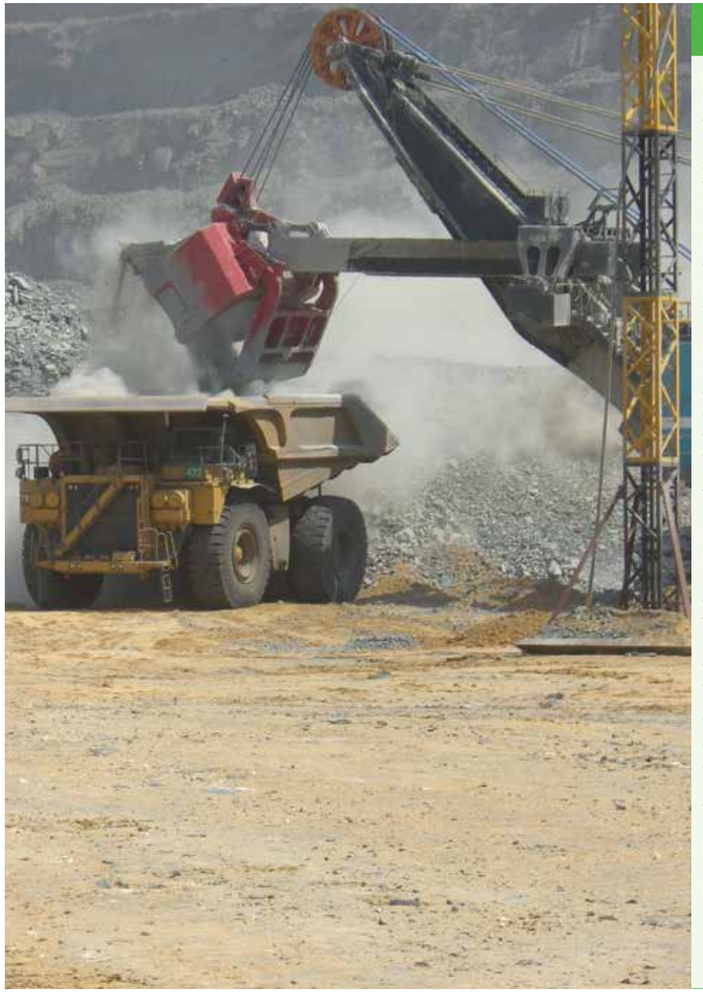
At the operational level, measures to facilitate cultural change in the public sector included the introduction of codes of conduct and rules of disclosure for public officials, as well as education and training programs. Constitutional changes now also require high ranking public officials, from the President down, to declare their assets on assuming and leaving office.

Rwanda's judicial system was also reformed. Conflicts of interest were prohibited, minimum education requirements were raised and proof of integrity and a history of exemplary conduct became prerequisites for judicial appointments. All court positions were made vacant under the reforms and a merit-based selection process was introduced.

Rwanda is now also a signatory to a number of international conventions against corruption including the United Nations Convention Against Corruption, the African Union Anti-corruption Convention and the UN Convention against Transnational Organised Crime (Transparency International UK 2011).

Rwanda is one of the few nations globally to report statistically significant improvements in a number of World Governance Indicators, including 'Control of Corruption'.

Children in Rwanda. Image: Women for Women.



Jwaneng diamond mine, Botwana. Image: Esther Dyson.

Box 8.1.6 Botswana – resource rich and transparent

Botswana inherited a legacy of underdevelopment at independence in 1966. However, the discovery of minerals in the late 1960s transformed it from a poor to a middle income nation. Resource development in Botswana is driven by private sector investment, and policies are considered to be amongst the best in the world, with open and transparent mineral licensing and taxation regimes operated by a competent and honest institutional structure (Sebudubudu 2003). In 2012 Botswana's Corruption Perceptions Index score of 65 made it the least corrupt nation in Central & Southern Africa, a position it has held since Transparency International first reported data for it in 1998.

Mining is an industry that can be fertile ground for corruption, but in Botswana it has been a major driver of social and economic development. The inclusive nature of Botswana's development is, in part, attributable to good institutions and economic management and political stability, which have deterred corruption.

These factors, combined with the government retaining a major share of resource rents in taxes, royalties and dividends has provided the framework for inclusive growth. Botswana is not, however free of corruption. Following a series of high profile, non-resource industry-related corruption scandals during the 1980s and early 1990s the government established the Directorate on Corruption and Economic Crime (DCEC) in 1994. The DCEC is designed specifically to deal with corruption, and has powers to investigate, prevent and teach the public about corruption and economic crime.

The DCEC has brought a sustained focus on the issue of corruption in Botswana, and the success of its anti-corruption campaigning is reflected in the high number of reports it receives. It has provided ordinary citizens with the opportunity to report corrupt activities (IAACA 2012).

Botswana has been relatively open regarding receipts from the mining industry (Jefferis 2009), and has been a signatory to the Extractive Industries Transparency Initiative since 2007.

References

ABS (2004). *Measures of Australia's Progress 2004.* Australian Bureau of Statistics, Canberra.

Abuzeid F. (2009). Foreign Aid and the "Big Push" Theory: Lessons from Sub-Saharan Africa, in *Stanford Journal of International Relations* **2009** (Fall).

Arezki R, Brückner M. (2009). *Oil Rents, Corruption, and State Stability: Evidence from Panel Data Regressions.* International Monetary Fund, Washington DC.

Arndt C, Oman C. (2006). *Uses and Abuses of Governance Indicators.* Development Centre of the Organisation for Economic Co-operation and Development, Paris.

Barcham M. (2007). C*orruption in Pacific Island Countries.* United Nations Development Programme Pacific Centre, Suva.

Barker B. (2010). *Nonstate Policing: Expanding the Scope for Tackling Africa's Urban Violence.* African Centre for Strategic Studies, Washington DC.

Baunsgaard T, Villafuerte M, Poplawski-Ribeiro M, Richmond C. (2012). *Fiscal Frameworks for Resource Rich Developing Countries.* Staff Discussion Paper. International Monetary Fund, Washington DC.

Charron N. (2011). Exploring the Impact of Foreign Aid on Corruption: has the "anti-corruption movement" been effective?, in *The Developing Economies* **49**(1).

Chene M. (2008). *Overview of Corruption in Rwanda.* Transparency International.

Cole J, Marroquín Gramajo A. (2009). Homicide Rates in a cross section of countries: Evidence and Interpretation, in *Population and Development Review* **35**(4).

Currie E. (1985). *Confronting Crime: An American Challenge.* Pantheon Books, New York.

Dani A. (2013) *Evaluation of World Bank programs in Afghanistan, 2002-2011* World Bank, Washington DC.

The Economist (2010). *Crime in Venezuela. Shooting the Messenger.* Print edition – 21 August 2010.

The Economist (2011). *Corruption and Development: Corrosive Corruption.* http://www.economist.com/blogs/dailychart/2011/12/corruption-and-development (accessed 10 August 2012).

ECOSOC (2012). *World Crime Trends and Emerging Issues and Responses in the Field of Crime Prevention and Criminal Justice.* E/CN.15/2012/19. United Nations Economic and Social Council, Vienna.

Furphy C. (2010). *Corruption in Africa: A Crime Against Development.* Consultancy Africa Intelligence, Pretoria.

Geneva Declaration on Armed Violence and Development (2011). *Global Burden of Armed Violence.* from: http://www.genevadeclaration.org/measurability/global-burden-of-armed-violence.html (accessed on 13 July 2012).

IAACA (2012). *Anti-Corruption Authorities.* International Association of Anti-Corruption Authorities. http://www.iaaca.org/AntiCorruptionAuthorities/ByCountriesandRegions/Botswanajigou/201202/t20120209_801149.shtml (accessed on 2 October 2012).

InSight Crime (2011). *Central America Regional Security Initiative.* http://www.insightcrime.org/security/central-america-regional-security-initiative (accessed on 13 July 2012).

Jefferis K. (2009). The role of TNCs in the extractive industry of Botswana, in *Transnational Corporations* **18**(1).

Karl T. (2004). Oil-Led Development: Social, Political and Economic Consequences, in *Encyclopaedia of Energy.* Elsevier. Rio de Janeiro.

Kaufmann D, Kraay A, Mastruzzi M. (2010). *The Worldwide Governance Indicators: Methodology and Analytical Issues.* Policy Research Working Paper No. 5430. The World Bank, Washington DC.

Lewis JM. (2007). The Resource Curse: Examining Corruption in the Extractive Industries, in *Perspectives on Global Issues* **2**(1).

Salas A. (2011). *Corruption Perceptions Index 2011: Why aren't all countries at the top?* Transparency International, Berlin.

Sebudubudu D. (2003). Corruption and its control in Botswana, in *Botswana Notes and Records* **35**.

Slater R. (2011). *What is Public Sector Corruption?* Transparency International, Berlin.

Transparency International (2011). Corruption Perceptions Index 2011. http://cpi.transparency.org/cpi2011/results/ (accessed on 10 August 2012)

Transparency International UK (2011). *Counter-corruption reforms in post-conflict countries: Metrics, indicators and impact in Rwanda, Liberia and Serbia.* London.

UN-HABITAT (2007). *Crime and Violence at a Glance: Causes of Crime and Violence.* United Nations Human Settlements Programme, Nairobi.

UNDP (1994). *Human Development Report.* United Nations Development Programme, New York.

UNDP (2007). *Human Development Report.* United Nations Development Programme. New York.

UNESCAP (2012). *What is Good Governance?* United Nations Economic and Social Commission for Asia and the Pacific. http://www.unescap.org/pdd/prs/ProjectActivities/Ongoing/gg/governance.pdf (accessed on 8 August 2012).

UNHCR (1997). *Social & Economic Impact of Massive Refugee Populations on Host Developing Countries as well as other Countries.* United Nations High Commissioner for Refugees http://rsq.oxfordjournals.org/content/19/4/158.full.pdf (accessed on 20 July 2012).

UNHCR (2002). A Critical Time for the Environment, in *Refugees Magazine* **127**.

UNHCR (2006). *The State of the World's Refugees – 2006.* Human Displacement in the New Millennium. United Nations High Commissioner for Refugees, Geneva.

UNHCR (2010). *UNHCR Global Trends 2010.* United Nations High Commissioner for Refugees, Geneva.

UNHCR (2011). *Providing Assistance to Colombian Refugees.* United Nations High Commissioner for Refugees, Geneva.

UNHCR (2012). *Statistical Online Population Database.* United Nations High Commissioner for Refugees http://www.unhcr.org/pages/4a013eb06.html (accessed on 6 February 2012).

UNHCR (2013). *Number of Syrian refugees tops 2 million mark with more on the way.* United Nations High Commissioner for Refugees http://www.unhcr.org/522495669.html (accessed on 10 September 2013).

UNODC (2003). *The Globalisation of Crime: A Transnational Organised Crime Threat Assessment.* United Nations Office on Drugs and Crime, Vienna.

UNODC (2005). *Crime and Development in Africa.* United Nations Office on Drugs and Crime, Vienna.

UNODC (2007). *Crime and Development in Central America: Caught in the Crossfire.* United Nations Office on Drugs and Crime, Vienna.

UNODC (2011). *Global Study on Homicide.* United Nations Office on Drugs and Crime, Vienna.

USIP (2010). *Governance, Corruption and Conflict.* United States Institute of Peace, Washington DC.

Uwimana C. (2011). *Corruption Perceptions Index 2011: A call to action.* Transparency International, Space for Transparency.

Wilkinson R. (1998). Going Home: Mozambique Revisited, in UNHCR *Refugees Magazine* **112.**

World Bank (2006). *Strengthening Bank Group Engagement on Governance and Anticorruption.* Development Committee Paper DC2006-0017. The World Bank, Washington DC.

World Bank (2011a). *World Development Report: The Impacts of Refugees on Neighbouring Countries: A Development Challenge.* The World Bank, Washington DC.

World Bank (2011b). *Crime and Violence in Central America: A Development Challenge.* The World Bank, Washington DC.

World Bank (2012). *World Development Indicators.* The World Bank http://data.worldbank.org/data-catalog/world-development-indicators (accessed on 2 August 2012).

Chapter 8.2

Governance | Gender Equality

'The education and empowerment of women throughout the world cannot fail to result in a more caring, tolerant, just and peaceful life for all.'

Aung San Suu Kyi

Vietnamese school girl.
Image: Mark Garten, UN Photo.

Summary of gender equality indicators

Indicator	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Ratio of Female to Male Adults (25+) with at least secondary education 1950-2010	**0.3-0.7**	0.4-0.5	0.2-0.6	0.2-0.7	0.3-0.8	0.7-0.9	0.7-0.9	0.7-0.9	1.1-0.9	**0.8-0.9**	**0.7-0.8**
Percentage (%) of women holding seats national parliament 1997- 2011	**10.3-18.1**	9.5-19.2	5.8-12.9	6.7-9.4	12.6-17.5	17.4-30.6	14.2-21.5	9.1-17	4.6-12.6	**13.2-20.2**	**12.1-19.5**

The link between equality and social and economic development is well documented, and improving wellbeing across society requires people to have similar opportunities with respect to education, employment and decision making. Improving opportunities for women is associated with clear improvements across a range of social and economic indicators. Healthy and educated women benefit their families, communities and nations.

Gender equality is achieved by changing cultural norms, beliefs and practices that discriminate between men and women. Attitude, beliefs, and practices that encourage gender inequality originate in the household, the community, and the workplace, and improving gender equality in these domains can positively affect the lives of men and women, boys and girls, and advance quality of life, personal autonomy, and economic and political freedoms.

The equality of men and women has been accepted as a fundamental principle of human rights since the adoption of the United Nations Charter in 1945.

Education is universally acknowledged to benefit individuals and promote national development. Educating girls and boys produces similar increases in earnings, opportunities and choices. However, educating girls has additional social benefits as it is associated with delayed marriage, lower fertility and improved health and survival rates for infants and children.

Indicators

Girls with secondary education – globally there has been considerable success in improving the access of girls to primary education. There is some indication however, that secondary level education may provide higher returns, especially for girls. Secondary education not only provides economic returns but is also consistently associated with greater decision making power and increased mobility for women.

Women in national parliament – a principle of democratic government is that parliament should represent and express the will of the people. Civil society is considered more effective if parliament is widely representative of the population. Relative to their proportion of the population, women are under-represented in national parliaments, which can lead to a large proportion of the population being under-represented in national level decision making.

Women and education

Is it getting better?

Girls with secondary education - Fewer females have access to secondary education relative to males in the Tropics than in the Rest of the World, but the gap is closing. In 2010 the ratio of female to male adults with at least secondary education in the Tropics was 0.747, well below the ratio of 0.855 for the Rest of the World (inequality for women exists if the value is less than 1). Nonetheless the margin between the Tropics and the Rest of the World has decreased considerably over the past 60 years.

Women in national Parliament - Globally, the representation of women in many facets of society is improving. The proportion of women in national parliaments increased from 12.1% in 1997 to 19.5% in 2011. The improvement is broadly similar in the Tropics and the Rest of the World, increasing from 10.3% to 18.1% and 13.2% to 20.2% respectively.

Globally, the changing gender balance is having some impact on the policy agenda, but there is scope for much greater change.

Dafur. Image: Albert Gonzalez, UNAMID.

Women and girls represent 70% of the world's poor (UNIFEM 2013), earn only 10% of the world's income and own only 1% of the world's property (CARE 2010). Against this backdrop, creating equal opportunities for men and women in education, employment, access to health care and representation in decision making is fundamental to social justice, and is also a critical pathway to economic and social development (UN 2012).

Education is a key contributor to improving gender equality and is recognised as one of the most powerful instruments for reducing poverty and developing a foundation for sustained economic growth (World Bank 2013). However, access to education is not always equitable, and can be influenced by factors such as gender, income and race.

Increased participation by girls and women in education generates significant individual, family and societal benefits. Recognising this, a suite of global and regional programs have been developed to emphasise the importance of girls' education to improving gender equality and human development outcomes, and reducing poverty. The outcome of these programs is higher primary school completion rates for girls, and growing demand from girls for secondary education.

Higher levels of education create a greater range of opportunities, and can help to prepare and position women to take on transformative positions in society. Research demonstrates that, relative to primary education, secondary schooling is more consistently and strongly associated with increased decision-making, freedom and mobility for women (Malhotra et al. 2003). Therefore, understanding female participation in secondary education[10] is a key indicator of gender equality.

Trends

Globally, the proportion of adult women that have undertaken secondary education is considerably lower than for males, but the gap is closing. Relative to the Rest of the World a considerably lower proportion of both men and women undertake secondary school in the Tropics, and the ratio of female to male adults with secondary education is considerably lower (Figure 8.2.1). In 2010 the ratio of female to male adults with at least secondary education in the Tropics was 0.75, well below the ratio of 0.86 for the Rest of the World (inequality for women exists if the value is less than one). Nonetheless the margin between the Tropics and the Rest of the World has decreased considerably over the past 60 years (see Figure 8.2.1), largely due to significant improvements in the Tropics, where the ratio increased from 0.34 in 1950 to 0.75 in 2010. In the Rest of the World it improved from 0.79 to 0.83 over the same period.

The Tropics recorded steady growth in this gender ratio in the past 60 years to 2010, though improvements were particularly strong in the 15 years to 1995, driven by rapid improvements in South East Asia and, to a lesser extent, South Asia and South America.

Despite the Tropics being below the world ratio in 2010, four of the eight tropical regions recorded ratios of female to male adults with at least secondary education above the world ratio. Seven out of eight regions increased, at varying rates, while the ratio of Oceania was below the 1950 level. Nonetheless, Oceania reported the second highest ratio of the tropical regions in 2010. South America recorded the highest ratio of the tropical regions in 2010 at 0.99 and, along with Oceania, the Caribbean and Central America also have high ratios, at 0.94 and 0.90 respectively (see Table 8.2.1).

South East Asia reported the greatest improvement, increasing from 0.29 in 1950 to 0.83 in 2010. South Asia and Northern Africa & Middle East also reported strong increases over this period. Oceania

[9] Secondary education around the world is diverse, but generally refers to any academic or vocational education beyond primary school level. The United Nations now includes the first two years of secondary school in their definition of 'Basic education'. Students in secondary school can generally choose from a wider range of general and specialised study programs offering different levels of instruction and leading to different career paths. Some programs focus on preparing students for tertiary education, while others prepare them for direct entry into the labour force. Source: www.unesco.org

was the only region to report a decline in the ratio, falling from 1.06 in 1950 to 0.95 in 2010 (see Table 8.2.1). The decline in Oceania is due to a fall in the ratio in the United States of America (i.e. Hawaii), with all other nations in the region for which data are available reporting improvements, especially Papua New Guinea (though it was from a very low base) and Fiji. For the United States the ratio was still above parity in 2010, and the highest in the region.

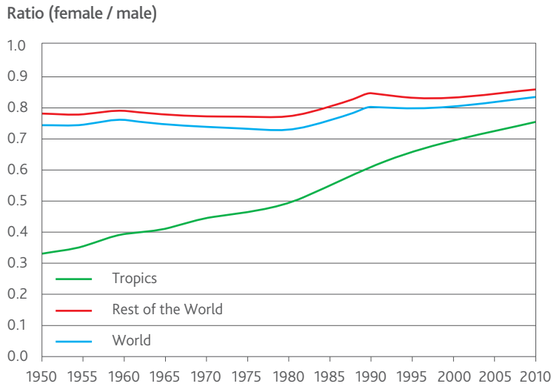
Steady improvement in the Tropics is being supported by a number of global programs which aim to improve educational opportunities and empowerment opportunities for women and girls. For example, UNICEF's African Girls Education Initiative (AGEI) started in 1994 to encourage more girls into schools, and has an underlying focus of learning by doing (Oxfam 2011). The success of AGEI was a factor in the establishment of the United Nations Girls Education Initiative (UNGEI) in 2000 – the first global partnership promoting gender issues in education. UNGEI promotes and supports initiatives which aim to improve the gender ratio of primary and secondary school attendees.

Other global programs supporting the education of girls and women over the past two decades include:

- The Adolescent Girls Initiative, launched in 2008 as part of the World Bank Group's Gender Action Plan, aims to help adolescent girls and young women to finish secondary school and make a successful transition from school to work. This initiative is being trialed in eight low income countries, five of which are in the Tropics.

- Education For All (EFA) is a global commitment, launched in 2000 and led by UNESCO, to provide quality basic education for all people. Through this program governments are encouraged to invest 4-6% of GNP and 15-20% of public expenditure on education, depending on demography and economic status. The EFA is linked to the Global Partnership for Education, which represents developing nations, donor government, NGOs and multilateral organisations and aims to improve education funding, planning and outcomes (UNESCO 2012a).

Figure 8.2.1 Ratio of female to male adults (25+) with at least secondary education*



Source: Barro & Lee (2013).
* The proportion of the 25+ female population with secondary education divided by the proportion of the 25+ male population with secondary education.

- The Coalition for Adolescent Girls brings together more than 30 international organisations targeting girls in poverty.

- CAMFED (Campaign for Female Education) aims to support girls' education and the empowerment of women thought community-based programs in Africa.

- Because I am a Girl Campaign was launched by Plan International in 2006 and aims to fight gender inequality, promote girls' rights and lift girls out of poverty.

- UN Adolescent Girls Taskforce is co-convened by UNICEF, the United Nations Population Fund, the World Health Organisation, and the United Nations Fund for International Partnerships to improve interagency cooperation on programs that address the most marginalised and disadvantaged adolescent girls.

Barriers to education and equality

Initiatives to empower women and girls have improved education, employment, and health outcomes over the past 60 years, but high levels of gender inequality still persist in many parts of the world. Women and girls are more likely to live in poverty, earn less income and own less property than men. Women and girls represent just under two-thirds of the illiterate population in the world (at 64% and 61% of the illiterate population respectively) (UNESCO 2012b). Broad inequalities in households and society prevent women from fully participating in society and from achieving returns from engagements with education and the labour force.

Despite worldwide attention and increased funding for women and girls' education, barriers exist which prevent girls from starting, and if they start, completing secondary school. A survey of professionals and teachers working in education and development worldwide found that the main barrier to girls going to secondary school is poverty (49%) followed by the undervaluing of girls (22%) (Fancy et al. 2012). Other barriers include negative parental attitudes towards school, the perceived quality of available schools, distance to the nearest school, girls' burden of chores and ongoing conflict or civil unrest.

Overcoming these barriers is a challenge for tropical nations, as many will experience some or all of these obstacles. Solutions proposed for keeping girls in school include scholarships, more (and better) schools, incentives for teachers, relevant curricula, better training and salaries for teachers, improved toilet facilities and the provision of free sanitary products (Fancy et al. 2012).

Nonetheless, poverty is the driving factor affecting whether children attend school, irrespective of improvements that may be made to schooling and education systems. Children from poorer households are less likely to attend school, with girls more likely than boys not to be educated due to poverty. An estimated 71 million children worldwide aged between 12-15 years did not attend secondary school in 2010, of which 53% were female (UN 2012).

Empowering women

Female empowerment is recognised as an important factor influencing the degree of gender inequality in a society. Women's access to health and education services is considered a necessary factor for female empowerment. Empowerment leads to increased economic opportunities for women, as well as access to transformative and decision making roles in households and society.

Education can provide the skills which enable women to more readily access and interpret information regarding health and disease, and this information can be critical during pregnancy and after childbirth. Education and health services empower women to take greater responsibility of their lives, including greater control and ownership of their bodies (USAID 2008). Women with higher levels of education can make better informed choices about work, marriage and children (World Bank 2012).

Box 8.2.1 Measures of gender equality

A range of indicators are available to measure gender equality, and many of the composite measures include an education dimension. Nonetheless, actually quantifying the extent of inequality can be complex due in part to differential life expectancies of men and women.

The Gender Parity Index (GPI) is a measure of access to education for males and females and is usually based on enrolment rates in a given stage of education (e.g. number of males enrolled against number of females in primary, secondary, or tertiary education) (USAID 2012). The GPI is expressed as a rate, with a score below or above one indicating inequality. For men inequality exists if the rate is above one and for women inequality exists if the rate is below one. For the Millennium Development Goals equality is considered to be achieved with a GPI rate of between 0.97 and 1.03.

The Gender Inequality Index (GII) was developed in 2010 by the United Nations, and replaces two previous measures: the Gender Development Index, and the Gender Empowerment Measure. The GII is a composite measure of loss in human development due to gender inequality. Inequality is reflected in three dimensions: reproductive health (adolescent fertility and maternal mortality); empowerment (parliamentary representation and educational attainment); and labour market participation. GII scores range from zero to one, with zero indicating equality and one indicating inequality. For example, the world average score on the GII is 0.492.

The Global Gender Gap Index is used by the World Economic Forum in its annual Global Gender Gap Report. This index examines the gap between men and women in four categories: economic participation and opportunity; educational attainment; health and survival; and political empowerment.

All three of these measures of gender equality suggest that the status of women has been improving over time.

School girls, Bolivia. Image: World Bank.

Table 8.2.1 **Ratio of female to male adults (25+) with at least secondary education***

	Ratio							Total difference (ratio) 1950-2010	Total difference (%) 1950-2010
	1950	1960	1970	1980	1990	2000	2010		
Tropics	**0.34**	**0.40**	**0.45**	**0.49**	**0.61**	**0.69**	**0.75**	**0.41**	**121**
Central & Southern Africa	0.35	0.29	0.27	0.33	0.40	0.46	0.54	0.19	54
Northern Africa & Middle East	0.18	0.20	0.21	0.25	0.36	0.48	0.58	0.40	217
South Asia	0.17	0.20	0.27	0.33	0.42	0.51	0.57	0.39	227
South East Asia	0.29	0.33	0.42	0.53	0.69	0.75	0.83	0.54	190
Caribbean	0.75	0.78	0.77	0.81	0.84	0.91	0.94	0.19	26
Central America	0.72	0.75	0.79	0.72	0.84	0.87	0.90	0.17	24
South America	0.66	0.70	0.76	0.84	0.96	1.00	0.99	0.34	51
Oceania	1.06	1.02	0.97	0.98	1.05	0.95	0.95	-0.11	-10
Rest of the World	**0.79**	**0.81**	**0.77**	**0.77**	**0.85**	**0.83**	**0.86**	**0.07**	**9**
World	**0.75**	**0.78**	**0.74**	**0.73**	**0.80**	**0.80**	**0.83**	**0.08**	**11**

Source: Barro & Lee (2013), State of the Tropics project.
* The proportion of the 25+ female population with secondary education divided by the proportion of the 25+ male population with secondary education.

Improved access and engagement with education have also assisted more women to enter the formal labour market. Women have increased their share in employment outside of the agricultural sector in developing countries, with a five percentage point rise recorded in the 30 years to 2010. Self-employment opportunities for women also improved in the 30 years to 2010, and women own and run more businesses than ever before (FAO 2013). Business ownership for women in developing nations – often established with microfinance – provides tangible alternatives to the informal labour market and opportunities to apply business and other skills that would otherwise be underutilised. These businesses can generate income and wealth for their owners, as well as employment opportunities for other members of the community. Women are also considered more likely than men to reinvest money earned from employment into their children's wellbeing, providing for education and health needs (UN 2010).

Looking forward

Improvements to women's and girls' lives have been immense in the past 60 years. Opportunities provided by higher levels of education can support women and girls to engage equally with men in society. Progress includes higher parity ratios in all levels of education, growth of businesses opportunities for women, greater freedom and mobility, and increasing numbers of women in decision-making and political roles. To advance gender equality further, female empowerment initiatives must aim to increase the number of women in secondary and tertiary education and in high-level formal employment.

In many societies men are increasingly being encouraged to use their influence in the household, in the workplace and in civic society generally, to engage in the deconstruction of gender stereotypes and discriminatory practices (UNESCO 2004). Men generally have a much higher share in upper-management including decision-making occupations emphasising the important role men have in balancing gender equality.

Many of the potential advantages to women from secondary education are conditional on culture and local social norms (Malhotra et al. 2003). Achieving equality for women and girls will be made possible by challenging the cultural traditions and perceptions of gender that influence discriminatory decision-making practices in legislation and social policy.

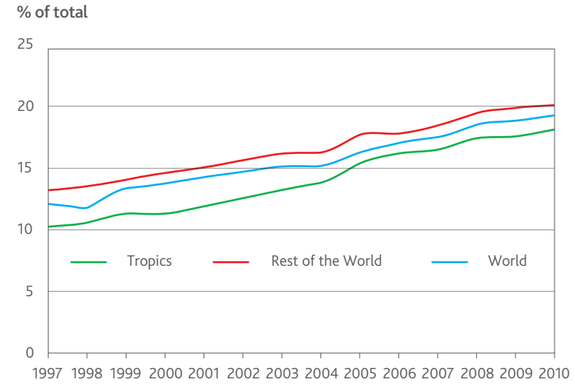
Women in national parliament

The proportion of women representatives in a country's national parliament[11] is an indicator of gender equality. Females typically represent more than half of a nation's population, but they tend to be significantly underrepresented in national parliaments. In only two of the 194 nations for which 2011 data are available did women hold more than 50% of seats and, globally, only 19.5% of seats in national parliaments were held by women (IPU 2012). Though significantly underrepresented as a proportion of the population, this is a solid improvement on the 12.1% reported in 1997, but still well short of the 30% targets suggested by various international bodies[12]. It has been suggested that a minimum representation of 30% is needed to influence political processes and policy development in legislative bodies (Krennerich 2009).

A range of socioeconomic, cultural and political impediments are known to affect the rates of female representation in national parliaments (IIDEA 2005). Socio-economic obstacles include low levels of education and literacy, low labour force participation, the dual burden of career and family commitments and often a lack of financial support. The costs of political campaigning are high and many women do not have the means to be effective candidates (WEDO 2008). Higher labour force participation tends to improve financial resources and provides a source of political contacts necessary to campaign effectively. Cultural factors can range from social stereotyping, secularism, and patriarchal values to a basic lack of confidence to stand for election. The type of electoral system can also influence the proportion of women in parliament, as can candidate selection rules, political party ideologies and, at a personal level, a lack of political knowledge and experience.

Nonetheless, many nations are seeking to improve opportunities for women to hold public office and contribute to policy and civic development. As cultural attitudes and socio-economic factors are quite slow to change, political reforms are typically the most effective mechanism to improve representation in the short term. Reflecting this, gender quotas have been adopted by a number of governments and political parties to increase female participation. In 2011 seven of the ten nations with the highest proportion of women in national parliament had some form of gender quota (IIDEA 2013).

Figure 8.2.2 **Women in national parliament***



Source: IPU (2012), State of the Tropics project.

Trends

Globally, the representation of women in many facets of society is improving. In politics this is reflected in the increase in the proportion of women in national parliaments from 12.1% in 1997 to 19.5% in 2011 (see Figure 8.2.2). The improvement is broadly similar in the Tropics and the Rest of the World, increasing from 10.3% to 18.1% and 13.2% to 20.2% respectively, with the Tropics performing marginally better. Globally, greater female representation is being supported by the introduction of gender quotas in many nations, with 59 nations having a quota in 2011 (32 of which are in the Tropics) compared to only 17 (11 of which were in the Tropics) in 1997.

The gradual increase in representation at the global level is not universal, and there is considerable variation across nations. Six of the seven nations with no female representatives in their national parliaments are in the Tropics. Also, unlike the slight narrowing of the gap between the Tropics and the Rest of the World, the gap between the tropical regions is large and has been increasing over time. This is because of consistently low representation in South Asia while, in the Caribbean, representation has increased significantly. The female representation gap between South Asia and the Caribbean increased from 10.7 percentage points in 1997 to 21.2 percentage points in 2011 (see Figure 8.2.3).

[11] 'National parliaments' refers to single and lower houses of parliament. If a nation has an upper and lower house of parliament, data and commentary here refers to the lower house.

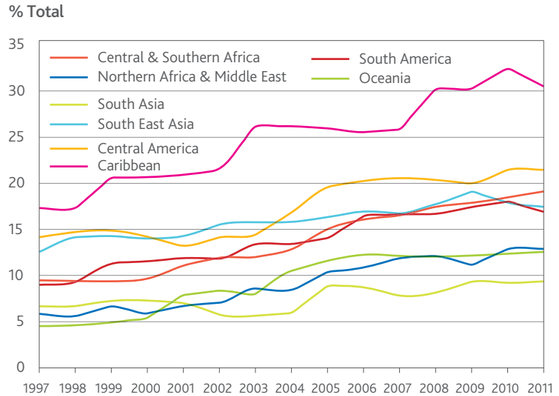
[12] During the United Nations Fourth World Conference on Women in 1995, 189 countries endorsed a target of 30% of seats in national parliaments being held by women. More recently, the United Nations Millennium Development Goal's set a target of 30% to be achieved by 2015.

In 1997 the Caribbean had the highest proportion of female representatives in national parliament in the Tropics at 17.4%, and retained this ranking through to 2011 when women made up 30.6% of representatives. In fact, the increase in the proportion of women in parliament in the Caribbean far exceeds that of the other tropical regions (see Figure 8.2.3) and the Rest of the World, and it is the only tropical region to exceed the Millennium Development Goal of 30% representation by 2015. The improvement has been driven by substantial increases in Cuba and Trinidad and Tobago. In Cuba's case progress has been associated with a government commitment to improve equality for women in all aspects of life.

At the other end of the scale, at 9.4%, South Asia had the lowest proportion of female parliamentarians in 2011, with a relatively small increase from the 6.7% reported in 1997. The Oceania region had the lowest representation in 1997 at 4.6%, increasing to 12.6% in 2011. This solid improvement is largely driven by French parity laws being implemented in French Polynesia and New Caledonia since 2001 (French Polynesia and New Caledonia are collectivities of France). These laws require political parties to include 50% of women on their electoral candidate lists. In elections following the introduction of the law the proportion of women representatives increased from 12% to 48% in French Polynesia and from 17% to 46% in New Caledonia (Bargel et al. 2010). Most other nations in Oceania, and particularly Pacific Island nations, continue to have low rates of representation, with four nations having no women in parliament and a further six with representation of less than 5%. Excluding French Polynesia and New Caledonia, representation in Oceania was only 2.5% in 1997, increasing to 3.4% in 2011.

In Central & Southern Africa the situation is far more encouraging. Coming from a relatively low starting point of 9.5% female representation in 1997, Central & Southern Africa achieved the second largest improvement to 2011, increasing by 9.6 percentage points to 19.1%. A number of nations in the region have achieved substantial improvements through a phase of post-conflict political and civil development, which has often included constitutional reform. (see Box 8.2.4)

Figure 8.2.3 **Women in national parliament – the Tropics**



Source: IPU (2012) State of the Tropics project.

The widening gap between the tropical regions suggests major differences in cultural, socio-economic and political characteristics. Limited progress in South Asia and many nations in Oceania suggests the barriers to reform are more entrenched in these areas.

Women's activism

Increasing female representation worldwide is influenced by a broad range of factors including improvements in the socio-economic status of women in many societies. National and international efforts to improve education, employment opportunities and the status of women in society have increased the capacity and confidence of women to contribute to political and civil life in decision making roles. This has been supported by the civil rights and women's movements which have exerted pressure on political parties and institutions to introduce changes which facilitate more equitable representation in parliaments and other institutions. For example, groups such as the United Women of Tanzania, the Collectifs Pro Femmes/Twese Hamwe (Pro-Femmes) in Rwanda and the Namibian Women's Manifesto have been influential in the introduction of reform agendas (Waring 2010). These (and other) groups have also provided education and training on parliamentary procedures and campaign management to build capacity and confidence in women to participate more effectively in the electoral process. In many nations, women's movements are also actively engaging in constitutional reform, contributing to the development of legislation and political rules that are more conducive to gender equality.

Box 8.2.2 Types of electoral systems

There are three main types of electoral systems: majoritarian, proportional representation, and mixed. The majoritarian system is the oldest and simplest electoral system. With this system there is usually only one seat per electoral district and the candidate that wins the majority of the votes is elected. Under this system cultural factors can have an influence when political parties are dominated by one gender as the candidate selection process may be skewed to favour the political aspirations of that gender.

In proportional representation systems parliamentarians are elected in multi-member electoral districts. The number of seats a political party wins is proportional to its overall share of votes received. The larger number of seats available in each electorate is an incentive for political parties to consider a range of candidates who are likely to appeal to a broad spectrum of voters, including women. As a result the proportional representation electoral system tends to deliver parliamentary representation that is broadly indicative of the society it serves. Where legislated quotas exist, such as the French 'law on parity', the proportional representation system can be even more effective in improving female representation. Nonetheless, party leaders can influence the gender and positioning of their candidates on electoral lists and, therefore, to some extent, gender representation in parliament.

The mixed electoral system combines elements from both the proportional and majoritarian systems. Typically part of the legislative assembly is elected using the majoritarian system, and the balance under some proportional representation arrangement.

Image: Sikarin Thanachairy, World Economic Forum.

In the case of Rwanda, in 2000 the Constitutional Commission was established to draft a new constitution. The Commission engaged in a series of consultations which allowed significant input by women. The women's umbrella organisation Pro-Femmes was particularly effective, and the new constitution requires that at least 30% of posts in all decision making institutions be held by women (IIDEA 2005).

Electoral systems

A range of cultural, social and political factors influence the outcome of elections, and it is recognised that the choice of electoral system can affect how women engage in the political process (see Box 8.2.2).

The design of the electoral system influences the way votes are translated to seats in parliament. The key variables in the system are the electoral formula (proportional representation, majoritarian, or mixed), district magnitude (number of seats in each electorate) and the ballot design (IIDEA 2008). The practices of political parties and the manner in which they interact with the electoral system also come into play. For example, the single seat in each electorate which is characteristic in majoritarian systems encourages political parties to select candidates they consider to be the most electable. In comparison, proportional representation allows political parties to put forward a larger number of candidates, which is generally more conducive to party lists including a broader cross section of society, including women.

During the past three decades there has been a significant increase in the parliamentary representation of women in nations with proportional representation, but only modest increases in those with majoritarian systems (Squires 2010). In 2011, in nations with proportional representation women held 22% of all seats in national parliaments compared to 18% in nations with a majoritarian system and the rate of growth has been significantly faster in

the proportional representation electoral system over the past 14 years.

That a significant number of nations in the Rest of the World (43 of 89) use the proportional electoral system compared to tropical countries (32 of 103) is likely to be a factor contributing to the variance in parliamentary representation of women between the two areas.

Nonetheless, proportional representation cannot guarantee greater female representation, and its impacts are maximised when favourable conditions prevail, including the presence of well organised political parties. Proportional representation has been found to be less effective when political systems are dominated by a large proportion of independent politicians.

Nations tend to change their electoral systems infrequently, though in recent years many post-conflict nations, notably in Africa, have undertaken constitutional reform, as have several nations in Central and South America. An outcome of this is that many nations are reviewing potential electoral systems. Many of these reforming nations have adopted proportional representation systems as they tend to deliver parliamentary representation that is more indicative of the wider community. Other positive features of proportional representation which make it popular are its tendency for high voter turnout, combined with fewer opportunities for biasing outcomes through gerrymandering.

Quotas

A gender quota is a mechanism to increase the number of women in parliament. There are several ways to implement quotas (see Box 8.2.3), and over the past 30 years they have become increasingly popular as an option to increase the proportion of women in national parliaments.

Quotas were first introduced by political parties in Western Europe in the 1980s to consolidate earlier increases in representation achieved from improved education and employment opportunities and the women's movements. Through the 1990s and early 2000s legislative quotas appeared in many African and Central and South American nations. In many instances women's activist movements were behind the introduction of quotas, which were seen as the only tool capable of overcoming deep seated cultural and socio-economic barriers inhibiting increased representation. Also, in post-conflict nations, the need to rebuild basic structures of civil society has provided an excellent opportunity to progress the equality agenda, including through the use of quotas (see Box 8.2.4).

Of the 109 nations in the State of the Tropics report identified as fully or partially in the Tropics, data are available for 103 and, of these, 11 had legislated gender quotas in 1997, increasing to 32 in 2011. Of the 89 nations of Rest of the World for which data are available, six had legislated quotas in 1997, increasing to 27 in 2011 (IIDEA 2005).

Of the 59 nations with legislated quotas in 2011, 18 had reserved seats quotas (with an average quota of 20%) and 41 had candidate quotas (with an average quota of 34%). Thirty-three of these nations had female parliamentary representation above 20%, and 20 of these (61%) were in the Tropics, with seven having a reserved seat system and the other 13 using candidate quotas.

The effectiveness of quotas is not guaranteed, as in 2011, 41 of the 59 nations with quotas had representation below mandated or implied levels. The type of electoral system, attitudes of political parties, monitoring effort and penalties for non-compliance all impact the success of quotas. In 2011, 14 of the 18 nations with reserved seat quotas (78%) complied, and non-complying nations tended to be close to the quota figure. In contrast, only 5 of the 41 nations with candidate quotas (12%) had the number of women in parliament as implied by their quota, and often there was a significant variation. In the Tropics, 10 of the 13 nations with reserved seat quotas (77%) and 2 of the 20 nations (10%) with legislated candidate quotas achieved their quota target.

This suggests that in the absence of penalties for non-compliance the candidate quota target is essentially aspirational, and political parties have no incentive to change their behaviour. Costa Rica is a tropical nation which successfully increased representation from 16% in 1997 to 39% in 2011 using candidate quotas, though this only occurred once political parties were monitored and incurred penalties for non-compliance (IIDEA 2005).

Box 8.2.3 Quotas

Gender quotas aim to increase the political representation of women in parliament and can be constitutional, legislated or voluntary party-based quotas.

Constitutional quotas are enshrined in the basic law of a nation, while legislative quotas are introduced through legislation. Common forms of constitutional and legislative quotas include candidate quotas (where political parties must put forward a minimum proportion of female candidates) and reserved seats (where a nominated proportion of seats are reserved for women). Though legally binding, the success of candidate quotas in increasing the number of women in parliament depends on the ability of candidates to actually go on and be elected. The success of candidate quotas also depends on the extent of compliance monitoring and, importantly, the consequences of non-compliance. Reserved seats may be contested by election, filled by appointment or allocated to political parties in proportion to the number of seats won in an election.

Voluntary quotas are not legally binding and are usually initiatives undertaken by political parties to field a minimum percentage of female candidates.

Parliament in Accra, Ghana. Image: Jonathon Ernst, World Bank.

Cultural factors

Over recent decades the status of women in most societies has improved across a broad range of socio-economic indicators ranging from health outcomes to education and employment opportunities. In nations with no formal gender-specific barriers to election to parliament it would be reasonable to expect this to translate to a substantial improvement in the representation of women in parliaments. However, most parliaments continue to be male-dominated owing to cultural, political, socio-economic and institutional factors. In many nations, including developed nations, women's access to parliament continues to be affected by attitudes about women's role in society, a lack of support by political parties and bias among the electorate, particularly where political and cultural leadership has historically been a male preserve (Fraenkel 2006).

Public attitudes to the role of men and women in society vary markedly across nations. For example, attitudes to whether it is preferable for women to focus on home activities varied from 24% to 64% in a 2009 survey across 18 Latin American nations (Latinobarómetro 2009). Compared with 2004 survey results, the lower and upper results were largely unchanged, though the regional figure fell from 43% in 2004 to 38% in 2009. In 2004 six nations reported more than 50% of the population preferring women to focus on the home, falling to two nations in 2009. Attitudes about whether men are better political leaders were largely unchanged with a range of around 20% to 50% and a regional figure of 33% in 2009 (up from 32% in 2004). Despite this, 17 of the 18 nations have quotas and seven have elected female presidents since 1990. This highlights that a broad range of factors are at play in determining the number of women in parliament.

To improve women's parliamentary participation it is recognised that an essential ingredient is a supply of motivated candidates, though in many nations cultural barriers can inhibit this. For example, the patriarchal control of political parties can make it difficult for women to gain entry into politics, and women are less likely to participate if elections tend to be marred by violence (Waring 2010).

The Caribbean is a region where cultural factors seem to have had a strong and positive influence on representation, and it consistently has the highest proportion of female parliamentarians of the tropical regions. The increase is driven by Cuba, and has been achieved without quotas.

Cuba's constitution guarantees women and men equal economic, political, social and cultural opportunities. Additionally, following the 1996 World Conference of Women the government initiated a broad ranging program to improve the status of women in society, backed up by a requirement for the annual reporting of progress. Implementation of the program was supported by the Federation of Cuban Women (FCW), which provided educational programmes and worked to improve the rights of women. Significantly, the FCW boasts a membership of around 85% of the female population aged over 14 years (Cuba Solidarity Campaign 2010). The program has also contributed to improving women's labour force participation, education and economic status which have contributed to their improved cultural, social, and political standing.

Impacts of increased representation of women in parliament

An implicit goal of improving the gender balance in national parliaments is to influence policy development to be more inclusive and reflective of the needs and aspirations of women, including issues of special concern such as family, health, education and sanitation. It is suggested that societies that elect large numbers of women tend to be more gender-equal in other respects than societies that elect fewer women (Wangnerud 2009), as the changing gender balance is having some impact on the policy agenda, even if evidence of a greater influence on policy implementation is mixed.

In most nations the proportion of women in parliament is increasing, though the gender re-balancing has not typically translated to meaningful change in the balance of power in many parliaments (IIDEA 2005). This may be because, as well as numbers, effectiveness is influenced by the degree of 'newness' to political processes, with a positive correlation between experience and effectiveness (Jeydel & Taylor 2003). In many nations there is also a tendency for women not to be promoted to positions of power and, where they do become ministers, the perception is they are allocated to portfolios dealing with social issues.

This is not to suggest an absence of power re-balancing. For example, women make up more than 50% of the parliament in Rwanda and there is evidence of cultural change, with women being appointed to a range of parliamentary committees and senior positions, including deputy speaker. At the policy agenda level women's issues are now raised with greater ease, and more regularly. However, the influence of more women in parliament on policy implementation in Rwanda is less evident, and suggests this area of the parliamentary process is more affected by a government's broader commitment to promote women's rights (Devlin & Elgie 2008). A number of significant legislative changes, such as the removal of prohibitions on

Box 8.2.4 Women in Rwanda's parliament

Rwanda is an example of a post-conflict nation that has successfully used parliamentary quotas to improve gender equality. Following the brutal genocide in 1994, 70% of the population was female. In November 1994 a transitional government was formed, and ruled until the first elections in 2003. The transitional government initially appointed eight of the 70 parliamentary seats to women, increasing this to 19 of 74 seats by 2000 (Devlin & Elgie 2008).

In 2003 Rwanda's new constitution included a quota assuring women a minimum of 30% of posts in all decision making bodies, or a minimum of 24 seats in parliament. These seats were to be contested in women only elections, where all candidates were women and voting was restricted to women. In the 2003 election 39 women were elected to parliament. That is, 15 women were elected to non-reserved seats, and women made up 49% of lower house representatives (IIDEA 2005).

The election result suggests that factors other than the quota system were at play, and had in fact been at play since the end of the genocide. The sharp drop in the male population saw women move into traditional male roles in the economy and society generally, with a subsequent impact on the potency of the traditional patriarchal system. Combined with the re-emergence of local women's organisations (which had disbanded during the genocide), these were positive impacts for the status of women in society.

Women's groups lobbied for gender equality provisions in post-conflict governmental and administrative systems, and mobilised women candidates by educating and preparing them to participate in the political process. The support of a dominant political party, the introduction of the proportional representation electoral system and a reserved seats quota all acted to create an environment conducive to women being elected.

With many of the major political, socio-economic and cultural obstacles overcome this is exactly what occurred in the 2003 elections. Following the most recent election in 2008, women currently hold 45 of 80 seats (56%) and Rwanda has the highest proportion of women in parliament globally.

Members of Parliament, Rwanda. Image: Rwanda Government.

women inheriting land and new laws against gender-based violence, have been passed since 1996.

Although not ideal, meaningful gender equality policies can be introduced without a large proportion of female parliamentarians. For example, the proportion of women in Ghana's parliament is consistently below 10%, yet it has passed a number of laws regarding domestic violence and human trafficking which have improved the rights of women.

Looking forward

In most parts of the world there is increasing recognition of the importance of establishing gender equality, even if the process of achieving it tends to be slow. In terms of political equity, the number of women parliamentarians is likely to continue to increase, as is their effectiveness as they become more experienced, confident and influential in implementing their policy agenda. The fact that in 1998 there were only eight elected female heads of state, and that it increased to 19 in mid-2013 suggests this process is well underway.

References

Bargel L, Guyon S, Rettig I. (2010). *Assessment of the application of the 'Parity Law' in New Caledonia, French Polynesia & Wallis and Futuna.* Secretariat of the Pacific Community, Noumea.

Barro R, Lee JW. (2013). *Barro-Lee Educational Attainment Dataset, Version 1.3.* http://www.barrolee.com/ (last accessed on 22 May 2013).

CARE (2010). *Strong Women, Strong Communities: CARE's Holistic Approach to Empowering Women and Girls in the Fight Against Poverty.* CARE Australia, Canberra.

Cuba Solidarity Campaign (2010). *Fact Sheet - Women in Cuba.* http://www.cuba-solidarity.org.uk/faqdocs/WomenInCuba.pdf (accessed on 4 June 2012).

Devlin C, Elgie R. (2008). The Effect of Increased Women's Representation in Parliament: The Case of Rwanda, in *Parliamentary Affairs* **61**(1).

Fancy K, Unterhalter E, Vaughan RP, Nussey C. (2012). *The State of the World's Girls, 2012.* Plan International.

FAO (2013). Gender Equity, United Nations Food and Agricultural Organisation http://www.fao.org/gender/gender-home/gender-programme/gender-equity/en/ (accessed on 26 February 2013).

Fraenkel J. (2006). *The Impact on Electoral Systems on Women's Representation in Pacific Parliaments.* A Report Conducted for the Pacific Islands Forum Secretariat by the Pacific Institute of Advanced Studies in Development & Governance, University of the South Pacific, Fiji.

IIDEA (2005). *Women in Parliament: Beyond Numbers.* International Institute for Democracy and Electoral Assistance, Stockholm.

IIDEA (2008). *Electoral System Design – The New International IDEA Handbook.* International Institute for Democracy and Electoral Assistance, Stockholm.

IIDEA (2013). *QuotaProject – Global Database of Quotas for Women.* International Institute for Democracy and Electoral Assistance http://www.quotaproject.org (accessed on 14 May 2013).

IPU (2012). *Women in National Parliament Statistical Archive.* Inter-Parliamentary Union http://www.ipu.org/wmn-e/world.htm (accessed on 14 May 2012).

Jeydel A, Taylor AJ. (2003). Are Women Legislators Less Effective? Evidence from the U.S. House in the 103rd - 105th Congress, in *Political Research Quarterly* **56**(1).

Krennerich M. (2009). *Report on the Impact of Electoral Systems on Women's Representation in Politics.* Study No. 482/2008. European Commission for Democracy through Law, Venice.

Latinobarómetro (2009). *Data Bank.* http://www.latinobarometro.org/ (accessed on 13 June 2012).

Malhotra A, Pande R, Grown C. (2003). *Impact of investments in female education on gender equality.* International Center for Research on Women, Washington DC.

Oxfam (2011). *Make it right – Ending the crisis in girls education.* Oxfam Global Campaign for Education, United Kingdom.

Squires J. (2010). Gender and Minority Representation in Parliament, in *Political Insight* **1**(3).

UNESCO. (2004). *Role of men and boys in promoting gender equality - Advocacy Brief.* United Nations Education, Scientific, and Cultural Organisation, Bangkok.

UNESCO (2012a). *Education for All Movement.* United Nations Education, Scientific and Cultural Organisation http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-all/ (accessed on 20 May 2013).

UNESCO (2012b). *Adult and Youth Literacy.* UNESCO Institute of Statistics Fact Sheet No. 20. United Nations Education, Scientific and Cultural Organisation, Paris.

UNIFEM (2013). *Women, Poverty & Economics.* United Nations Development Fund for Women http://www.unifem.org/gender_issues/women_poverty_economics (accessed on 11 March 2013).

UN (2010). *The World's Women 2010: Trends and Statistics.* Department of Economic and Social Affairs, New York.

UN (2012). *The Millennium Development Goals Report 2012.* United Nations, New York.

USAID (2012). *Gender Equality and Female Empowerment Policy.* United States Agency for International Development, Washington DC.

Wangnerud L. (2009). Women in Parliaments: Descriptive and Substantive Representation, in *Annual Review of Political Science* **12**.

Waring M. (2010). *Women's Political Participation.* UK Department for International Development and International Development Research Centre.

WEDO (2008). *Getting the Balance Right in National Parliaments.* Women's Environment and Development Organization, New York.

World Bank (2012). *World Development Report 2012: Gender Equity and Development.* The World Bank, Washington DC.

World Bank (2013). *Education.* The World Bank http://data.worldbank.org/topic/education (accessed on 27 February 2013).

Chapter 8.3

Governance | Infrastructure

Laos.
Image: Bart Verweij, World Bank.

Summary of infrastructure indicators

Indicator	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Gross capital formation 1980- 2011 (% GDP)	**23 - 25**	19 - 20	25 - 26	21 - 35	30 - 29	21 - 14	23 - 25	20 - 21	21 - 20	**23 - 22**	**23 - 22**
Access to improved water source 1990-2010 (% of population)	**67 - 81**	45 - 60	54 - 59	70 - 91	70 - 88	79 - 85	83 - 94	87 - 95	66 - 63	**82 - 93**	**76 - 88**
Access to improved sanitation1990-2010 (% of population)	**35 - 50**	23 - 28	21 - 29	21 - 37	42 - 68	66 - 67	64 - 82	66 - 78	64 - 62	**57 - 73**	**49 - 63**

Infrastructure is the basic physical and organisational structures needed for a society and economy to function. It includes transport services (road, rail, air and port), water supply, sewers, energy networks and telecommunications, and can be funded from both public and private sources. Improvements in infrastructure can improve productivity, income and health.

The development and maintenance of infrastructure is considered essential for economic growth. Functionally it facilitates the production and distribution of goods and services and the provision of basic social services such as schools and hospitals. From a strategic perspective, spending on infrastructure represents an investment in a nation's future capacity.

Infrastructure that provides clean drinking water and effective sanitation is essential to the well-being of communities and nations. In many nations rapid population growth and urbanisation combined with budget constraints have often placed limitations on water and sanitation infrastructure.

Indicators

Gross capital formation - This indicator monitors the proportion of current economic activity that is being invested for longer term economic and social returns. It includes private and public outlays on additions to fixed assets plus changes in the level of inventories (physical stock).

Improved water source - Access to social infrastructure such as an improved water source can have significant impacts on a community, particularly with respect to health outcomes. Clean and safe water is considered the single most important determinate of public health. Improved water sources dramatically improve water quality.

Improved sanitation facilities - Sanitation refers to the provision of facilities and services for the safe disposal of human wastes, including through services such as garbage collection and wastewater disposal. Sanitation promotes health through prevention of human contact with the hazards of wastes. Inadequate sanitation is a major cause of disease. Improving sanitation is known to have a significant and beneficial impact on household and community health.

Capital formation

Is it getting better?

Gross capital formation – Worldwide, the rate of gross capital formation has been declining at an average of 0.1% of GDP per annum. Conversely, the Tropics have shown an upward trend in gross capital formation, growing on average by 0.5% of GDP per annum. The performance of the Tropics varied substantially with some regions displaying higher growth and variability than others. Maintenance and appropriate utilisation of capital will be vital for sustaining economic growth and improving wellbeing into the future. Nations with more effective institutions, secure property rights and non-corrupt governments tend to invest more in physical and human capital, to use these factors more efficiently, and to have higher income.

Access to improved water – Although the gap has narrowed, less people have access to safe drinking water in the Tropics than in the Rest of the World. In 2010 around 88% of the global population had access to drinking water from an improved source, an increase of 2 billion people since 1990. In the Tropics the proportion of the population with access to safe drinking water increased from 67% to 81% between 1990 and 2010.

Access to improved sanitation – Sanitation is a major issue in many tropical nations, especially those with rising populations and increased urbanisation. Globally, sanitation coverage increased from 48% of the population in 1990 to 63% in 2010, and the number of people with access to improved sanitation facilities increased from 2.5 billion to 4.3 billion. In the Rest of the World the served population increased by 1 billion in the 20 years since 1990, reaching 2.8 billion in 2010. In contrast, the number of people with access to improved sanitation facilities in the Tropics increased from 0.7 billion to 1.4 billion.

Kenya. Image: Doreen Mbalo, Sustainable Sanitation Alliance.

Nations and regions in the world develop in different ways and at different rates. Economic growth is occurring in some regions of the Tropics at a rapid rate. Indonesia and Brazil now have a higher life expectancy than members of the British nobility did at the beginning of the 20th Century (Weil 2009). What contributes to economic and social growth, and why does it vary between nations and regions?

A key way to evaluate a nation or region's economic growth prospects is to measure investment in the tools and infrastructure that facilitate economic and productivity growth.

In this case, capital refers to physical, not financial capital. Nonetheless, access to finance – and debt finance – will be critical for many infrastructure projects to proceed. Gross capital formation tells us about how nations are investing in physical assets. It includes private and public outlays on additions to fixed assets plus changes in the level of inventories (physical stock) (see Box 8.3.1). Fixed assets include land improvements; plant, machinery and equipment purchases; and the construction of roads, railways, schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Capital does not include non-reproducible assets such as natural forests, land, and mineral deposits.

Essentially, this indicator reports how much economic activity is invested rather than consumed, and does not take into consideration the extent of past investment in physical capital assets (that is, the existing stock of physical capital).

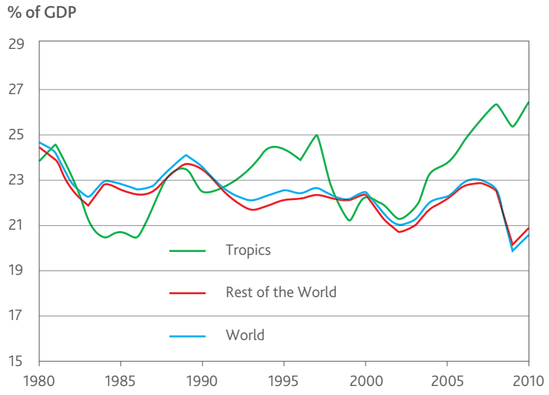
Fluctuations in gross capital formation are an indicator of future business activity, business confidence and the pattern of economic growth. In times of economic uncertainty or recession, business and government investment in fixed assets (new buildings, machinery etc.) is often delayed or reduced as it ties up additional capital for a long interval of time, with a risk that it will not pay itself off (and fixed assets may be also be scrapped faster). Conversely, in times of robust

economic growth, fixed investment tends to increase, as it is more likely an investment will be profitable.

Understanding how tropical countries have invested in their past and how they are investing in their future will help us determine future social and economic capacity in the Tropics. Capital accumulation (among other economic variables) is significantly influenced by distance from the equator (Ram 1997). Underinvestment could result in long term environmental, social and economic consequences. Additionally, capital formation as a single indicator should be combined with some measure of effectiveness to truly understand the impact of infrastructure investment on economic growth.

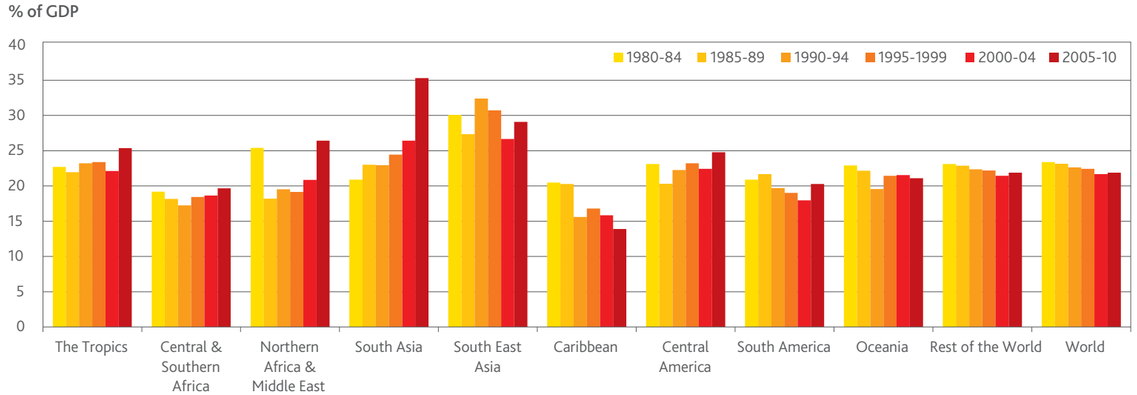
Most human activities rely on some past capital investment, whether it is the homes that people live in, the roads or airports they use, their place of work or the buildings and other infrastructure used by governments to deliver services.

Figure 8.3.1 **Capital formation**



Source: World Bank (2013), State of the Tropics project.

Figure 8.3.2 **Capital formation – the Tropics**



Source: World Bank (2013), State of the Tropics project.

Trends

Gross capital formation

Worldwide the proportion of GDP which is accounted for as gross capital formation tends to be between 20% and 24%. In 2011 the figure was at the lower end of the range, with 20.7% of global GDP invested in capital formation, somewhat below the 30 year average of 22.5% (see Figure 8.3.1). The private sector typically accounts for around two-thirds of this capital investment, with the remainder sourced from the public sector (Everhart & Sumlinski 2001). As a percentage of GDP, capital formation in the Tropics has shown a strong upward trend over the past 30 years, driven by increases in South East Asia and, more recently, South Asia. In the Rest of the World there has been a slight downward trend over the past 30 years.

Capital formation as a proportion of GDP has varied substantially across and within the regions of the Tropics over the past 30 years (see Figure 8.3.2). There was also substantial variation temporally – often over very short timeframes – reflecting prevailing economic and political conditions in regions. From a modest base of 22% of GDP in 1981-85, South Asia reported the greatest increase in capital formation in the Tropics, increasing by 14 percentage points to 36% in 2006-10.

Even though it was coming from a high base, South East Asia reported strong growth in capital formation's proportion of GDP in the early to mid-1990s. This was followed by a marked downturn in the late 1990s as the Asian Financial Crisis spread across the region. Capital formation as a proportion of GDP in South East Asia has only recently returned to its longer term average rate of around 30% (this is well above the global longer term average of 22.5%). South Asia experienced a period of rapid growth in capital formation as a proportion of GDP in the first decade of the 21st century supported by strong investment in the services sector in India (see Box 8.3.3). In Northern Africa & Middle East the proportion can be volatile and is affected by the scale of investment for large resource sector projects. At the other end of the investment scale, there has been a significant and sustained decline in gross capital formation as a proportion of GDP in the Caribbean since the 1980s. Other regions have shown year to year variability, but have displayed more modest trends.

Overall though, in the past 30 years the difference between regions in the Tropics has increased, affected by different policies and economic growth trajectories.

Barelang Bridge, Indonesia. Image: Soham Banerjee.

Box 8.3.1 Measures of capital formation

Capital formation is the addition to a nation's capital stock, and is often referred to as investment. Common measures of investment are gross fixed investment and gross fixed capital formation. These measures capture additions to the capital stock, and do not take into account depreciation in the value of the existing capital stock. Investment is undertaken by both the private and public sectors, and is called capital formation to distinguish it from financial investment.

Definitions of the common measures are:

Gross fixed capital formation: includes land improvements; plant, machinery, and equipment purchases; and the construction of roads, railways, schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.

Gross capital formation: consists of outlays on gross fixed capital formation plus net changes in the level of inventories.

Drivers of investment in capital formation

Strong investment in capital formation tends to demonstrate confidence in medium to longer term economic and political conditions. Available data report that although capital formation as a proportion of GDP has been rising in the Tropics, it is highly variable within and across regions.

Many factors affect gross capital formation in the Tropics, including the price of primary commodity exports, private external financing, foreign debt, and local governance arrangements, all of which impact a nation's or region's ability to invest in or secure external capital (Greene & Villanueva 1991). Outside of the financial sector, foreign aid, civil unrest and extreme weather events and disasters will also contribute to the ability of a country to invest in the future.

Gross capital formation has an important role in sustaining GDP, and is considered to be more important for economies in earlier stages of development (Madsen 2002). Large scale investments in nation building infrastructure such as airports are important drivers of capital formation (See Box 8.3.4)

Private fixed capital formation

Private investment plays a very important role in gross capital formation – particularly in developing nations (Madsen 2002) – and is the largest and most variable component of gross capital formation. Private sector investment is driven by commercial principles, and is considered to be more efficient and productive than public sector investment, and therefore more likely to underpin and sustain economic growth. Research has demonstrated that private investment plays a larger and more important role in economic growth than public investment (Tanzi & Davoodi 1997), notwithstanding that development encompasses more than economic growth.

Box 8.3.2 Globalisation of capital

Globalisation refers to the growing integration of national economies and societies, so that no society is isolated or remote from changes and developments in other societies (Dossani & Kenney 2007).

There have been huge increases in the value of cross-border capital transfers (mostly financial) in recent times, including the expansion of foreign direct investment by trans-national companies. The International Monetary Fund reports that, worldwide, the stock of foreign direct investments has increased from 8% of GDP in 1989 to 22% in 2003 (Patterson et al. 2004). There have also been global shifts in production and consumption, notably the rapid shift of production activities from developed to developing nations over the past few decades. This may well account for the Tropics maintaining or increasing capital formation.

A key advantage of globalisation for developing economies is that it encourages foreign investment, but it also creates global scale risks that are beyond a nation's control, but which can have major impacts on economic performance and stability (e.g. the Global Financial Crisis). Unless open markets are combined with secure property rights and stable government, increased economic connectivity with the Rest of the World may have negative economic impacts (Milanovic 2003).

Hong Kong. Image: Steve Wedel.

The available data for private sector capital formation are insufficient to make regional comparisons within the Tropics or between the Tropics and the Rest of the World. However, based on the available data (representing 40% GDP in the Tropics), private investment in fixed assets in the Tropics ranged from 13-19% of GDP. This is consistent with research which suggests that, globally, private sector investment in fixed capital is the major component of capital formation (Reinhart & Khan 1989).

Private investment in capital is influenced by a number of factors. High domestic inflation and external debt appear to have a negative impact on private investment rates while solid rates of productivity, economic growth and public investment have a positive relationship with private capital formation (Madsen 2002).

Although private investment is considered the most important component of capital formation, there is clear evidence that public and private investments are complementary (Fisher & Turnovsky 1998). Public sector investment provides necessary 'enabling' infrastructure (roads, electricity, schools) which have a strong influence on the productivity of private sector capital formation. Similarly, research from OECD nations reports a positive relationship between public capital formation and growth in labour productivity (Nourzad & Vreize 1995). The long term economic benefits of investment in public infrastructure have particular relevance for tropical nations, and particularly for developing nations which tend to have an infrastructure deficit, where under-investment by the public sector can constrain both economic and social development. Public capital formation is often reduced in times of financial stress to ease debt burdens. Given tropical nations generally have high debt burdens, there is the risk that a lack of investment in public infrastructure may constrain private sector investment, and subsequent economic growth prospects.

Infrastructure effectiveness

Increased capital investment does not always lead to stronger economic growth. Despite rising capital formation in many tropical nations there have also been high rates of depreciation on the capital stock as a result of poor maintenance, unnecessary discard and underutilisation (Bu 2006). These are major issues as they limit the effectiveness of capital investment to promote long term growth.

The 1994 World Development Report focused on infrastructure for development and raised a number of issues around appropriate investments in infrastructure, monitoring and maintenance (World Bank 1994). It estimated that maintenance expenditures of US $12 billion, invested at the right time, would have saved road reconstruction costs of US $45 billion in Africa in the decade to 1994, and that poor maintenance of power and water supply systems that is inherent in many tropical nations reduces service quality and increases costs for users, and hence undervalues the initial investment.

Inefficient use of infrastructure can be responsible for more than 25% of the difference in economic growth rates between some economies. Coupled with lower rates of investment than in other tropical regions poor maintenance of capital stocks has been a major factor in relatively slow rates of social and economic development in sub-Saharan Africa compared with South East Asia (Hulten 1996).

Another reason why capital investment does not lead to stronger rates of economic growth in some tropical nations may be corruption. Research suggests that widespread corruption is associated with high public investment in infrastructure projects, but lower spending on maintenance and operation (Tanzi & Davoodi 1997). This suggests that public investment and aid programs focused on delivering new infrastructure – without considering the funding needed for ongoing maintenance – may have a limited impact on longer term economic growth. Additionally, investing in quality governance systems and strengthening the role and independence of institutions which monitor and maintain capital investments will facilitate returns to investments in public sector infrastructure programs.

The geography and climate of the Tropics affects the contribution of capital to economic growth, as roads, bridges, harbours and electricity networks as well as houses and other buildings are particularly vulnerable to extreme events such as tropical cyclones (Wilbanks et al. 2007).

Weather and climate can affect infrastructure in other ways. The rate of deterioration of the external shells of building structures is often weather-related, depending on how they are constructed (Wilbanks et al. 2007). The Tropics is also characterised by diverse weather conditions; constantly warm temperatures, high humidity, extreme rainfall and high levels of evaporation (Galvin 2007), all of which potentially contribute to faster deterioration of capital assets than in temperate regions. The onset of climate change is likely to exacerbate these conditions and lead to even faster depreciation of the value of capital assets.

[13] The Asian Financial Crisis began in July 1997 when the government of Thailand was forced to float the Thai baht due to lack of foreign currency to support its fixed exchange rate. This was followed by the devaluation of currencies throughout the region and subsequent economic downturn (Richardson 1998).

Box 8.3.3 Capital formation in India

Increased capital formation in India during the past two decades is part of a strategic development program to create and maintain high rates of economic growth (Acharya 2007). In the decade to 2010 India averaged real GDP growth of 7.4% per annum, compared with 3.3% worldwide and 4.1% across the Tropics. During this time India increased its gross capital formation as a proportion of GDP from 24% to 36% (see Figure 8.3.3).

In 2006 India was the most successful developing economy with respect to attracting private infrastructure investment, accounting for 15% of the total private investment in developing countries (Harris 2008). Despite this massive investment, India is still facing an infrastructure deficit if it maintains its current growth trajectory.

The services sector – The service (or tertiary) sector is the part of an economy which includes all economic activities not covered by the agricultural, mining or manufacturing sectors. It includes activities associated with the supply of water, electricity and gas, transport and communications, wholesale and retail trade, finance and insurance, business and personal services, and community and social services. The services sector is where Indian investment and growth has been centered in the past two decades.

To maintain strong rates of economic growth though, more investment will be needed. Telecommunications has accounted for 64% of investment in infrastructure from 2001-06. In 2008, more than 2 million people had access to phone services, compared with only 35,000 in 2002. Transport infrastructure is an important component of investment totaling 34% in 2006. However, investment in energy and water has been falling (<17%) and this is where the lag is considered to be. Very few cities in South Asia have continuous access to water and power which is a major constraint to future development.

The contribution of various programs and investments to India's growth is debated, though it is clear there is some relationship between increased capital investment (particularly in the services sector) and recent solid economic growth.

For India to sustain high levels of growth the private sector will need to invest in water and power, and broaden its trade beyond the current emphasis on services into a wider variety of goods, production and trade (Harris 2008).

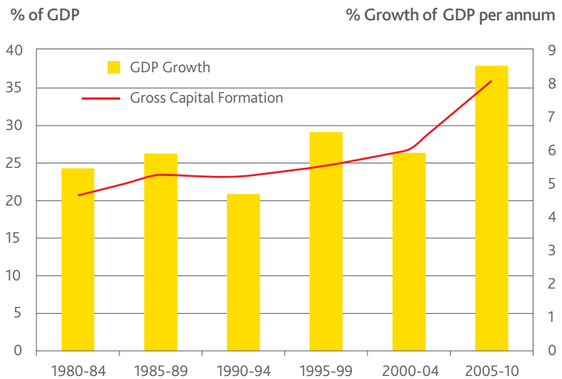
In the past, the Indian government has financed most of India's infrastructure development, however it does not have the financial resources to meet the growing nation's needs. In 2013, the Indian government set a target of attracting $500 billion in private infrastructure spending in the next five years (PwC 2013). The government is encouraging investment in infrastructure through further liberalising foreign investment, extending tax holiday periods and developing public private partnerships

Looking forward

Ongoing investment and maintenance of capital stocks is critical for the social and economic development of all nations. However, to optimise the return on investment, timing is critical (to ensure capital utilisation rates are sufficient to warrant the investment) and there is a clear need to budget for ongoing maintenance to maximise the asset life. Evidence suggests that nations with strong institutions and governance, and secure property rights invest more in physical and human capital, and subsequently use these factors more efficiently to achieve higher levels of income (Alfaro et al. 2003).

To ensure that scarce (especially public) capital is invested in projects that deliver the greatest benefits to society it will be critical that broader outcome-based measures of effectiveness are developed to assist policy makers and financiers assess economic, social and environmental outcomes.

Figure 8.3.3 **Gross capital formation and economic growth in India**



Source: World Bank (2013), State of the Tropics project.

Box 8.3.4 The air transport industry in the Tropics.

Airports are among the most important infrastructural elements of modern cities and nations. The air transport industry plays a vital role in connecting nations and contributing to trade and economic growth, especially in industries which rely on rapid transit times such as tourism, logistics and high-tech manufacturing.

In the Tropics the number of airline passengers (an indicator of investment and growth in this industry) grew from 183 million to more than 400 million in the decade to 2010 (ICAO 2013). Despite this rapid growth, only 13% of air travellers worldwide were carried on airlines based in the Tropics. The vast majority of air travel still occurs on North American and European airlines.

Nonetheless tropical airport hubs are playing an increasingly important role in global air transport, particularly those in South East Asia. In 2010, Hong Kong's Chek Lap Kok International Airport became the world's biggest cargo hub, exceeding Memphis (USA).

Air travel and the number of major airports have been growing quickly in the Tropics in the past 15 years, particularly in South East Asia. South East Asia now has four major hub airports at Hong Kong, Kuala Lumpur, Bangkok and Singapore, which have invested in major expansions to allow increased air traffic and provide access to more destinations throughout Asia, Europe and North America (Homsombat et al. 2011). The number of passengers carried in South East Asia has more than doubled since the turn of the century, from 94 million to more than 200 million (ICAO 2013).

Hong Kong Airport.

External to the financial system, the impacts of climate change are likely to increase the vulnerability of tropical assets and infrastructure to damage or destruction. As many tropical nations are at earlier stages of development than those in the Rest of the World, they have the opportunity to invest now in climate resilient and sustainable infrastructure and other capital.

Capital investment is not the only driver of economic growth: education, rising equality, science and technology, foreign investment and the global economy also have important roles in shaping development. Nonetheless, growing the stock of public and private sector assets in tropical nations will be vital to ongoing economic growth and social development into the future.

Access to improved water sources

Water is essential to all life on Earth. At a base level human existence depends on access to ample clean water while, at the societal and individual levels, access to reliable and affordable water is integral to a healthy and productive life. The consumption of water containing pathogenic organisms or toxic chemicals, and not having enough water for hygiene, are the principal impacts on human health. Water is also essential to the health and vitality of natural ecosystems, and the ecosystem services they provide to society (UNDP 2006) (See Chapter 3).

Two billion additional people gained access to drinking water from an improved source between 1990 and 2010, yet there are still almost 800 million people without access to this basic requirement. Almost all of these people live in developing nations, and the majority in rural areas (UN 2012). The most serious consequence of not having access to safe drinking water is the increased likelihood of sickness and death from preventable water-related diseases, particularly in young children. This can have significant social, cultural and economic costs (Gleick et al. 2001).

Water quality can be affected by a range of factors, including pollution from domestic and industrial sources, poor sanitation and hygiene, inadequate infrastructure and geogenic contamination of groundwater[14] (UNICEF-WHO JMP 2011). In many developing nations rapid population growth and urbanisation combined with budget constraints have often placed a strain on water infrastructure, and contributed to water related diseases which are amongst the most common causes of illness and death.

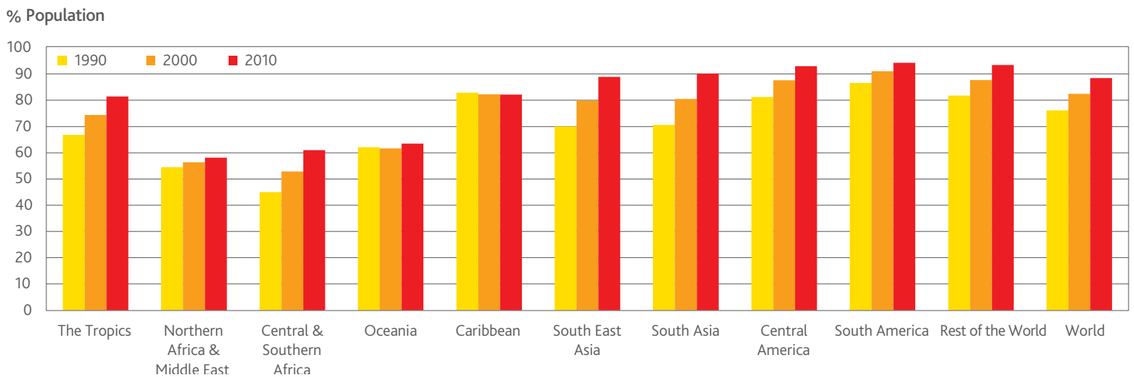
Trends

Comprehensive statistics on safe drinking water are generally unavailable as it is complicated to measure and definitions vary. Nonetheless, the Joint Monitoring Program (JMP) of the United Nations Children's Fund and World Health Organization have developed the proxy indicator 'use of an improved drinking water source' as a measure of access to safe water (see Box 8.3.5). This measure has a tendency to overestimate the number of people with access to safe drinking water, but provides a reasonable measure for comparative purposes.

In 2010 around 6 billion people, or 88% of the global population, used an improved drinking water source, an increase of 2 billion people since 1990 when it was 76%. In the Tropics the proportion of the population which used an improved drinking water source increased from 67% to 81%, while in the Rest of the World it increased from 82% to 93%, meaning the gap between the two regions narrowed by three percentage points.

Half of the additional 2 billion people that gained access to an improved drinking water source live in the Tropics, with the number increasing from 1.3 to 2.3 billion people in the 20 years to 2010.

Figure 8.3.4 **Use of an improved drinking water source**



Source: UNICEF-WHO JMP (2013), State of the Tropics project.

In the Rest of the World the number of people increased from 2.7 billion to 3.7 billion.

In the Tropics, in three of the eight regions, more than 90% of the population had use of an improved drinking water source in 2010, namely South America (93%), Central America (93%) and South Asia (90%) (see Figure 8.3.4). A further two regions had rates higher than 80% – South East Asia (89%) and Caribbean (82%). In contrast, coverage is low in Northern Africa & Middle East (58%), Central & Southern Africa (61%) and Oceania (63%).

In terms of improvements over time, the smallest gain was made in Oceania where the proportion of the population using an improved drinking water source increased by one percentage point (to 63%) in the 20 years to 2010. Nonetheless, this translated to an additional 3 million people using an improved drinking water source. The result in Oceania is driven by Papua New Guinea (PNG), where the large population in rural, remote and often inaccessible areas can make infrastructure development costly and problematic (WaterAid 2013). A general lack of access to clean water and sanitation may be some of the key reasons behind PNG's high infant and child morbidity and mortality rates (ADB 2012). If PNG is removed from the analysis, coverage in Oceania increases to 91% in 1990 and to 95% in 2010.

South Asia and South East Asia stand out for significant improvements in the proportion of the population that uses drinking water from an improved source, which increased by 19 percentage points in both regions in the 20 years to 2010, to 90% and 89% respectively (see Figure 8.3.4). Other regions to report solid improvements include Central & Southern Africa where it increased from 45% to 61%. Although starting from a relatively low base, improvements in Northern Africa & the Middle East have been modest, and this reflects a number of factors, including political instability, high population growth in urban and slum areas and the low priority given to improving water services in budget allocations. In addition, the costs to supply water in this region are relatively high, due in part also to the difficulty of regulating prices charged by private small-scale providers of water (UNEP 2010).

In South America and Central America, where coverage was already high in 1990, gains have been more modest, at 8.1 percentage points and 10.8 percentage points respectively.

Rural/urban disparities

The United Nations Millennium Development Goal to halve the proportion of the global population without sustainable access to safe drinking water was achieved five years ahead of schedule (UN 2012). As encouraging as this is, a large proportion of the global population still does not have access to safe drinking water and challenges to improving access remain, especially in rural areas where rates tend to be markedly lower than in urban areas and in urban areas of developing nations which are experiencing rapid population growth.

Globally it is estimated that around 96% of the urban population had access to safe drinking water in 2010, compared with 80% in rural regions (see Figure 8.3.5). Although significant, this gap has narrowed by 17 percentage points since 1990. To some extent this has been influenced by slower population growth in rural areas, rather than infrastructure improvements. Nonetheless, the urban/ rural distribution of people that gained access to drinking water from an improved source between 1990 and 2010 was relatively equal, with an additional 1.2 billion people in urban areas, and 1.1 billion in rural areas. However, almost 85% of the 780 million people estimated to not have access to an improved water source lived in rural areas in 2010 (WHO 2012a).

In the Tropics 89% of the urban population used an improved drinking water source in 2010, compared to 73% in rural areas (see Figure 8.3.5). In Northern Africa & the Middle East and Central & Southern Africa the gap between urban and rural areas is more than 30 percentage points, and in Oceania it is 49 percentage points. In each of these regions less than 50% of the rural population use drinking water from an improved source.

Rural areas have lower population densities which are often widely dispersed, and economic activity tends to be lower compared with urban areas. This can make the delivery of safe drinking water more expensive on a per capita basis, and contributes to relatively low access rates in rural areas. The fragmented nature of political representation for people living in rural areas (even where the majority of the population may live in rural areas) can also mean that securing financial commitments to provide safe drinking water are difficult. The distribution of international aid also appears to be a factor, with the proportion of water and sanitation aid going to rural areas falling from 27% in 2003 to 16% in 2008 (UNICEF-WHO JMP 2011).

In urban areas the major issue has not been changes in access rates, but changes in the absolute number of people with access. In 1990 the global urban access rate was already high at 95%, and has since increased to 96%. With rapid urbanisation however, this translates to an additional 1.2 billion urban dwellers using drinking water from an improved source. At the same time, the urban population without access to safe drinking water has increased from 107 million to 137 million due to large numbers of people living in informal settlements or slums.

[14] Geogenic contaminants refer to naturally occurring elevated concentrations of certain elements in groundwater which have a negative health effect on humans consuming this water. Arsenic and fluoride are the most widespread geogenic contaminants in groundwater worldwide.

Effects of poor water quality on health

Safe water for drinking and other purposes is vital for the good health and well-being of humans and ecosystems. Approximately 3.5 million deaths related to inadequate water supply, sanitation and hygiene occur each year, predominantly in developing nations (UNESCO 2012). In addition to having sufficient quantities, water quality is also a concern, as any microbial or chemical contamination can have significant health, environmental, social or economic impacts. Relative to having access to adequate quantities of water, water quality has received far less public attention and investment in recent decades (UNESCO 2012).

Significant progress has been made with respect to access to safe drinking water globally, but recent research suggests that JMP's definition of an improved water source (and therefore 'safe' water) is not sufficient to ensure that water is at low risk or free of contaminants. In addition to the 780 million people relying on water from unimproved sources in 2010, it is estimated that 1 billion people accessing water from improved sources could also be facing significant sanitary risks (Onda et al. 2012).

Water-related pathogens can be transmitted to humans by ingestion, skin contact or through vectors (see Box 8.3.6). At the household level it is the transmission of waterborne and water-washed disease that is most closely related to poor water supply or quality (WHO 2012b). While water-related diseases have largely been eliminated in developed nations, they remain a major risk in much of the developing world.

Poor water quality can increase the risk of diarrhoea, which kills around 1.5 million children under the age of five every year (UNESCO 2012). Cholera, an acute diarrhoeal disease, is a significant public health issue in many regions, and globally the number of reported cases increased by 130% between 2000 and 2010, although this was driven by a significant outbreak in Haiti following the 2010 earthquake

Box 8.3.5 UNICEF-WHO JMP measures of improved drinking water source

The JMP method assesses the final source of water prior to use as an indicator of whether it is safe or unsafe. If water is sourced from an improved source it is deemed to be 'safe', while water from unimproved facilities is deemed to be 'unsafe'. According to the JMP, an improved drinking-water source is one that, by the nature of its construction, adequately protects the source from outside contamination, particularly faecal matter.

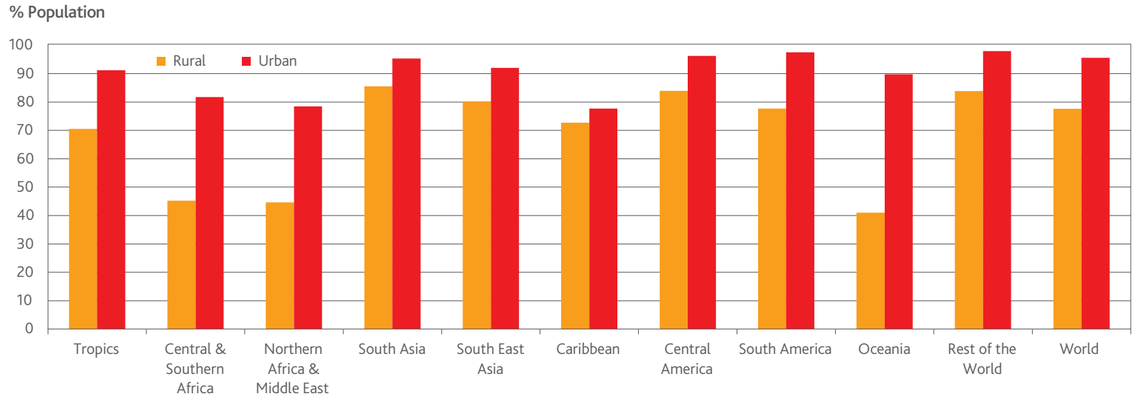
Improved drinking water sources include piped household connections inside the user's dwelling or plot, public taps and standpipes, borehole and tube wells, protected springs and dug wells and rainwater collected and stored in containers. Piped water on premises is considered the optimal service level as this water tends to be treated, and provides the most convenient supply.

Unimproved drinking water sources include unprotected dug wells and springs, surface water (river, dam, lake, pond, stream, canal, irrigation channel) and vendor-provided water (carts and tanker trucks).

The JMP methodology is useful in estimating the number of people that have access to safe drinking water, but it does not consider important parameters – other than the water source itself – that will influence how safe or accessible water is. For example, the JMP methodology does not assess water quality or the availability of adequate quantities of water. Another important aspect is accessibility, as the distance to a water source or the travel time spent to access the source may inhibit the actual volume of water that is available for use (UNICEF-WHO JMP 2012).

Safe, clean water in Benin. Arne Hoel, World Bank.

Figure 8.3.5 Access to improved water in urban and rural areas in 2010



Source: UNICEF-WHO JMP (2013), State of the Tropics project.

(UNESCO 2012). Nations with a high incidence of peri-urban slums, refugee camps and exposure to humanitarian crises tend to be at greater risk of cholera outbreaks. Typhoid, which is transmitted through polluted water, remains a serious public health problem in South Asia, South East Asia, Africa and South America (Crump & Mintz 2010), and globally there were an estimated 13.5 million cases in 2010 (Buckle et al. 2012).

Arsenic and fluoride occur naturally in groundwater, sometimes at concentrations dangerous for humans. As groundwater use increases so too does the potential for large scale public health impacts. Although the number of fatalities is smaller than for waterborne pathogens, a significant number of people are at risk. For example, around 130 million people are at risk of consuming groundwater with arsenic concentrations above global standards (UNICEF-WHO JMP 2011). Long term exposure to arsenic in drinking water can cause skin lesions and lead to cancer. Fluorosis is a widespread public health problem and high fluoride concentrations in groundwater have been reported in Asia, South America, the Middle East and Northern Africa. Fluoride poisoning, in its severest form, causes skeletal damage to bones and joints (Godfrey et al. 2010).

The presence of piped water infrastructure – which is often used as an indicator of improved water supply – does not guarantee that water is fit for human consumption. Population growth, inadequate and aging infrastructure and climate change impacts can influence the quality and availability of safe water. Processing systems often operate intermittently or at a fraction of their capacity due to poorly maintained pipes, illegal connections and deliberate reduction of water pressure in pipelines to conserve water. This can lead to stagnant water and micro-organism growth (Lee & Schwab 2005). Water utilities in most regions across the Tropics report less than 24 hours of service a day (Latin America and the Caribbean – 22 hours per day, South East Asia – 20 hours per day, and South Asia – 11 hours per day). Continuity of urban water services is most variable in sub-Saharan Africa, and can be as low as six hours per day, while in South Asia daily average service continuity is less than 10 hours per day (UNICEF-WHO JMP 2011).

Gender disparities

Access to drinking water also has a gender dimension, as in almost three-quarters of households without on-premises access, women and girls have the primary responsibility for collecting water (UNICEF-WHO JMP 2011). It is estimated that girls and women in developing nations spend 40 billion hours every year hauling water, spending as much as eight hours a day, and carrying up to 40kg of water (Cap-Net & GWA 2006).

In the Tropics this problem is more pronounced in sub-Saharan Africa, where water collection times of more than 30 minutes per trip are common, particularly in rural areas (UNICEF-WHO JMP 2011). The long term consequences of this burden can be quite significant, as it can inhibit involvement in education and opportunities to engage in productive work and income generation, as well as social and political activities.

If the time needed to collect water is considered in assessing whether a source is improved, access is significantly lower than is currently reported. In sub-Saharan Africa for example, if 30 minutes is used as the cut-off, coverage drops by eight percentage points (UNICEF-WHO JMP 2011). Research also indicates that if the round trip to collect water is more than 30 minutes, households tend to collect less water, increasing the risk that minimum daily requirements for drinking and good hygiene practices will not be met (UNICEF-WHO JMP 2011). Close contact with water also means that people collecting water are more susceptible to waterborne diseases (Cap-Net & GWA 2006).

Looking forward

By 2015 it is estimated that 92% of the world's population will have access to safe drinking water. This is extremely positive but it still means that more than 600 million people from the world's poorest nations will still not have access safe and clean water (WHO 2012a).

Median government expenditure for sanitation and drinking water is just one third of that for health and one sixth for education (WHO 2012a). In many nations it seems policies and programs place far too little emphasis on ensuring adequate financial and human resources to maintain and expand access to improved water sources.

A focus on some of the more basic interventions such as household level water treatment and safe storage can provide widespread health benefits at a relatively low cost. Point of use technologies such as the treatment of water with disinfectants or chlorine just prior to consumption, are an example of household treatments used in areas where centralised systems have been ineffective (Montgomery & Elimelech 2007).

Looking forward, the provision of safe drinking water for rapidly expanding urban, peri-urban and slum populations will be a major consideration for planners in tropical nations.

Box 8.3.6 Water-related disease

Water has a profound effect on human health, both as a means to reduce disease and as a medium through which disease-causing agents may be transmitted. Water-related diseases are frequently linked to poor sanitation, low hygiene standards and low volumes of water quantity. Transmission routes are classified into four major categories: water-borne, water-washed, water-based and water-related vectors. The first three are associated with lack of access to an improved domestic water supply.

Water-bourne diseases are contracted by the ingestion of drinking water contaminated by human and animal waste containing pathogenic bacteria or viruses. The most common are cholera, typhoid, amoebic and bacillary dysentery and other diarrhoeal diseases. These illnesses are particularly prevalent in areas lacking adequate sanitation facilities.

Water can also transmit toxic chemicals which have been linked to cancer and organ failure. These toxic substances may be naturally sourced (such as arsenic and fluoride) or sourced from human activities (for example, pesticides). Compared to the global importance of waterborne disease, toxic substance risks and impacts tend to be quite regionalised.

Water-washed diseases occur when there is insufficient clean water for washing and personal hygiene or when there is skin or eye contact with contaminated water sources – most often faecal contaminants. Diarrhoeal diseases and trachoma (an eye infection) are the more common diseases in this group.

Neglected tropical diseases such as schistosomiasis (a parasitic worm carried by freshwater snails) and dracunculiasis (guinea worm) are spread by organisms that develop in water and then become human parasites either through skin contact or ingestion of drinking water.

Water-related vector diseases are not typically associated with water supply or quality. The spread of these diseases is facilitated by insects – notably mosquitos – that breed or feed near water. In many instances the large-scale development of water systems has created favourable conditions for these vectors. Malaria and dengue fever are two of the more well-known vector borne diseases that are especially prevalent in the Tropics (UNICEF-WHO JMP 2012).

Washbasins in India.
Image: Antony Robbins, Overseas Development Institute

Access to improved sanitation

Universal access to basic utilities such as water and sanitation is enshrined in international human rights instruments (UN Millennium Project 2005). History demonstrates that poor sanitation is one of the most significant contributors to the world's morbidity and mortality, and that improved sanitation provides considerable social, economic and environmental benefits.

Globally the provision of sanitation has been a key development goal since the 1970s, but progress toward universal coverage has been slow. Although an estimated 1.8 billion people worldwide gained access to improved sanitation facilities between 1990 and 2010, some 2.5 billion people (40% of the global population) do not have access to adequate sanitation, with many more lacking access to good quality sanitation.

A lack of infrastructure and poor maintenance of existing infrastructure are at the centre of the sanitation problem. Funding shortages, geographical and technological constraints and a lack of incentives for commercial involvement mean that many governments and communities are unable to support the installation and maintenance of the necessary infrastructure (UNDP 2006). Sanitation is often given a low priority in government and donor budgets, and it is often those that are most in need of improved sanitation that are the least empowered to improve their circumstances or to afford such services. A health system focus on treating rather than preventing diseases has also been identified as a factor that can contribute to a lack of sanitation coverage (WaterAid 2011).

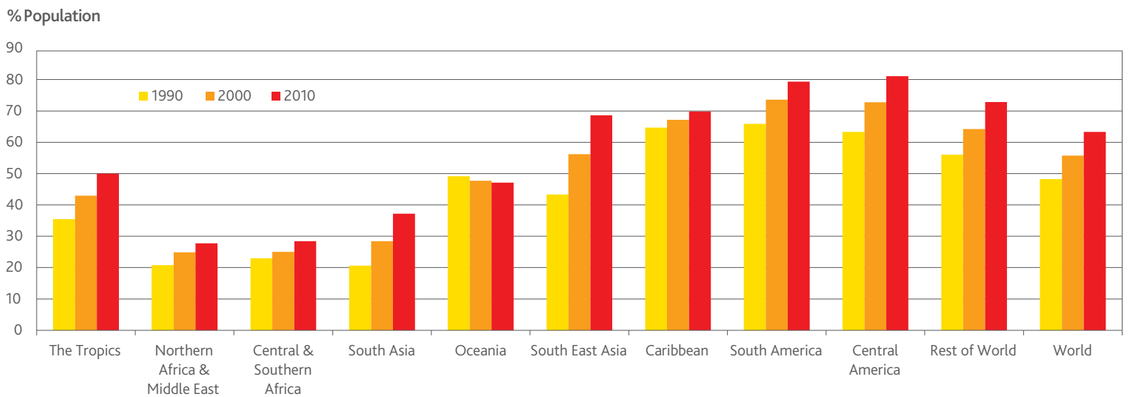
Poor sanitation can have many adverse impacts. Polluted water and living environments can lead to disease, premature death and child mortality. Poor sanitation can also decrease productivity, economic activity and lead to widened gender inequalities (World Bank 2008). These impacts highlight the need for sanitation having a higher priority on the international development agenda.

Trends

Differences in national interpretations of safe sanitation and variations in reporting methods are challenges to global analysis of sanitation standards. The United Nations Children's Fund and the World Health Organisations Joint Monitoring Program (JMP) have developed a proxy indicator – people using improved sanitation facilities – to measure sanitation progress (see Box 8.3.7). The JMP methodology has the potential to overestimate the number of people with access to improved sanitation sources, but it provides a reasonable measure for comparative purposes.

Globally, sanitation coverage increased from 48% in 1990 to 63% in 2010, with the number of people using improved sanitation facilities rising from 2.5 billion to 4.3 billion (see Figure 8.3.6). Sanitation coverage in the Tropics increased from 35% to 50%, while in the Rest of the World it increased 56% to 73%. That is, one-half of the population of the Tropics still

Figure 8.3.6 Improved sanitation source



Source: UNICEF-WHO JMP (2013), State of the Tropics project.

Box 8.3.7 **UNICEF-WHO JMP measures of improved sanitation**

The UNICEF WHO JMP sanitation data set estimates the population with access to improved sanitation technologies such as flush/ pour toilets and hygienic latrines. For the JMP an improved sanitation source is a facility which hygienically separates human excreta from human contact. The facility is required to isolate faeces from the individual and prevent flies and small animals from coming in contact with faeces (FIVAS 2011).

Improved sanitation sources include flush/ pour toilets piped to a sewer system, septic tank, pit latrine, ventilated improved pit latrines, pit latrines with a slab and composting toilets. Other forms of sanitation (including no sanitation) are considered to be 'unimproved'. The JMP also classifies any sanitation facility that is shared or public in nature as being 'unimproved'.

A limitation of the JMP methodology is that it doesn't consider the quality of the improved sanitation source. For example, redefining sewerage-without-treatment as 'unimproved sanitation' is estimated to reduce the JMP-reported proportion of the global population with access to improved sanitation by 11 percentage points in 1990, and by 22 percentage points in 2010 (Baum et al. 2013).

Water treatment plant, Philippines. Image: Danilo Pinzon, World Bank.

does not have access to improved sanitation, compared with one-quarter of the population of the Rest of the World. The gap between the two regions with respect to the proportion of population using improved sanitation facilities has widened slightly since 1990. In the Rest of the World the number of people using improved sanitation increased by 1 billion to 2.8 billion, and in the Tropics there was a 0.7 billion increase to 1.4 billion.

Across the Tropics gains in access to improved sanitation have been variable. In 1990 improved sanitation coverage ranged from 21% in South Asia and Northern Africa & the Middle East to around 65% in the Caribbean, Central America and South America. At around 80%, coverage remains relatively high in Central America and South America, but progress in the Caribbean has been slow, affected by natural disasters, civil unrest and political instability in Haiti. In 2010 Central & Southern Africa and Northern Africa & the Middle East had the lowest proportions for improved sanitation coverage in the Tropics, at less than 30%. Civil unrest, poverty and rapid unplanned urban growth in many nations of these regions have affected the capacity to deliver sanitation infrastructure and solutions (SIWI 2005).

In the Tropics the greatest progress has been in South East Asia where the coverage rate increased from 43% in 1990 to 69% in 2010. This resulted in an additional 280 million people having use of improved sanitation facilities – the largest regional increase in the Tropics – followed by South Asia (an additional 170 million people) and Central & Southern Africa (100 million).

Oceania is the only region of the Tropics where coverage declined, from 49% in 1990 to 47% in 2010. This is driven by Papua New Guinea where, despite there being an additional 0.45 million people that now use improved sanitation facilities, infrastructure investment has not kept pace with population growth (ADB 2012). In Oceania the proportion of the population using improved sanitation declined in four of the 14 nations for which data are available.

Investment, socio-economic and cultural barriers

The means of improving sanitation are seemingly straightforward, but efforts to improve global access are complex and involve a range of financial, technical, political and cultural issues. Common barriers to increased access include inadequate investment in the necessary infrastructure, a lack of political will and a focus on conventional interventions without community involvement. On top of this, many programs do not assess the sustainability and success of interventions as input to future program development (Moe & Rheingans 2006).

Investments in sanitation infrastructure typically involve a long project cycle and high capital and operating costs. Poor economic and budget conditions in many nations with low coverage means that improving sanitation is often a lower order or neglected infrastructure issue, a situation not helped by the difficulty of quantifying the broad range of society-wide benefits that improved sanitation delivers[15]. High costs coupled with funding shortfalls mean that many developing nations rely on international aid to improve sanitation infrastructure.

Governments and international bodies typically combine water and sanitation into the same sector for development and administrative purposes, despite each having unique issues. As a development issue, water has historically received greater international attention and resourcing than sanitation, and this has led to sanitation being viewed as a less important add-on to water supply programs (Harvey 2008). In the decade to 2000, public investment in sanitation globally was just one-quarter that of water (World Bank 2008). In Africa it is estimated that sanitation made up just 12% of the water and sanitation sector investments between 1990 and 2000 (Graham 2011). These funding anomalies are widening, and in 2010 sanitation represented one-fifth of the total water, sanitation and hygiene sector expenditure in 2010 (WHO 2012b). Efforts to improve sanitation coverage have not been helped by the proportional decline in international aid provided for water and sanitation compared with 20 years ago (Graham 2011).

Aside from the reported investment shortfalls in the sector, the allocation of limited financial resources to unsuitable interventions has compounded the challenge of extending improved sanitation services to unserved populations. Traditional sanitation projects focusing on the construction of centralised treatment systems have been somewhat ineffective in their ability to serve rural areas and rapidly growing, unplanned urban areas. Centralised approaches are frequently plagued by high capital costs, lack of proper operation and an overreliance on treatment technologies that are expensive and difficult to maintain (Montgomery & Elimelech 2007). Most people who do not have access to improved sanitation live on less than US$2 per day, making the cost of conventional sanitation systems (US$50-100 per month) not affordable (Rijsberman & Zwane 2012).

A lack of consideration for community culture, needs and priorities in decisions regarding location and type of sanitation facilities has ensured weak support from local populations for hardware interventions. This has led to a legacy of abandoned sanitation products and the use of sanitation facilities for a range of non-sanitation purposes including storage and animal shelters. In India, for example, a recent study showed that about 50% of toilets built by a large government program are not used for their intended purpose (Duncan et al 2010). Furthermore, in many areas of South Asia (Rajgire 2013) and Africa, the practice of open defecation is ritualised and bound in tradition and in certain circumstances it

[15] Improved sanitation in developing nations has been estimated to yield about US$9 worth of benefits for every US$1 spent. The majority of the benefits accrue from time savings, but also from reduced direct and indirect health costs, higher returns to investments in education, protecting investments in improved water supply, safeguarding water resources and by boosting tourism revenues (UN Water 2008a). Other research suggests that for every US$1 invested in achieving the MDG sanitation target and universal sanitation access in non-OECD nations would result in a global return of US$9.1 and US$11.2 respectively (Van Minh & Nguyen-Viet 2011). At the global level, the economic return on sanitation spending is estimated at US$5.5 per US dollar invested (WHO 2012b).

Box 8.3.8 Community-Led Total Sanitation in Bangladesh

Even in the late 20th century open defecation was practised by up to one-third of the Bangladeshi population. With rapid population growth, and the lack of knowledge of the links between open defecation and disease transmission, the risk of sanitation-related infections and disease increased accordingly.

Early government programs to improve sanitation did little to address deeply entrenched attitudes, and tended to target households that were able to pay for such services. Latrines were seen as a luxury good rather than a necessity. But even in households with improved sanitation, people are still at greater risk of disease simply by being in such an environment.

Efforts to introduce low cost sanitation into Bangladesh have a long history. The Community-Led Total Sanitation approach (CLTS) – initially introduced to rural areas by non-government organisations (NGOs) in 2000 – has been the most effective.

At the core of CLTS is the recognition that provision of toilets does not guarantee their use or improved sanitation and hygiene practises. As such, CLTS is a communication-based approach that focuses on behavioural change by raising awareness of the link between open defecation and disease. The process requires whole of community involvement, with an emphasis on highlighting the collective benefits of eliminating open defecation, rather than focusing on individual behaviour or toilet construction.

Early success with the CLTS encouraged political support and national and state governments expanded efforts to improve household sanitary practices, with a goal to achieve nationwide sanitation coverage and stop open defecation in rural areas by 2010. Sanitation coverage increased from 38% in 1990 to 54% in 2010, and open defecation rates fell from 32% to 5%, driven by major improvements in rural areas. The CLTS is believed to be a major contributor to this outcome.

There are also positive signs that reducing open defecation is delivering considerable health benefits to rural communities. A 2008 study assessing the impact of CLTS found that it reduced diarrhoea cases by 30% for men and 50% for women, and halved the length of illness (Howes et al. 2009).

New latrines in Bangladesh. Image: Water.org.

is believed that these cultural values and beliefs have led to a resistance in the use of toilets (WaterAid 2009).

Aside from investment in infrastructure, a key factor to improving sanitation outcomes is providing education and training in good hygiene practices and improving awareness of the benefits of good sanitation practices, especially in communities that have not previously had sanitation.

Past shortfalls in infrastructure provision has led to a major shift in policy orientation towards demand-led approaches to improving sanitation. These are aimed at motivating people to improve their own sanitation and accelerate sanitation coverage in both rural and urban settings. One of these approaches is Community-Led Total Sanitation (CLTS) which was first developed in the rural communities of Bangladesh in 2000. CLTS has had considerable success in improving sanitation outcomes, and is being implemented in an increasing number of Tropical nations in Asia, Africa and Latin America (see Box 8.3.8) (Duncan et al. 2010).

The links between sanitation, water pollution and health

For developed nations access to onsite flush toilet facilities and the removal of waste via a sewer or septic tank at the push of a button is taken for granted. Yet for more than 50% of the people that live in the Tropics, such facilities are unavailable, and the separation of water and excrement is a formidable public health issue. In urban slums and rural communities the absence of quality sanitation facilities frequently means human waste is disposed in fields, on streets and in drains, creating an immediate local hazard and ideal conditions for disease vectors. In some regions human excreta contaminates surface and ground water or is discharged untreated into rivers and water systems, causing serious pollution and endangering the health of downstream users, plant life and aquatic resources (UN Water 2008b).

The anticipated health benefits of improved water supply have been severely limited by poor progress in the management of human excreta, one of the primary pathogenic sources of water contamination (UN Water 2008b). Diseases associated with poor sanitation account for about 10% of the global burden of disease, with diarrhoeal diseases – generally due to faecal-oral transmission of viral and bacterial pathogens – the most prevalent, causing up to 2.5 million deaths annually, mostly children in developing nations (Duncan et al. 2010). In 2008 diarrhoea was the leading cause of death among children aged under five years in sub-Saharan Africa (accounting for 19% of all deaths in this age group). It is estimated that improved sanitation could reduce rates of diarrhoeal diseases by up to 37% (Duncan et al. 2010).

The practice of open defecation – the last recourse for those without any form of sanitation – poses one of the more serious pollutant threats to ground water resources and agricultural produce, and is a major contributing factor to diseases such as diarrhoea, worm infestations, hepatitis, cholera and typhoid. Despite the proportion of the world's population practising open defecation declining from 24% in 1990 to 15% in 2010, more than one billion people still participate in this unhygienic practice, with 90% of these living in rural areas, and around two-thirds of them living in the Tropics. In the Tropics rates of open defecation are highest in South Asia (46%), followed by Northern Africa & the Middle East (42%) and Central & Southern Africa (24%), with the incidence reportedly greatest in rural areas. In other tropical regions the problem is less acute, with rates ranging from 3% in Central America to 12% in South East Asia.

Although the scale of sanitation needs in rural areas is large, public health risks in urban slums where inhabitants live in cramped and squalid living conditions are considered more acute. The illegal status of many of these settlements means they are not recognised by the authorities responsible for providing sanitation and are excluded from town planning. Even in slum areas where the use of improved sanitation facilities such as pit latrines is common, the risk of faecal-oral disease remains high. At any given time it is estimated that close to one-half of the urban populations of Africa, Asia and Latin America have a disease associated with poor sanitation, hygiene and water (Duncan et al. 2010).

Looking forward

Currently, more people have access to a mobile phone than a clean, functioning toilet. Future progress in the sector requires both adequate investment and collaborative action across developing nation and donor governments, civil society, multilateral agencies and the private sector. Progress has been made in the formation of the World Toilet Organisation through the United Nations which aims to provide sanitation for all. World Toilet Day (19 November) became an official UN day in 2013 based on Singapore's first resolution to the UN.

Nations that have established clear institutional responsibility and specific budget guidelines for sanitation quite distinct from the water sector have had greater sanitation outcomes. Top-down centralised supply led infrastructure solutions have historically dominated the sanitation landscape with limited effectiveness. Decentralised demand led strategies such as the Community-led Total Sanitation programs have met with considerable success in a number of tropical nations.

However in order for these bottom-up approaches to have a greater impact on sanitation coverage, future programs will need to be implemented on a much larger scale than has occurred to date.

References

Acharya S. (2007). *India's Growth: Past and Future.* Paper for presentation at the Eighth Annual Global Development Conference of the Global Development Network, January 14-16, Beijing.

ADB (2012). *Papua New Guinea: Critical Development Constraints.* Asian Development Bank, Manila.

Alfaro L, Kalemli-Ozcan S, Volosovych V. (2003). *Why doesn't capital flow from rich to poor countries?* An empirical investigation. International Monetary Fund, Washington DC.

Baum R, Luh J, Bartram J. (2013). Sanitation: A Global Estimate of Sewerage Connections without Treatment and the Resulting Impact of MDG Progress, in *Environmental Science & Technology* **47**.

Bu Y. (2006). Fixed capital stock depreciation in developing countries: some evidence from firm level data, in *Journal of Development Studies* **42**(5).

Buckle G, Walker C, Black R. (2012). Typhoid fever and paratyphoid fever: Systemic review to estimate global morbidity and mortality for 2010, in *Journal of Global Health* **2**(1).

Cap-Net, GWA (2006). *Why Gender Matters. A tutorial for water managers.* Cap-Net International Network for Capacity Building in Integrated Water Resources Management, Delft.

Crump JA, Mintz ED. (2010). Global trends in typhoid and paratyphoid fever, in *Clinical Infectious Diseases* **50**(2).

Dossani R, Kenney M. (2007). The next wave of globalization: relocating service provision to India, in *World Development* **35**.

Duncan M, Lane J, Scott B, Trouba D. (2010). Sanitation and Health, in *PLoS Medicine* **7**(11).

Everhart SS, Sumlinski MA. (2001). *Trends in private investment in developing countries; Statistics for 1970-2000 and the impact on private investment of corruption and the quality of public investment.* International Finance Corporation Working Paper 44. The World Bank, Washington DC.

Fisher WH, Turnovsky SJ. (1998). Public investment, congestions and private capital accumulation, in *The Economic Journal* **108**.

FIVAS (2011). *Sanitation for all – an engine of economic growth for urban Africa.* Foreningen for Internasjonale Vannstudier (Association for International Water Studies), Oslo.

Galvin JFP. (2007). The weather and climate of the tropics Part 1 – Setting the scene, in *Weather* **62**(9).

Gleick P, Singh, Shi H. (2001). *Emerging Threats to the World's Freshwater Resources.* Pacific Institute for Studies in Development, Environment and Security, Oakland.

Godfrey S, Labhasetwar P, Wate S, Pimpalkar S. (2010). How safe are the global water coverage figures? Case study from Madhya Pradesh India, in *Environmental Monitoring and Assessment* **176** (1-4).

Graham J. (2011). Sanitation and Hygiene: Taking Stock after Three Decades, in Selendy JMH. (ed) *Water and Sanitation-Related Diseases and the Environment: Challenges, Interventions, and Preventative Measures.* John Wiley & Sons, Hoboken.

Greene J, Villanueva D. (1991). Private investment in developing countries – An empirical analysis, in *IMF Staff Papers* **38**(1).

Harrris C. (2008). *India leads developing nations in private sector investment.* Gridlines Note No 30. Public-Private Infrastructure Advisory Facility. The World Bank, Washington DC.

Harvey P. (2008). Environmental Sanitation Crisis: More than just a health issue, in *Environmental Health Insights* **2**.

Homsombat W, Lei Z, Fu X. (2011). Development status and prospects for aviation hubs – a comparative study of the major airports in south-east Asia, in *The Singapore Economic Review* **56**(4).

Howes M, Huda E, Naser A. (2009). *Community-Led Total Sanitation and its Successors in Bangladesh:* The Evidence From Three Cases. London Institute of Development Studies, London.

Hulten CR. (1996). *Infrastructure capital and economic growth: how well you use it may be more important that how much you have.* NBER Working Paper No. 5847. National Bureau of Economic Research, Cambridge.

ICAO (2013). Civil Aviation Statistics of the World and ICAO staff estimates. International Civil Aviation Organization http://www.icaodata.com/ (accessed 20 May 2013).

Lee E, Schwab K. (2005). Deficiencies in drinking water distribution systems in developing countries, in *Journal of Water and Health* **3**(2).

Madsen JB. (2002) The causality between investment and economic growth, in *Economics Letters* **74**(2).

Milanovic B. (2003). The two faces of globalization: against globalization as we know it, in *World Development* **31**(4).

Moe C, Rheingans R. (2006). Global Challenges in Water, Sanitation and Health, in *Journal of Water and Health* **4**(Suppl 1).

Montgomery M, Elimelech M. (2007). Water and Sanitation in Developing Countries: Including Health in the Equation, in *Environmental Science & Technology* **41**(1).

Nourzad F, Vreize MD. (1995). Public capital formation and productivity growth: some international evidence, in *The Journal of Productivity Analysis* **6**.

Onda K, LoBuglio J, Bartram J. (2012). Global Access to Safe Water: Accounting for Water Quality and the Resulting Impact on MDG Progress, in *International Journal of Environmental Research and Public Health* **9**(3).

Patterson N, Montanjees M, Motala J, Cardillo C. (2004). *Foreign Direct Investment: trends, data availability, concepts and recording practices.* International Monetary Fund, Washington DC.

References | Continued

PwC (2013) *India*: a snapshot in: Gridlines, Summer 2013.

Rajgire A. (2013). Open Defecation: A Prominent Source of Pollution in Drinking Water in Villages, in *International Journal of Life Sciences Biotechnology and Pharma Research* **2**(1).

Ram R. (1997). Tropics and economic development: an empirical investigation,in *World Development* **25**(9).

Reinhart C, Khan M. (1989). *Private investment and economic growth in developing countries.* IMF Draft Working Paper. International Monetary Fund, Washington DC.

Richardson D (1998) Asian Financial Crisis, Current Issues Brief 23 1997-1998. http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Publications_Archive/CIB/CIB9798/98cib23 (accessed 19 February 2013).

Rijsberman F, Zwane A. (2012). Water & Sanitation. Copenhagen Consensus 2012. http://www.copenhagenconsensus.com/ (accessed 3 April 2013).

SIWI (2005). *Securing Sanitation – The Compelling Case to Address the Crisis.* Stockholm International Water Institute, Stockholm.

Tanzi V, Davoodi H. (1997). *Corruption, public investment, and growth.* IMF Working Paper No. 97/139. International Monetary Fund, Washington DC.

UN Millennium Project. 2005. Investing in Development: A Practical Plan to Achieve the Millennium Development Goals. Earthscan, New York

UN Water (2008a). *Sanitation is an Investment with High Economic Returns.* Un Water, New York.

UN Water (2008b). *Tackling a global crisis: International Year of Sanitation 2008.* UN Water, New York.

UN (2012). *The Millennium Development Goals Report 2012.* United Nations, New York.

UNDP (2006). *Human Development Report 2006.* Beyond Scarcity: Power, poverty and the global water crisis. United Nations Development Programme, New York.

UNEP (2010). *Africa Water Atlas.* United Nations Environment Programme http://na.unep.net/atlas/africaWater/downloads/chapters/africa_water_atlas_123-174.pdf (accessed on 6 February 2013).

UNESCO (2012). *The United Nations World Water Development Report 4. Volume 1. Managing Water under Uncertainty and Risk.* United Nations Educational, Scientific and Cultural Organization, Paris.

UNICEF-WHO JMP (2011). *Drinking Water: Equity, safety and sustainability.* United Nations Children's Fund and World Health Organization Joint Monitoring Programme, New York.

UNICEF-WHO JMP (2012). *Progress on Drinking Water and Sanitation 2012 Update.* United Nations Children's Fund and World Health Organization Joint Monitoring Programme, New York.

UNICEF-WHO JMP (2013). *Data Sources and Estimates for Water Supply and Sanitation.* United Nations Children's Fund and World Health Organization Joint Monitoring Programme http://www.wssinfo.org/data-estimates/ (last accessed 7 June 2013).

Van Minh H, Nguyen-Viet H. (2011). Economic Aspects of Sanitation in Developing Countries, in *Environmental Health Insights* **5**.

WaterAid (2009). *Towards total sanitation. Socio-cultural barriers and triggers to total sanitation in West Africa.* WaterAid, London.

WaterAid (2011). *Sanitation Framework.* WaterAid, London.

WaterAid (2013). *Papua New Guinea.* http://www.wateraid.org (accessed on 6 February 2013).

Weil DN. (2009). *Economic Growth – Second Edition.* Pearson Education, Boston.

WHO (2012a). *GLAAS 2012 Report. UN-Water Global Analysis and Assessment of Sanitation and Drinking Water. The Challenge of Extending and Sustaining Services.* World Health Organization, Geneva.

WHO (2012b). *Global costs and benefits of drinking-water supply and sanitation interventions to reach MDG targets and universal coverage.* World Health Organization, Geneva.

Wilbanks TJ, Romero Lankao P, Bao M, Berkhout F, Cairncross S, Ceron J-P, Kapshe M, Muir-Wood R, Zapata-Marti R. (2007). Industry, Settlement and Society, in Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. (Eds), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge University Press, Cambridge.

World Bank (1994). *World Development Report 1994 – Infrastructure for development*. The World Bank, Washington DC.

World Bank (2008). *Economic Impacts of Sanitation in South East Asia.* The World Bank, Washington DC.

World Bank (2013) World Development Indicators. The World Bank, Washington DC. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 10 December 2013).

Image: Stuart Barr.

Chapter 8.4

Governance | Information technology and communications

Kalen Sing, a fisherman from Vanuatu.
Tom Perry, World Bank.

Summary of communication indicators

Indicator	Tropics	Central & Southern Africa	Northern Africa & Middle East	South Asia	South East Asia	Caribbean	Central America	South America	Oceania	Rest of the World	World
Mobile phone subscriptions 1993-2010*	**0.1 – 68**	0 – 42	0 – 50	0 - 61	0.2 – 85	0.4 – 58	0.3 – 92	0.2 – 101	1 – 51	**1 - 83**	**1 - 77**
Fixed broadband subscriptions 2000-2010*	**0.03 - 2.4**	0.0 - 0.07	0.0 - 0.56	0.0 - 0.86	0.08 - 4.1	0.0 - 3.3	0.01 - 7.4	0.04 - 5.7	0.3 - 6.3	**0.4 - 11.3**	**0.3 - 7.6**
Internet users 1993-2010**	**0.01 – 17**	0 -10	0- 10	0 - 7	0.02 - 23	0 - 23	0.02 - 26	0.02 - 38	0.51 - 21	**0.3 - 38**	**0.2 - 29**

* Represents subscriptions as a percentage of total population. ** Represents users as a percentage of total population.

Is it getting better?

Mobile phone subscriptions - Over the past decade the mobile phone has emerged as one of the fastest growing consumer technologies ever introduced. In the Tropics mobile telephony has become the dominant means of communication and the principal gateway to increased information communication and technology (ICT) access and use, with penetration rates reaching 68% in 2010 up from 0.1% in 1993. The rapid growth of mobile phones in the region is partly due to low initial access. In absolute terms the Tropics remains well behind the Rest of the World, with subscriber numbers still only around a third of the global total. Despite a significant increase in diffusion across all Tropical regions considerable inter regional disparity persists, with rural populations experiencing the lowest rates of mobile connectivity.

Market liberalisation in combination with technological and commercial innovation have generated more affordable infrastructure, cheaper handsets, competitive markets and business models oriented to the needs of poorer population segments living in the Tropics thereby enabling greater mobile take up.

Internet users - Internet diffusion in the Tropics has grown quickly in terms of both users and penetration, though access is considerably less widespread than mobile communications. Growth rates of 30% per annum in the preceding decade (twice that in the Rest of the World) enabled the number of Internet users in the Tropics to reach 471 million in 2010 and achieve a penetration rate of 16.5%. Despite these positive developments Internet use in the Tropics is progressing slowly in some regions and overall diffusion is considerably lower here than in the Rest of the World. As with fixed broadband, Internet penetration remains lowest in Central & Southern Africa, Northern Africa & the Middle East and South Asia. Poor telecommunications infrastructure, market control by incumbent telecommunications operators, low rates of personal computer ownership, cost of access, low literacy levels and lack of relevant content in local languages are some of the factors which make the Internet a more difficult ICT to disseminate in these regions.

In the absence of fixed broadband infrastructure, access to the Internet via public access points such as Internet cafes and more recently through mobile broadband networks has contributed to increased Internet connectivity within many nations in the Tropics.

Fixed broadband internet subscriptions - In the Tropics fixed broadband subscriptions increased one hundred fold in the 10 years to 2010. Despite progress, this technology remains in its infancy, with penetration sitting at just 2.4% of regional population in 2010. The Rest of the World continues to dominate global subscription numbers and the gap in terms of penetration with the Tropics has widened since 2000. Diffusion in the Tropics is now one fifth of that in the Rest of the World and variations between the different Tropical regions are also significant. Subscriptions as a proportion of population were less than 1% in Central & Southern Africa, Northern Africa & the Middle East and South Asia in 2010. Infrastructural and market differences have created price conditions that are less ideal for the adoption of broadband by consumers in these regions.

The rapid growth of information technology in the late 20th and early 21st century has facilitated social and economic development and global coordination of business, trade, governance and security on an unprecedented scale. Information Communication Technology (ICT) refers to any technology that enables the communication and electronic capture, processing and transmission of information. The concept encompasses older technologies such as radio, television and fixed line telephony as well as the more recent innovations including personal computers, mobile phones, broadband networks and the Internet. The potential of the new ICTs lies in their capacity to instantaneously connect vast networks of individuals, organisations and governments across all corners of the world. ICTs have become key enablers of globalisation, facilitating world-wide flows of information, capital, ideas and products.

Over the past decade nations in the Tropics have experienced rapid but uneven growth in ICT access and use. The unprecedented expansion of mobile technologies, driven by private sector investment and supported by reforms to promote competition, has improved affordability and enabled the expansion of phone services to previously underserved populations. Beyond mobile telephony, large disparities exist in Internet access, high speed broadband connectivity, and in the diffusion and use of ICT in services, business and government.

The benefits that information and communication technology can bring to societies and their inhabitants arise from societal improvements based on economic growth and other developments, such as enhancements in education, business facilitation, access to markets and government processes. At the individual level, ICT enables people to communicate more easily, undertake tasks more efficiently and access income generating opportunities more readily.

By increasing productivity and therefore economic growth in developing nations, ICT has a formidable role to play in reducing poverty and improving living conditions and opportunities for the poor.

Headline indicator

Mobile phone subscriptions: Mobile phone subscriptions per capita are an indicator of mobile phone diffusion within a nation. Frequently the first gateway to ICT in developing nations, mobile telephony has enabled developing nations to overcome infrastructure barriers and deliver communication networks to previously unconnected populations. The mobile phone industry has emerged as an enabler of substantial economic and social development, helping to lift citizens out of poverty and extending social and digital inclusion. Mobile broadband has the potential to expand the transformative capabilities of mobile technologies through its capacity to bring Internet to consumers in developing nations.

Supplementary indicators

Internet users: The Internet, the global system of interconnected computer networks, is a mechanism for information dissemination and a medium for interaction between individuals, businesses and governments across all types of traditional boundaries. Information and content availability over the Internet is seen as a critical enabler to greater inclusion, empowerment and human development for its users.

Fixed broadband internet subscriptions: Fixed broadband facilitates access to the highest quality Internet services via a variety of high speed technologies including digital subscriber line (DSL), cable modems and fibre optic cable. Apart from high speed, the ever present, always connected and secure characteristics offered by broadband technologies allow individuals access to a greater range of services and a richer Internet experience. Broadband generates substantial benefits to the productivity, education and economic development of society in general.

Although increasingly commonplace and affordable in many areas of the world, fixed broadband services remain either unavailable or prohibitively expensive in many developing nations. Low penetration levels constitute a significant barrier to a nation's meaningful entry into the global information economy, economic competitiveness and macroeconomic growth. Nonetheless, the rapid roll out of mobile broadband infrastructure and services is contributing to significantly stronger take up of broadband using mobile technologies.

Links to other dimensions

Infrastructure; Economic output; Poverty; Gender equality; Work.

Mobile phone subscriptions

Telecommunication plays a vital role in modern society and is instrumental to the organisation and operation of the global economy. Since the 1990s rapid technological change, globalisation and significant increases in the information intensity of economic activity have made information and communication technology (ICT) critical to a nation's competitiveness, growth and social development (World Bank 2006).

Over the past 30 years ICT access in most nations has increased considerably, with much of the recent growth centred on mobile (or cell) telephony. In 2002 the number of mobile phone subscriptions reached 1 billion, surpassing the number of fixed line connections for the first time (Zhen-Wei 2009). In comparison, it took over a century for the world to accumulate the first billion fixed telephone lines. By 2010, mobile phone subscriptions had increased to 5.3 billion, representing 77% of the world's population.

In the developed world mobile phone subscriptions increased incrementally as the technology complemented or replaced existing services. In developing nations however, mobile technology has often provided households with their first access to telecommunications, and take-up rates have been high. The rapid spread of mobile phone technologies in developing nations has also been enhanced by a number of other factors, such as technological improvements that have lowered costs relative to fixed wire networks, falling handset prices, the introduction of prepaid subscriptions, rising incomes and strong competition among service providers (World Bank 2012a).

In many societies mobile technology is so entrenched that the story is no longer about the phone itself, but rather how it is used, and the content and applications to which the phones provide access. The mobile phone also offers a range of economic, political and social capabilities, and some commentators suggest that it is the single most transformative technology for development (Bloomberg Business Week 2007). Mobile phones allow users quick and efficient access to health, education, employment, public safety, transportation and legal services. Many core economic activities are increasingly conducted over mobile networks as new technologies and innovations change business and service delivery models. This is bringing new services and opportunities to many regions of the world, and is especially apparent in the banking and retail industries.

The expansion of mobile networks has been supported by the deregulation of state controlled monopolies and massive private sector investment in infrastructure and ICT in general. Especially in developing nations, this liberalisation has facilitated access to foreign capital and technology, which has encouraged competition and delivered modern and affordable services (World Bank 2006). Between 1990 and 2010 some 329 projects in the mobile telecommunications sector in developing regions attracted $441 billion in private sector investment, much of it from foreign multinational corporations (World Bank 2012a).

Trends

The mobile phone was introduced more than 30 years ago and is now the most widely used communication technology in the world. The traditional measure of mobile telephony penetration is the number of mobile phone subscriptions as a percentage of the population and, despite its imperfections it is used in the analysis here.

Between 1993 and 2010 the number of global mobile phone subscriptions increased from 33.6 million to 5.3 billion (33% per annum), with the result that the penetration rate increased from less than 1% in 1993 to 76.8% in 2010.

The Tropics has followed a similar pattern to the Rest of the World with respect to mobile phone take up, albeit with a lag (see Figure 8.4.1). Mobile phone use was initially concentrated in industrialised nations, most of which are in the Rest of the World, where subscription rates increased from 0.9% of the population in 1993 to 83.3% in 2010. The mobile penetration rate has consistently been lower in the Tropics (at 0.1% in 1993 and rising to 67.7% in 2010) but the gap has been narrowing over time. In 1993 the penetration rate in the Tropics was only around 10% that of the Rest of the World, increasing to more than 80% in 2010. Nonetheless, the gap between the Tropics and Rest of the World, at 15.6 percentage points in 2010, is still significant, but a considerable improvement from the 25.6 percentage point gap in 2006. At just 1.2% in 2010, the tropical nation of Burma/Myanmar had the lowest mobile phone subscription rate in the world (1.2%), followed by North Korea at 1.8%.

Mobile phone subscriptions in the Tropics increased from 2.45 million in 1993 to 1.9 billion in 2010, compared with an increase from 31.1 million to 3.3 billion in the Rest of the World (see Table 8.4.1).

For developed nations, greater access to capital and skilled labour combined with generally more stable political and industry networks assisted with the initial transition to mobile technologies. As many of these nations are in the Rest of the World, this goes some way to explaining variations compared with the Tropics. The difference between the Tropics and Rest of the World has also been compounded by the initial perception by some phone companies that mobile telecommunications was a non-essential service with limited growth prospects in low and, to a lesser extent, middle-income nations (Andjelkovic 2010). This contributed to delays in many companies entering these markets and the gap that still exists between developed and developing nations.

All tropical regions report large increases in mobile phone subscriptions since 1993 but there is considerable variation between regions. From subscription rates ranging from 0% to 1.2% in 1993, they now range from around 40% in Central & Southern Africa to over 100% in South America (see Figure 8.4.2). Market liberalisation in many Latin American nations saw the region attract a large share of foreign investment in telecommunications in the 1990s and early 2000s which, combined with competition, were key drivers for high take-up rates in South America and Central America. One of the largest transactions was the 1998 privatisation of Telebras, Brazil's state owned monopoly telephone (World Bank 2006). Eight separate mobile companies emerged from the privatisation, and mobile subscriptions increased from 6 million in 1998 to 174 million in 2010, an average growth rate of 32% per annum.

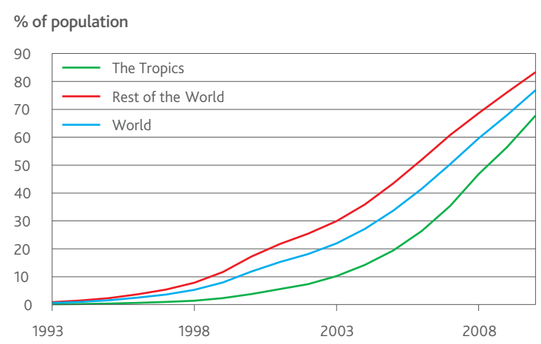
At 42%, Central & Southern Africa has the lowest mobile subscription rate in the Tropics. While mobile coverage in this region followed a similar pattern to South Asia until 2005 (both regions had subscription rates around 0.5% in 2000 and 8% by 2005), by 2010 Central & Southern Africa lagged South Asia by almost 20 percentage points. Stronger growth in South Asia was influenced by low tariff rates coupled with a significant increase in household incomes in India around the same time (Singh 2006). In addition, a large proportion of Central & Southern Africa's population is under the age of 15, limiting the size of the mobile phone market in this region (GSMA 2012). Interestingly, up until 2000 the pattern of growth in Central & Southern Africa was confined to a small sample of nations, but by 2010 it was widespread, with almost half of the nations in this region reporting subscription rates higher than 50%.

In absolute numbers South East Asia has consistently been the largest market for mobile telephones in the Tropics, with subscriber numbers increasing from 1.5 million in 1993 to almost 650 million in 2010. Indonesia, another significant beneficiary of foreign investment, has accounted for more than one-third of the increase.

In the Tropics South Asia has also had rapid growth in the number of mobile phone subscribers, increasing from 15,000 in 1993 to 474 million in 2010. India has driven this growth, with the penetration rate reaching 61% in 2010, up from zero in 1993. The emergence in India of a competitive and innovative private sector contributed to the development of cost-effective business models which reflected local needs. These firms have been very successful in attracting new customers (see Box 8.4.1). Rapid progress in India masks much slower development in other nations in the South Asia region.

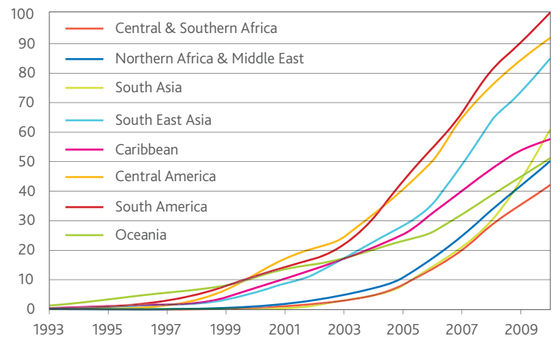
Affordability has been a major factor influencing the rapid penetration of mobile technologies in

Figure 8.4.1 **Mobile phone subscriptions**



Source: ITU (2013), State of the Tropics project.

Figure 8.4.2 **Mobile phone subscriptions – the Tropics**



Source: ITU (2013), State of the Tropics project.

Table 8.4.1 **Mobile phone subscription trends**

	1993		2000		2006		2010		1993 to 2010		
	%	Million	%	Million	%	Million	%	Million	PPT* change	Million	Av. An. Growth
Tropics	**0.1**	**2.45**	**3.7**	**91**	**26.4**	**706**	**67.7**	**1,932**	67.7	1,932	45.5%
Central & Southern Africa	0.0	0.02	0.5	3	13.5	84	42.2	288	42.2	288	71.6%
Northern Africa & Middle East	0.0	0.01	0.9	1	16.8	23	50.2	76	50.2	76	62.9%
South Asia	0.0	0.01	0.4	3	14.7	108	61.0	474	61.0	474	81.3%
South East Asia	0.2	1.48	5.5	37	35.4	259	85.0	646	84.8	645	41.1%
Caribbean	0.4	0.12	7.3	3	32.6	13	57.7	23	57.3	23	34.7%
Central America	0.3	0.31	11.9	14	50.2	62	92.0	120	91.6	120	39.8%
South America	0.2	0.38	11.5	30	54.7	155	100.6	299	100.4	299	45.9%
Oceania	1.2	0.11	10.9	1	26.1	3	51.2	6	50.0	6	24.6%
Rest of the World	**0.9**	**31.1**	**17.2**	**629**	**52.0**	**2,010**	**83.3**	**3,337**	82.4	3,337	30.4%
World	**0.6**	**33.6**	**11.8**	**720**	**41.5**	**2,716**	**76.8**	**5,269**	76.2	5,269	32.9%

Source: ITU (2013), State of the Tropics project.
* Percentage point.

most tropical regions. Access to prepaid services and the development of cheaper handsets have reduced the cost of mobile services, making them more accessible to people in developing nations, and particularly in the cash-based societies of Central & Southern Africa and South Asia (The Economist 2009).

Direct and indirect benefits

The mobile phone industry has become a significant sector in many economies, with operators generating an estimated US$848 billion in revenue in 2011 (World Bank 2012a), as well as contributing to and facilitating economic growth more broadly. Research suggests there is a correlation between mobile phones and economic growth, with a study of 120 nations indicating that an additional ten mobile phones per 100 people is associated with an increase in economic growth of 0.8 percentage points in developing nations, and 0.6 percentage points in developed nations (Zhen-Wei 2009).

The mechanisms by which mobile telephony can impact economic activity vary considerably. In developing regions where the movement of people, goods and information may be constrained by poor infrastructure, the introduction of cheap mobile communications has become a substitute for transport. Mobile phones also allow for more efficient dissemination of information and can improve the functioning of firms and markets by reducing transaction costs, and have the capacity to improve productivity in both the public and private sectors. As these issues tend to be more acute in developing economies, the economic benefits from improved telecommunications access are more pronounced in developing nations.

Notwithstanding significant indirect impacts, mobile telephony is an increasingly significant industry in its own right. In Vietnam mobile network operator revenues as a percentage of GDP increased from 3.2% in 2008 to 5.8% in 2010, driven by the mobile phone penetration rate increasing from 87% to 127% (GSMA 2011), while in sub-Saharan Africa the mobile sector accounted for 4.4% of regional GDP in 2011. In emerging markets this has included the development of 'tech hubs' such as Nokia's dedicated research centre in Nairobi, which is focussed on developing regionally specific products (GSMA 2012).

Box 8.4.1 Mobile phones in India

The spread of mobile phones in the developing world has been accompanied by the rise of local operators, many of which now rival or exceed international competitors. A factor contributing to this is the development of new business models and industry structures by local service providers that enable them to make a profit from serving low-spending customers – customers that many Western firms would not pursue. An example of this is the initial focus by Western firms on post-paid plans, which are more onerous and costly to operate, and which severely limit the potential market size and demand.

In the developing world Indian service providers have been at the forefront of this innovation process, and their models and products have been adopted by operators in other nations. A key to their success has been a focus on affordability.

Outsourcing and infrastructure sharing are at the centre of the 'Indian model'. The outsourcing of functions such as information technology operations, mobile network operations and customer care contributed to efficiencies in managing and mitigating risks associated with a rapidly growing subscriber base, and allowed operators to concentrate on revenue-generating activities such as innovation, marketing and strategy. The sharing of infrastructure such as towers, network antennae and generators has also been a key feature of the Indian model. This is not a new strategy, but the extent of voluntary, market-led sharing to reduce costs is significantly higher in India.

Lifetime prepaid schemes (where customers pay a one-off fee and can receive incoming calls indefinitely); widespread use of paperless top-ups (reducing the cost of distributing top-up vouchers), and energy reduction measures (for instance, where equipment is automatically turned off at night or when traffic volumes fall), are examples of innovations used by mobile operators to lower costs and improve affordability.

Despite cheap call charges and relatively low average revenues per user, mobile operators in India reported operating margins comparable with leading international operators, at around 40% in 2008 (The Economist 2009). However, after years of rapid growth subscription rates have started to moderate as businesses have had to increase tariffs to remain viable, with impacts on those new and existing consumers that are particularly price sensitive. This is more likely to be the case in rural areas, where infrastructure and subscription rates are relatively low. In 2011 the mobile phone subscription rate in rural India was 11%, compared with 156% in urban areas (PwC 2011).

Image: M DeFreese, CIMMYT.

As technology has improved, mobile phones have also evolved from being simple communications tools to multi-purpose devices offering a range of voice and data services. Combined with rapid service innovation, this means mobile phones have become truly transformative devices. Today mobile phones provide the platform for a variety of health care, banking and other services, as well as creating a range of previously unavailable employment opportunities, especially in developing nations.

For example, exclusion from the formal financial system is recognised as a barrier to poverty alleviation and economic growth, and can also exacerbate inequality between the rich and the poor (World Bank 2012a). Prior to mobile phones many households in developing nations, and especially in rural areas, did not have access to formal banking services. Since mobile banking services first emerged in the developing world more than a decade ago, it has brought millions of people into the financial system for the first time. At least 110 mobile money systems had been deployed by 2012 providing financial services to 40 million users, many of which are in sub-Saharan Africa (World Bank 2012a).

Rapid growth in the mobile phone industry has also created significant direct and indirect employment opportunities. In 2011, the mobile phone industry in sub-Saharan Africa created more than 3.5 million jobs across both the formal and informal sectors (GSMA 2012), while in India the sector employs around 2.8 million people directly, and another seven million people indirectly (PwC 2011).

Entrepreneurial ventures based on mobile technology include short-term renting of phones, which has significantly improved the connectivity of communities – and especially rural communities. First introduced in Bangladesh, this style of business has now successfully expanded into many tropical African nations. For entrepreneurs and business people the mobile phone has also become essential for accessing market and price information, customer liaison, coordinating logistics, and financial transactions, and is making it easier to operate in locations where it would otherwise be impossible.

In the public sphere mobile technology is significantly expanding the capacity of governments to deliver services. Governments in various stages of economic development have adopted the concept of mobile government (m-Government) – an extension of the e-Government concept – focused on using mobile technologies to improve client access, service delivery and productivity. Already m-Government is being used to cost-effectively deliver SMS and Internet-based information and interactive services in areas such as health, education, employment, transportation, finance and public safety (OECD & ITU 2011). Research also suggests that using online or mobile technologies to engage the public in decision making can have a positive impact on trust and perceptions of government responsiveness.

Although still in its infancy, as mobile technology reaches more people, m-Government has great potential to benefit unserved and under-served populations. Many of these people will live in rural areas and, combined with improved business and employment-related opportunities, mobile technologies can improve wellbeing through economic and social development.

Regulatory environment and spectrum management

There is growing consensus that inefficient regulatory practices negatively impact the introduction and growth of mobile technologies and services, and have contributed to higher prices and artificial scarcity in a number of nations (ITU 2007). For example, low-income African nations with more competitive markets have 31% higher rates of mobile penetration than those with uncompetitive markets (World Bank 2012b). As a consequence, more and more nations are introducing reforms to improve regulatory practices, including measures such as competitive spectrum auctions.

Radio spectrum[17] is the airwaves over which mobile voice and data travel, and is critical for all forms of wireless communication. At the global level, spectrum is managed by the International Telecommunication Union which, amongst other things, aims to prevent interference between competing services, such as mobile phones, radio and television broadcasting and satellite communication systems. Beyond this spectrum allocation, individual nations are responsible for spectrum management within their own borders (for example, decisions regarding the quantity of spectrum to be released to individual operators).

Spectrum is a finite resource, and shortages can often coexist with under-utilisation as a result of inefficient use. Over the past two decades there has been a move away from the prescriptive 'command and control' approach (typically a legacy of earlier government practices) to spectrum management and more market-orientated systems. A number of controlling Government practices have been abolished or changed to improve the efficient use of spectrum. These practices include the following: retention of large underutilised parcels for public sector entities like the military; the assignment of spectrum on an exclusive or national basis regardless of demand, neglecting to reallocate spectrum left vacant by changing technology; and spectrum hoarding.

More efficient spectrum management will become increasingly important as users shift from voice and SMS services to more data-intensive web services, which also leads to significant volatility in spectrum loads. Globally, mobile data traffic is expected to increase substantially in the next few years. In the Tropics, nations such as India, Brazil and China have, on average, more than doubled data usage every year since the technology was introduced (GSMA 2012).

Mobile networks in sub-Saharan Africa anticipate a 25-fold increase in internet traffic in the four years to 2016 as smart phone technologies become increasingly available (GSMA 2012). Nations in this region have among the lowest spectrum allocations in the world, which will need to be addressed if demand is to be accommodated without significant increases in user costs and/or lower service quality in the form of poor network access, congestion and lower speeds – each of which is likely to inhibit the full transformative potential of mobile technologies. Although these issues may be more acute in developing regions, spectrum supply constraints are an issue that all nations are likely to face at some stage.

There are always exceptions though, and spectrum authorities in a number of developing nations have emerged as leaders in developing regulatory environments that support competition and innovation. For example, in Guatemala spectrum-related reforms have improved the efficiency and affordability of mobile technologies (see Box 8.4.2).

Box 8.4.2 Guatemala

Prior to 1996 radio spectrum in Guatemala was owned by the government, which issued prescriptive and revocable licenses for its use. Radio spectrum management was highly regulated and inefficient by international standards. Frequencies above 800 megahertz (MHz) were controlled by a state-owned company, with frequencies below 800MHz regulated by an agency (Elbittar 2010). Additionally, exclusive mobile telephony rights had been awarded to one private company. Mobile phone penetration rates were low at this stage, but similar to many other middle income nations.

Reform and deregulation of Guatemala's telecommunication sector commenced in 1996 when mobile telephony was in its infancy. While state ownership of the spectrum was maintained, the reforms gave companies access to a greater range of spectrum, allowed licensees to lease, sell, subdivide or consolidate their spectrum titles, created an independent regulator, and generally encouraged new entrants and competition.

The impact of these changes was immediate, and in the five years to 2001 the number of fixed and mobile telephone connections increased at an average rate of 38% per annum, compared with 9% per annum between 1985 and 1995 (ITU 2003). Guatemala's three leading mobile phone providers entered the market between 2003 and 2004, and their scale and innovation contributed to competition, improved affordability and increased connections, with subscription rates increasing from 13% in 2002 to 140% in 2011.

Mexico provides a counterpoint to Guatemala. Since 2000 growth in mobile subscription rates in Mexico has been considerably lower than other nations in Central America, including Guatemala. In 2000 Mexico had the highest penetration rate in Central America at 14%, but by 2011 it had slipped to sixth highest. Although Mexico has a liberal regulatory environment, the impacts of asymmetric concessional arrangements granted to one operator when the mobile market was emerging – and which have subsequently been wound back – has resulted in it retaining significant market power (Prieto 2011). Combined with foreign investment restrictions, this has contributed to a situation where the telecommunications sector is dominated by one operator which has around 70% market share. This market power, combined with other barriers to entry, has contributed to relatively weak competition, high prices when connecting across networks, low rates of innovation and slow growth in subscription rates.

Mobile phone tower. Image: R512.

Looking forward

Looking forward, mobile access, capacity and affordability should continue to improve, and mobile technologies represent a powerful platform for the development of commercial and social applications. The main challenges facing the continued uptake and utilisation of mobile technologies in many developing and tropical nations will be creating the regulatory environment that encourages investment and competition, and ensuring that spectrum management is adequate to cater for the rapid uptake of data-intensive smart phone technologies.

While mobile take-up rates are increasing rapidly (there were 28 mobile connections for each fixed line subscription in sub-Saharan Africa in 2010), in some nations and sub-populations – especially in the rural areas – take-up is relatively low, and often reflects the extent of limited infrastructure development into these areas. Increased investment in network coverage into rural and remote areas will encourage greater connectivity and diffusion of other technologies, and will act to narrow the digital divide that exists both within and between nations (World Bank 2008).

[17] Radio spectrum refers to electromagnetic radiation of different wavelengths and frequencies used for fixed and mobile communication, broadcasting, radio navigation and fixed and mobile satellite services. The optimal bandwidth for mobile communications is between 400 megahertz to 5 gigahertz.

Internet users

The Internet is one of the most important technological developments in recent history. With origins dating back four decades it was only through the development of the World Wide Web in the early 1990s that the Internet emerged as a commercial undertaking, revolutionising the way people communicate with one another and obtain information. Today the Internet is a widespread information infrastructure providing near instant communication on a global scale via email, instant messaging, video conferencing and social networking. Its influence reaches not only to the technical and social fields of computer communications but throughout society there is increasing use of online tools for electronic commerce, information acquisition and to access public services.

In 2010 there were 2 billion people connected to the Internet worldwide. Although usage has diffused rapidly there are inequalities, both within and across regions. For example, penetration rates in developed nations average around 75%, while in developing nations it is just 24% (UNCTAD 2011). In developing nations usage is concentrated in urban areas, with limited connectivity into rural areas. This disparity in access underlies the digital divide, which is increasingly significant as a global development issue given that Internet access has become important for economic and productivity growth, and for the delivery of government and business services.

Major barriers to Internet access include: limited or underdeveloped telecommunications infrastructure; low household incomes and literacy levels; cost of access; low rates of personal computer ownership; a lack of computer literacy; and a limited supply of web content in local languages adapted to local needs. The impact of these barriers differs with the level of economic and social development of a nation.

In the past decade fixed broadband technologies have emerged as the next step in Internet development (see Box 8.4.3). This has occurred as relatively static content is increasingly replaced by graphically rich multimedia which requires greater bandwidth, high speed transmissions and high quality Internet connectivity. Fixed broadband requires major investment in infrastructure, and its availability is largely confined to developed nations at present.

More recently, next-generation mobile cellular technologies and the wider adoption of sophisticated broadband-enabled mobile devices have raised the possibility of more rapid and cost-effective infrastructure development, with potential impacts on access and take-up.

Trends – Internet users

Rapid technological advances in ICT and a steady increase in the number of Internet users are affecting the way people communicate and do business, and are changing the global economy. Growing from 10 million users in 1993 (0.2% of global inhabitants), there were 2 billion Internet users in 2010 (29%). Internet use has been driven by non-tropical regions, where user numbers increased from 9.7 million in 1993 to 1.5 billion in 2010. In contrast, there were around 470 million Internet users in the Tropics in 2010 up from 230,000 in 1993. The Internet and World Wide Web originated in Europe and North America and until recently has been dominated by nations in these regions.

Despite the obvious disparity in absolute numbers, Internet user growth rates are higher in the Tropics, increasing at 30% per annum in the ten years to 2010, almost double the growth rate of 16% per annum in the Rest of the World. By 2010 the penetration rate had reached 17% in the Tropics (up from 0.01% in 1993), while it was 38% in the Rest of the World (up from 0.3% in 1993) (see Figure 8.4.3). The widespread introduction of wireless broadband services via mobile phones has contributed to strong growth in the Tropics (UNCTAD 2011). Despite this progress in the number of users, the gap in penetration rates between the Tropics and the Rest of the World continues to increase, and was almost 22 percentage points by 2010.

The diffusion of the Internet across the eight Tropical regions has been uneven, and considerable disparities exist, with penetration rates ranging from 7% in South Asia to 38% in South America (see Figure 8.4.4).

Oceania initially led the way, with Internet user penetration rising from 0.5% in 1993 to 18% in 2005, driven by Australia and the United States. User rates in both nations exceeded 60% in 2005, while in many of the region's small island nations it was less than 5%. Since 2006 South America has had the highest penetration in the Tropics. All eight nations in South America have penetration rates of 30% or higher. Infrastructure expansion combined with competitive and flexible pricing by telecom companies and Internet service providers (ISPs) have contributed to strong take-up rates (Madory 2013).

In absolute numbers South East Asia has the largest number of Internet users in the Tropics, increasing from 0.12 million in 1993 to 173 million in 2010. This region accounts for more than one third of all Internet users in the Tropics in 2010. Improving Internet access from public facilities such as cafes, libraries and schools is also contributing to growth in many developing nations where household connections are often limited, and many people work in the informal economy. In Brazil and Peru over half of all Internet users log on from public facilities (UNCTAD 2009). More recently strong growth in Internet usage in the Tropics has been via mobile phones, notably in South East Asia (UNCTAD 2011).

Internet penetration in tropical South Asia, Central & Southern Africa and Northern Africa & the Middle East remains low by global standards, at 7%, 10% and 10% respectively in 2010. While cost and infrastructure limitations are known obstacles in these regions; unreliable electricity supply, low literacy rates, low computer literacy and limited awareness of the

Box 8.4.3 Internet access technologies

Over the past ten years an Internet connection has become just as important as a television, radio and telephone connection, and methods of connecting to the Internet have evolved considerably.

Initially, dial-up access via standard telephone lines was the only means to connect to the Internet. Over time technology has advanced rapidly, in line with demand for faster and more reliable services, and today broadband connections such as digital subscriber line (DSL)-enabled phone line, cable TV modems, wireless and fibre optic connections are increasingly common in developed nations. In most nations dial-up subscriptions now represent less than 10% of all fixed Internet subscriptions (ITU 2011). Nonetheless, dial-up still provides the only means of Internet access in many rural and remote areas where population densities are low and infrastructure costs are high.

Broadband is commonly used to describe Internet connections that are significantly faster than dial-up technologies, and which enable high-speed transfer of data, voice and video over the Internet. Broadband access is typically classified as being either fixed or wireless. Fixed broadband currently provides the bulk of high-speed Internet connectivity. DSL and cable modem technologies have largely been built onto existing telecommunications networks, while fibre optic cable is a newer technology. DSL accounts for around 65% of the world's fixed broadband connections, followed by cable (ITU 2011).

Wireless technologies enable Internet access without the need for underground copper, fibre or other forms of network cabling. Compared to wired services, wireless technology provides greater convenience and mobility to connect to networks via portable modems, mobile phones or other mobile devices. Common wireless technologies include mobile broadband, WiFi and WiMAX.

Satellite links can be used to deliver broadband in remote or sparsely populated areas that are difficult or uneconomical to service using more conventional methods.

High speed broadband, Tonga. Tom Perry, World Bank.

Internet are also significant constraints (Kelly et al. 2012).

The availability of local language content is also a major influence on Internet use, and has contributed significantly to the disparity observed across the Tropics. Research suggests that making more content available in local languages can increase a nation's Internet subscription substantially (Samanta et al 2019). Around 90% of web content is in just ten languages, with English content making up 55%. Content is also available in at least another 150 languages (W3Techs 2013).

Trends – Fixed broadband subscribers

Globally, fixed broadband subscriptions have increased more than 30 fold in the ten years to 2010, from 16 to 521 million. Most of the increase occurred in the Rest of the World where subscriptions increased from 15 million in 2000 to 453 million in 2010. In the Tropics subscriptions increased by a factor of 100, from 670,000 to 68 million (see Figure 8.4.5).

Relative to the Internet though, fixed broadband diffusion is low, with global penetration increasing from 0.3% in 2000 to around 8% in 2011. As with other ICT indicators fixed broadband use in the Tropics lags the Rest of the World with the divide widening considerably over time. Both the Tropics and the Rest of the World had penetration rates of less than 1% in 2000, and by 2011 this had increased to just 2.6% in the Tropics, while in the Rest of the World it increased to 12.8%.

The limited number of fixed telephone lines in the Tropics, at eight per 100 inhabitants, (compared with 24 in the Rest of the World) is a major constraint to fixed broadband access in the Tropics.

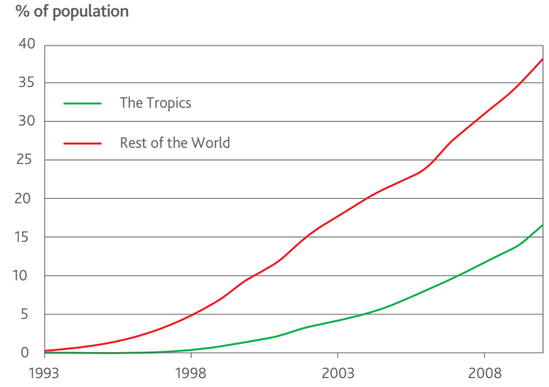
With lower infrastructure costs, mobile access to broadband services is more common than fixed line services in both the Tropics and the Rest of the World. Nonetheless, a 'digital divide' exists between the two regions, with the penetration rate for mobile broadband in the Tropics being 6% in 2010, compared with 23% in the Rest of the World.

In 2000 when fixed broadband technologies were in their infancy, subscription rates in tropical regions ranged from zero (in four of the eight regions) to 0.3% (in Oceania). Subscription rates now range from less than 1% in Central & Southern Africa (0.1%), Northern Africa & the Middle East (0.6%) and South Asia (0.8%), to 7.4% in Central America (see Figure 8.4.6). Rapid increases in Central America are driven by Mexico, where fixed broadband subscriptions increased three-fold between 2007 and 2010, as the entry of three cable companies into the market increased competition (OECD 2012).

In Central & Southern Africa communications infrastructure is limited and fixed broadband subscriptions are low. The limited number of fixed telephone lines, inadequate terrestrial networks between nations and high costs are critical factors constraining take-up. The cost of fixed broadband Internet services can be more than seven times the average income in some African nations (ITU 2012). The rapid diffusion of mobile communication promises to enhance Internet access in the region in the coming years.

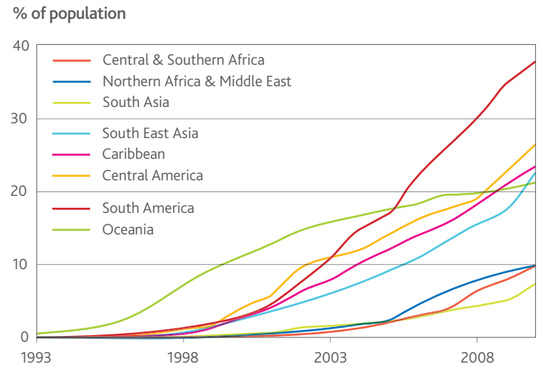
Although national time series data on mobile broadband are not readily available, regional data report rapid increases in penetration rates since 2010 as technologies improve and telecommunications companies and consumers opt for more cost effective mobile services. In Africa for example, penetration rates for mobile broadband increased from 1.8% in 2010 to 10.9% in 2013, while the fixed line rate increased from 0.2% to 0.3%. Globally, growth in the number of mobile broadband subscriptions is more than five times that for fixed broadband subscriptions over the same period.

Figure 8.4.3 **Internet users**



Source: ITU (2012), State of the Tropics project.

Figure 8.4.4 **Internet users – the Tropics**



Source: ITU (2012), State of the Tropics project.

Technology convergence

Over the past decade mobile broadband has redefined the way people access the Internet. Its greatest impact has been in developing nations, where lower infrastructure costs have encouraged investment and improved the affordability of high-speed Internet access in previously unconnected areas. Compared with fixed services, mobile broadband offers significant economies of scale and a more affordable means of reaching developing markets (World Economic Forum & INSEAD 2012). For example, in Cambodia, Indonesia, Kenya and Namibia fixed broadband penetration is less than 1%, while mobile broadband subscriptions range from 6% to 10% (ITU 2011).

Mobile broadband subscriptions surpassed fixed broadband subscriptions in 2008 (ITU 2011), supported by the development of 'smart' phones. An estimated 750 million people used a mobile phone to access the Internet in 2010, up from 180 million in 2005. Asian nations accounted for more than half these users in 2010, with two-fifths of mobile Internet users from China alone (World Bank 2012a), and in many other developing nations , mobile broadband has emerged as the main platform for the Internet (GSMA 2012).With strong take-up, mobile data traffic is increasing at a staggering rate, and more than doubled in 2010 (World Economic Forum & INSEAD 2012).

Mobile communications in general, and broadband in particular, have a strong influence on the economies of rural areas in developing nations, where three out of four of the world's poor reside. The expansion of broadband networks into these areas has created new opportunities for non-agricultural employment, better-paying agricultural jobs and greater overall productivity. Access to broadband has also fostered small-business growth, allowing people in remote areas to work from home, and enabling rural businesses to compete more effectively in national and global markets. (World Bank 2009) (See Box 8.4.4).

Impacts of the internet and broadband

Greater access and use of internet and broadband technologies impact economic growth in several ways. They facilitate more efficient business processes (such as marketing, inventory and supply chain management), and accelerate logistics and consumer-focussed innovation (ITU 2012). Other economic benefits of Internet and broadband penetration include lower costs of trade facilitation, which can improve access to foreign markets and international trade. The Internet economy has also generated a multitude of innovative internet based companies, led to the development of entirely new business models and provided the basis for a broad range of new products and services, as well as transforming how consumers shop and corporations source inputs and sell products. In 2009 the economic benefits of e-commerce were estimated at US $1.5 trillion, with expectations that it could reach US $3.8 trillion by 2020 (ITIF 2010).

Nonetheless, of the technologies, broadband is recognised as having the greatest impact on economic activity, productivity and employment, in both developed and developing nations. A 2009 study suggests that in developing nations a ten percentage point increase in broadband penetration can yield an additional 1.1 percentage points (ppt) of GDP growth (compared with 0.8ppt in developed nations), while for broadband it is an additional 1.4 percentage points (compared with 1.2ppt in developed nations) (Qiang et al 2009). Along with its direct impacts on GDP, increased broadband penetration also contributes to significant job growth. In Latin America and the Caribbean in 2012 a ten percentage point increase in broadband penetrations was estimated to generate 67,000 new jobs (Zaballos & Lopez-Rivas 2012). Another study suggests that a US$20 billion investment in third generation networks could benefit India's economy by US$70 billion within a decade, and generate up to 14 million jobs (World Economic Forum & INSEAD 2012).

Table 8.4.2 **Internet users - penetration**

	1993		2000		2006		2010		1993 to 2010	
	%	Million	%	Million	%	Million	%	Million	PPT* change	Million
Tropics	**0.01**	**0.23**	**1.5**	**35**	**6.4**	**215**	**16.5**	**471**	**16.6**	**473**
Central & Southern Africa	0.00	0.00	0.2	1	2.0	19	9.9	67	9.8	68
Northern Africa & Middle East	0.00	0.00	0.3	0	2.2	6	9.9	14	9.9	14
South Asia	0.00	0.00	0.5	3	2.2	20	7.4	57	7.4	56
South East Asia	0.02	0.12	2.5	17	9.2	80	22.7	173	22.6	173
Caribbean	0.00	0.00	2.8	1	12.1	5	23.4	9	23.5	9
Central America	0.02	0.02	4.1	5	14.1	20	26.4	34	26.5	36
South America	0.02	0.04	2.7	7	17.0	64	37.9	113	37.9	113
Oceania	0.51	0.04	11.3	1	17.8	2	21.2	3	20.7	3
Rest of the World	**0.30**	**9.66**	**9.7**	**355**	**21.8**	**916**	**38.0**	**1,520**	**37.8**	**1,520**
World	**0.20**	**9.89**	**6.4**	**390**	**15.6**	**1,131**	**29.1**	**1,991**	**29.0**	**1,992**

Source: ITU (2013), State of the Tropics project.
* Percentage point.

Mobile broadband quality and cost

Despite rapid improvements in mobile technologies there are still considerable differences between fixed and mobile broadband services, with a major one being the speed, capacity and applications that mobile services can support. This can mean that mobile services are not entirely suitable for intensive users, particularly for some businesses and institutions.

High-speed, reliable broadband is particularly important for the delivery of e-commerce and public services such as those related to education and health. The potential benefit of broadband-delivered services may therefore be constrained if they are delivered via mobile technologies, as is the situation in many developing nations in the Tropics. As applications become more bandwidth intensive it is anticipated that the broadband 'gap' will become a quality divide, and that people and businesses with low 'quality' broadband will be limited in their capability to generate economic and social benefits relative to those with higher quality services (World Economic Forum & INSEAD 2010).

Infrastructure and access costs however represent a real hurdle to the rollout and take-up of broadband technologies, especially in poorer developing nations in the Tropics, where broadband is still unaffordable for many people. Although affordability in many nations is increasing quite rapidly, the investment in handsets and other devices necessary to access mobile broadband can represent a considerable proportion of household income in many nations. For example, the basic costs of mobile telephony averages 7.5% of monthly GNI per capita in developing nations compared with 1.2% in developed nations. In Africa the figure is significantly higher at 16.7% (ITU & UNESCO 2011).

Internet security

A significant economic impact of Internet technologies has been the development of e-commerce. The largest e-commerce markets are in the United States, the United Kingdom and Japan at present, and e-commerce has been slow to drive economic growth in the Tropics.

In developing markets concerns over privacy, security, legal uncertainty concerning contracts and terms of delivery, and a lack of financial infrastructure have been identified as barriers to greater use of e-commerce. Cultural aspects have also affected the take-up of e-commerce in some developing nations.

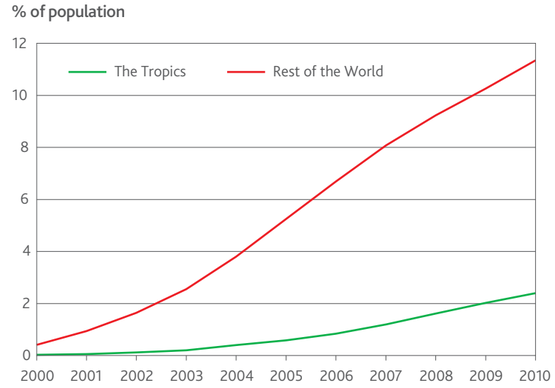
Identity theft and online fraud have followed the growth of e-commerce and, where security is inadequate or uncertain, have undermined user trust in e-commerce and other services. For example, in Thailand, despite strong growth in the number of Internet users between 2006 and 2007 there was a lack of a concomitant increase in e-commerce, and 71% of users had never made an online purchase due to a distrust of electronic payment systems and credit card security (UNCTAD 2007). Nonetheless, in many nations there is a strong commitment to improve Internet security to maximise economic and other benefits (see Box 8.4.5).

Security is emerging as one of the more critical impediments to the e-commerce divide between the Tropics and the Rest of the World with significant differences reported in the use of security technologies between the two regions. The use of secure servers – the principal method of protecting information transmitted online – is less prevalent in the Tropics, with the number of secure servers sitting at 10 per one million people in 2010 compared to 255 per one million people in the Rest of the World.

Looking forward

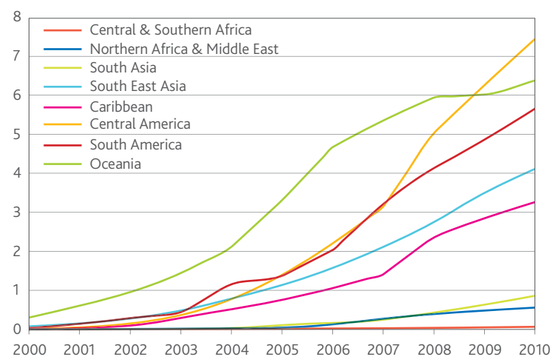
ICT innovation over the past three decades has been a story of empowerment and growth. The Internet in particular has transformed the way people communicate, conduct business, learn and socialise. Given its increasing importance in today's society, not just as a means of communication and source of information, but also in terms of cultural, economic and political development, efforts need to be made

Figure 8.4.5 **Fixed broadband internet subscribers**



Source: ITU (2012), State of the Tropics project.

Figure 8.4.6 **Fixed broadband internet subscribers – the Tropics**



Source: ITU (2012), State of the Tropics project.

Box 8.4.4 Bangladesh

Small scale farmers in Bangladesh represent an important component of the economy. Although experienced and knowledgeable due to generations of on land learning, these farmers generally operate outside of the information society which limits their ability to respond to changing markets and safeguard themselves against shocks (Katalyst 2012). The government has attempted to provide information via an agricultural advisory service. However, geography and lack of infrastructure have historically restricted access to this service for those living in remote rural communities.

The 'Katalyst' program is a joint venture between an international non-profit-organisation and a local telecommunications operator. Under the program, Community Information Centres have been set up across the rural areas of Bangladesh to provide local entrepreneurs with access to mobile phone and Internet services which in turn connect communities to previously inaccessible networks and communication (Katalyst 2012).

The combination of multiple technologies (Internet, call centres and mass media links), make it possible to provide high/volume, low cost services for the benefit of both the providers and the rural users. The majority of the Community Information Centres are profitable and generate a daily income of US$3-4 per day (I4D 2010). The program represents a shift in the mindset in the rural population in Bangladesh and allows farmers to access information quickly and cheaply. The programme has created an estimated 17,000 jobs in farms and small business, improved access to government helpline services and contributed to improved and safer incomes (I4D 2010).

Experimental farm, Bangladesh. Image: T Krupnik, CIMMYT.

Box 8.4.5 E-commerce in China

The take-up of e-commerce in China has been relatively slow, with concerns about digital piracy, identity theft and a lack of online payment options being significant roadblocks. Over half of the population cite privacy concerns as a major deterrent to online shopping, and of the 40 million small to medium enterprises in China in 2007, just 100,000 sold products online (ITIF 2010).

To address these low take-up issues a range of government and banking industry initiatives have been introduced to accelerate e-commerce capacity and growth. These have included developing laws, policies and technical standards. Specialised e-commerce supporting systems such as digital authentication and e-payments are also being developed to improve online payment options.

These developments, in combination with a rapidly growing Internet user base, have contributed to greater use of e-commerce. Between 2006 and 2009 the proportion of the population shopping online rose from 3% to 8%, but this is estimated to increase to 19% by 2012, with the value of online transactions projected to increase from US$37 billion in 2009 to US$100 billion in 2012 (ITU & UNESCO 2011). The majority of the growth in Internet and e-commerce has been in Beijing, Shanghai, and in Guangdong, which is located in the Tropics.

Guangzhou. Image: Ilya.

Table 8.4.3 **Fixed and active mobile broadband subscriptions (per 100 inhabitants)**

	1993		2000		2006		2010		1993 to 2010	
	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile
Africa	0.1	n.a.	0.2	1.8	0.2	4.7	0.3	7.1	0.3	10.9
Arab States	1.6	n.a.	1.9	5.1	2.1	10.8	2.6	14.3	3.3	18.9
Asia & Pacific	4.7	n.a.	5.5	7.4	6.4	11.2	6.9	15.8	7.6	22.4
CIS**	6.1	n.a.	8.2	22.3	9.8	31.3	11.3	36.0	13.5	46.0
Europe	22.2	n.a.	23.6	28.7	24.8	36.6	25.8	50.5	27.0	67.5
The Americas	13.1	n.a.	14.1	22.9	15.0	33.6	16.0	39.8	17.1	48.0

Source: ITU (2013).
* Estimate. ** Commonwealth of Independent States (formerly the USSR). n.a. not available.

to expand Internet connectivity in developing nations both globally and within the Tropics.

The convergence of mobile telephony into the broadband space signifies the possibility of ubiquitous Internet access for the first time. Although great success has been achieved as coverage and access has increased in the Tropics, the process is far from complete. Much of the Tropics' population continues to live outside the range of a mobile network, and there are indications that the annual increases in coverage over the past decade are starting to slow down. The challenge that now remains is how to extend broadband to communities that are not commercially profitable, most notably in rural areas. Tropical nations that fail to develop affordable broadband Internet services are likely to be at a social and economic disadvantage in the years to come as the world becomes increasingly interconnected.

To achieve the expansion of broadband requires top-level political leadership and joint efforts by the private sector and by governments. Most important of all, these efforts should be coordinated across all sectors of industry, administration and the economy. Developing isolated projects or piecemeal, duplicated networks, is not only inefficient; it also delays provision of infrastructure that is becoming as crucial in the modern world as roads or electricity supplies.

References

Andjelkovic M. (2010). The Future is Mobile: Why Developing Country Entrepreneurs Can Drive Internet Innovation, in *SAIS Review of International Affairs* **30**(2).

Bloomberg Business Week (2007). Upwardly mobile in Africa http://www.businessweek.com/magazine (accessed on 2 May 2013).

The Economist (2009). *Mobile Marvels.* A special report on telecoms in emerging markets. 26 September 2009.

Elbittar A. (2010). *Radio Spectrum Allocation and Management in Central American Countries and their Impact on the Development of the Mobile Telecommunications Services Sector.* Regional Dialogue on the Information Society, Lima.

GSMA (2011). Asia Pacific Mobile Observatory 2011. Driving Economic & Social Development through Mobile Broadband. Groupe Speciale Mobile Association, London.

GSMA (2012). Sub-Saharan Africa Mobile Observatory 2012. Groupe Speciale Mobile Association, London.

I4D (2010). Swisscontact and GTZ-International, Bangladesh: Information System for small business. Information for Development from: http://i4d.eletsonline.com/swisscontact-and-gtz-international-bangladesh/ (accessed 30 April 2013)

ITIF (2010). *The Internet Economy 25 Years After .com: Transforming Commerce & Life.* The Information Technology and Innovation Foundation, Washington DC.

ITU (2003). *Spectrum Management for a Converging World: Case Study on Guatemala.* International Telecommunication Union, Geneva.

ITU (2007). *Radio Spectrum Management.* International Telecommunication Union, Geneva.

ITU (2011). *Measuring the Information Society 2011.* International Telecommunications Union, Geneva.

ITU (2012). *Measuring the Information Society 2012.* International Telecommunications Union, Geneva.

ITU (2013). *Statistics.* International Telecommunications Union http://www.itu.int (accessed on 11 October 2013).

ITU & UNESCO (2011). *Broadband: A Platform for Progress.* International Telecommunications Union and United Nations Educational, Scientific and Cultural Organization.

Katalyst (2012) *Making ICT Work for Bangladesh's Farmers – the Katalyst Cases Number 6.* Katalyst, Dhaka.

Kelly S, Cook S, Truong M. (2012). *Freedom on the Net 2012. A Global Assessment of Internet and Digital Media.* Freedom House, Washington DC.

Madory D. (2013). *'Crecimiento'* in Latin America. http://www.renesys.com (accessed on 4 October 2013).

OECD (2012). *OECD Review of Telecommunication Policy and Regulation in Mexico.* OECD Publishing, Paris

OECD & ITU (2011). M-Government. *Mobile Technologies for Responsive Governments and Connected Societies.* Organisation for Economic Co-operation and Development and International Telecommunications Union, OECD Publishing, Paris.

Prieto JP. (2011). *Telecommunications Industry in Mexico: Performance and market structure analysis, and conflicts of interest prevailing between operators and authorities.* Mexican Institute for Competitiveness, Mexico City.

PwC (2011). *Indian Mobile Services Sector – struggling to maintain sustainable growth.* PricewaterhouseCoopers, India.

Qiang C, Rossotto C, Kimura K. (2009). Economic Impacts of Broadband, in World Bank, *Information and Communications for Development 2009: Extending Reach and Increasing Impact.* The World Bank, Washington DC.

Samanta SK, Woods J, Ghanbari M. (2009) *Language Diversity and its Impact on Internet Subsriptions* Working Paper – Unpublished.

Singh S. (2006). *The Diffusion of Mobile Phones in India.* India Institute of Technology, Kanpur.

UNCTAD (2007) *Information Economoy Report 2007-2008: Science and Technology for development: the paradigm of ICT* United Nations Conference on Trade and Development, Geneva.

UNCTAD (2009). *Information Economy Report 2009: Trends and Outlooks in Turbulent Times.* United Nations Conference on Trade and Development, Geneva.

UNCTAD (2011). *Information Economy Report 2011: ICTs as an Enabler for Private Sector Development.* United Nations Conference on Trade and Development, Geneva.

W3Techs (2013). *Usage of content languages for websites.* http://w3techs.com (accessed on 4 October 2013).

World Bank (2006). *Information and Communications for Development Global Trends & Policies.* The International Bank for Reconstruction and Development and The World Bank, Washington DC.

World Bank (2008). *Global Economic Prospects. Technology Diffusion in the Developing World.* International Bank for Reconstruction and Development and The World Bank, Washington DC.

World Bank (2009), *Information and Communications for Development: Extending reach and increasing impact.* The International Bank for Reconstruction and Development and The World Bank, Washington DC.

World Bank (2012a). *Information and Communications for Development 2012. Maximizing Mobile.* The International Bank for Reconstruction and Development and the World Bank, Washington DC.

World Bank (2012b). *ICT for Greater Development Impact. World Bank Group Strategy for Information and Communication Technology 2012-2015.* The World Bank, Washington DC.

World Economic Forum/ INSEAD. (2010). *The Global Information Technology Report 2009-2010: ICT for Sustainability.* World Economic Forum, Geneva.

World Economic Forum/ INSEAD. (2012). *The Global Information Technology Report 2012: Living in a Hyperconnected World.* World Economic Forum, Geneva.

Zaballos A, Lopez-Rivas R. (2012). *Socioeconomic Impact of Broadband in Latin America and Caribbean Countries.* Inter-American Development Bank, Washington DC.

Zhen-Wei Qiang C. (2009). Mobile Telephony: A Transformational Tool for Growth and Development, in *Private Sector and Development* **4.**

Women with mobile phone, India.
Image: Erik Newth.

Kalahari, Namibia.
Image: Vice.

Essay 5

Expansion of the Tropics – Evidence and implications

Dr Joanne Isaac

Joanne Isaac is currently a post-doctoral researcher in the Centre for Tropical Biodiversity and Climate Change, at James Cook University in Townsville. She completed a PhD in the life history of brushtail possums in 2005, and has since undertaken a number of post-doctoral positions and also writes freelance popular articles for a variety of magazines and other markets.

Professor Steve Turton

Steve is currently a Professor in Geography at James Cook University. He is honorary Treasurer of the Association for Tropical Biology and Conservation (ATBC), Asia-Pacific Chapter. In 2010 he was a member of the Engineering & Environmental Sciences Panel for the Australian Government's Excellence in Research Australia initiative. He is Immediate Past President of the Australian Council of Environmental Deans and Directors and President-elect of the Institute of Australian Geographers. He was an expert reviewer for Working Group II of the Intergovernmental Panel for Climate Change's Fifth Assessment Report. Steve's current research focuses climate change impacts and adaptation pathways for natural resource management in northern Australia.

Expansion of the Tropics

Dr Joanne Isaac & Professor Steve Turton.

There is accumulating evidence that the tropical zone is expanding poleward in both hemispheres, and that the subtropics are also expanding into regions which have previously enjoyed a more Mediterranean climate. This essay is a follow-up to an initial report by the same authors conducted in 2009; there has been considerable further work in this field since 2009 and so we include up-to-date research, investigate how thinking has changed, or not, and whether predictions from five years ago still hold true.

A poleward expansion of the tropical and subtropical zones is likely have significant consequences for a number of the issues raised in the State of the Tropics Report (2014), including the peoples of the Tropics, and for ecosystems and biodiversity.

For example, The State of the Tropics report highlights that the resources required to sustain larger populations and economic growth are putting significant pressures on the natural environment in tropical regions. An expansion of tropical regions will only increase these demands further, and may also cause a shift in ecosystems as some regions will become drier, and others may see more frequent heavy rain events.

The Report also highlights the fact that almost half the human population of the Tropics is vulnerable to water stress – a shift in climatic zones, and potentially drying in regions currently neighbouring the subtropics could increase the number of people who are at risk.

Furthermore, the State of the Tropics report finds that despite improvements in health and nutrition over the past 50 years, the Tropics still bears a 'disproportionate share of the global burden of many communicable and preventable diseases.' An expansion of the tropical zone could increase the prevalence of many diseases, particularly vector-borne diseases, as more areas become climatically suitable for insect vectors.

Introduction

Climate change is unequivocally one of the most important threats facing humanity and the environment (Williams et al. 2008; IPCC 2014). Documented changes already include warming of the atmosphere and ocean, melting of snow and land and sea ice, rise in sea levels and increases in concentrations of greenhouse gases (GHGs) to unprecedented levels (IPCC 2014). While some of the earliest signs of climate change included the warming of temperate regions and the melting of ice in the Arctic, a suite of studies have demonstrated significant impacts in tropical regions which are likely to be disproportionately affected (eg refs of some of the 'suite of studies'). The most recent IPCC Working Group II Report (2013) states that, with high-confidence 'relative to natural internal variability, near-term increases in seasonal mean and annual mean temperatures are expected to be larger in the Tropics and subtropics than in mid-latitudes'.

Additionally, long-term meteorological measurements indicate that climate-driven changes may be responsible for the expansion of the earth's tropical zone (reviewed by Seidel et al. 2008, IPCC 2013, Lucas et al. 2014).

The tropical zone is commonly defined as the portion of the Earth's surface that lies between the Tropic of Cancer at 23.5º north latitude and the Tropic of Capricorn at 23.5º south. The origin of this Cartesian definition lies in astronomy, as these lines mark the northern and southern-most points on the Earth where the sun reaches its zenith at solar noon during the boreal (June 21) and austral (December 21) summer solstices.

However, the definition of the Tropics varies among scientific disciplines, and climatologists use different indicators to define the boundaries of the Tropics, commonly based on surface temperature and precipitation patterns (Seidel et al. 2007). Another, easily tracked characteristic of the Tropics lies high above the Earth, at the boundary between the troposphere, the lowest layer of the earth's atmosphere where weather systems form, and the stable stratosphere above it. This boundary is known as the tropopause and is at its highest over the Tropics where it can reach 18 km in altitude, while over the poles it occurs at around 8 km. Thus, the height of the tropopause is another feature used by climatologists to define tropical regions. In general, climatologists and meteorologists estimate the boundaries of the Tropics extend further from the equator than the traditional Cartesian definition, to around 30º latitude north and south of the equator. This latitude roughly separates the generally slow moving tropical and subtropical air masses from the highly mobile air masses that typify the weather and climate of the mid-to-high latitudes.

The tropical zone is straddled by the less well-defined subtropical zone, the climatic region found adjacent to the Tropics, usually between 20 and 35 degrees latitude in both hemispheres, but occasionally found at slightly higher latitudes.

Tropical regions are characterised by a warm to hot climate, with comparatively smaller seasonal changes in day-to-day temperatures compared to other regions. Another important feature of the Tropics is the prevalence of rain in the moist inner regions near the equator – the 'deep Tropics' - which distinguishes tropical regions from the much drier conditions of the subtropics, where the world's major desert regions are located (Seidel et al. 2007). Seasonality of rainfall in the Tropics increases with distance from the equator.

How much has the tropical zone expanded?

In 2009, we reviewed a number of, then current, studies employing varying methodologies to measure the expansion of the tropical zone. For example, Hudson et al (2006) used long term satellite measurements of ozone concentration and estimated that the area of the northern hemisphere occupied by the Tropics had expanded by approximately 1º latitude per decade in the period 1979-2003 – a total widening of 2.5º. Fu et al. (2006), over the same time period, used satellite temperature observations from 1979-2005 and estimated a slightly lower widening of 2º latitude across both hemispheres, while Seidel and Randal (2007) - using data from weather balloons and climate models - estimated a significantly larger increase of between 5 to 8º in the same period.

Since our initial review, there have been a number of new studies that have estimated the total widening of the tropical zone, recently reviewed by Lucas et al. (2014). There are now at least 32 different estimates of the degree of expansion of the tropical zone - across different time periods (Figure E5.1). An updated mean of the estimates is slightly lower than in 2009, at around 0.5 – 1.0º per decade (summarised in Lucas et al. 2014). However, considerable variation is evident among the estimates, possibly in part due to the different methodologies that have been employed in the studies and the number of years comprising the data.

A thorough critique of these methodologies can be found in Lucas et al. (2014); however we will briefly review the four main ways researchers have estimated the degree of widening of the tropical zone:

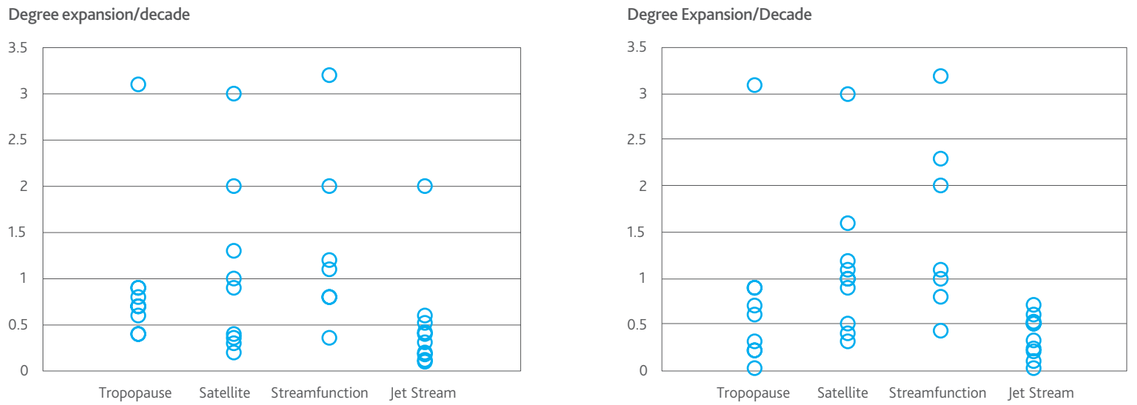
- Tropopause methods: this method uses the tropopause height frequency to estimate widening of the Tropics both vertically and horizontally. This method is sensitive to the choice of the tropical tropopause threshold and the definition of the tropical edge. Studies using this method generally estimate a horizontal widening of less than 1º latitude per decade, although there is some variation.

- Satellite methods: Various metrics, such as outgoing long-wave radiation from satellite-based platforms have also been used to investigate expansion. Differences between data sets are large using these methods, and estimates also often differ between the hemispheres – with greater widening seen in the southern hemisphere. Lucas et al. (2014) identify this method as likely to be most problematic.

- Stream-function methods: This metric is the edge of the Hadley Circulation (described below) derived from calculation of the (isobaric) mass stream-function. It generally gives a lower estimate of expansion, averaging less than 0.8º latitude widening per decade in both hemispheres, and shows seasonal differences.

- Jet Stream Methods: this method uses the change in the position of the various jet streams to estimate tropical expansion. Estimates using this method average the lowest of all the different methodologies, around 0.2º latitude per decade.

Figure E5.1 **Figure 1: Summary of studies which have provided an estimate of the degree of expansion of the tropical zone for a) the southern hemisphere, and b) the northern hemisphere (data collated from Lucas et al. 2014)**



Source: Lorem Ipsum

Thus, while evidence has continued to accumulate for the widening of the tropical zone, the estimates now suggest a lower degree of expansion than was reported in our 2009 review. In their recent review, which used all known published estimates, Lucas et al. (2014) found an average trend of 0.5 – 1.0º in latitude expansion per decade, translating to 1.25 – 2.5º per 25 years, or 138 – 277 km. This is much reduced from the estimate of 222 to 533 km per 25 years taken from studies we reviewed in 2009.

In 2006, Fu et al. (2006) also suggested a stronger longitudinal trend for an expansion of the tropical zone in the southern hemisphere, compared to the northern hemisphere. A number of more recent studies have also found a similar trend (i.e.: Lu et al 2009, Birner 2010, Davis and Rosenlof 2012), however this seems more common in studies utilising the troposphere method. Other studies have found the opposite, with the Northern Hemisphere having greater expansion (i.e.: Zhou et al 2011, Hu et al 2011, Hu and Fu 2007) – this seems to be most common in satellite-based studies. Theoretically, one would expect great expansion in the northern hemisphere due to its land dominance compared with the moderating influence of the Southern Ocean in the southern hemisphere. Currently any potential asymmetry in expansion between the north and southern hemispheres is still unclear and may be a methodological artifact.

In addition to observations of the poleward expansion of the tropical zone, studies also suggest that the height of the Tropics, as measured by the height of the tropical tropopause, has also increased by some tens of metres over the past few decades (Seidel and Randal 2007; Zhou et al. 2001; Santer et al. 2003). Taking all estimates into account, Seidel et al. (2008) proposes that the overall three-dimensional growth of the tropical zone over the 25 years prior to 2008 was around 5%.

However, measuring tropopause height is controversial, sensitive to methodology and also varies across seasons (Lucas et al. 2014). For example, a 2010 study by Birner found that using statistics of tropopause height to distinguish between Tropics and extratropics (areas outside the tropical zone) in studies was problematic, and that widening trends were particularly sensitive to changes in the tropopause height threshold.

Additionally, a number of studies have identified shifts and changes in intensity in tropical circulation systems and climatic phenomenon. The primary driver of the climate in the Tropics and sub-tropics is the Hadley Circulation (HC) system, which can be most simply explained as a large-scale overturning of the atmosphere in the tropical zone, driven by latitudinal heating gradients (Webster 2004). The HC system drives the trade winds - and the point at which the trade winds of the northern and southern hemisphere converge and rise is known as the intertropical convergence zone (ITCZ). The ITCZ is a high-precipitation band of thunderstorms and results in the high rainfall patterns typical of the tropical equatorial zone. Following the loss of water vapour over the equatorial Tropics, the descending air dries out and moves further north and south towards higher latitudes. As this dry air begins to sink back toward Earth's surface over the subtropics, it warms, driving evaporation. This is the mechanism leading to the dry conditions experienced in many subtropical regions.

In 2006, Hu and Fu found a poleward expansion of the HC of between 2.0 to 4.5º in each hemisphere since 1979, concluding that this implied a poleward shift of the tropical and subtropical zones. In a more recent analysis, Hu et al. (2011) find a smaller, but still significant expansion of the HC from 1979 -2009 of around 1.23º in latitude in both hemispheres, based on a number of different methods. Similarly, extensive re-analysis by Nguyen et al. (2013) showed an expansion of the HC in both hemispheres of around 1.6º latitude per decade. However they found that this expansion was seasonal and most pronounced and statistically significant during summer and autumn. Choi et al. (2014) recently found a significant poleward shift of the southern edge of the HC, during the austral summer (November-March), from the South Atlantic Ocean eastward to Australia. This is estimated to be equivalent to around 0.22º per decade from 1980 – 2012.

Sachs et al. (2009) indicated that the ITCZ had also moved poleward and was now located more than 500km farther away from the equator than previously; equivalent to a shift of around 4.5º in latitude. The authors estimate the ITCZ is moving poleward in the northern hemisphere at a rate of approximately 1.4 km per year (Sachs et al. 2009). A more recent analysis confirms that the ITCZ is extremely sensitive to high- and low-climate forcings (factors that influence climate – such as energy from the sun, volcanic eruptions, etc), and depending upon cooling or warming conditions, can migrate ± 7º in latitude from its usual position over the Atlantic Ocean (Arbuszewski et al. 2013). Thus, these estimates of the latitudinal expansion of the HC and ITCZ generally fit with studies which demonstrating an expansion of the tropical zone, but can be subject to methodological and temporal/seasonal variability.

Shifts in other climatic phenomenon have also been reported for the same period. For example, a number of studies show a longitudinal, westward extension of around 10º in the Western Pacific subtropical high (WPSH) over 30 years (Ho et al. 2004; Wu et al. 2005). This is significant, as the WPSH is the predominant driver of climate and precipitation patterns across Asia. Hu and Fu (2006) suggest that other changes in more regional circulation patterns, such as the WPSH, may also be contributing to the general expansion of the tropical zone.

Mechanisms behind a tropical expansion

In addition to a general lack of consensus regarding the magnitude of shift, there has also been considerable speculation regarding the proximate and ultimate mechanisms resulting in the widening of the tropical zone (Lucas et al. 2014).
In our initial review, research suggested a role for climate change in the expansion of the tropical zone, and associated changes in climatic events and circulations systems. At that time, the IPCC in their Fourth Assessment Report (2007) stated that increases in greenhouse gases and associated changes in climate could lead to a variety of changes in atmospheric and climatic phenomenon, including warming of the troposphere, cooling of the stratosphere, rise of the tropopause and a weakening of tropical circulation patterns – all of which may contribute to an expansion of the tropical zone. Hu and Fu (2006) further suggested that an increase in sea surface temperatures (SST) in the Tropics, associated with climate change, could result in an increase in the height of the tropopause and a wider HC.

Since then, numerous studies confirm that the tropopause is indeed warming (reviewed by Thorne et al. 2010), with the majority also suggesting a strong human influence (i.e.: Santer et al. 2013). As a result, the Fifth Assessment Report of the IPCC (IPCC 2013), is much clearer, and certain, on the warming of the troposphere, stating 'It is virtually certain that globally the troposphere has warmed since the mid-20th century. More complete observations allow greater confidence in estimates of tropospheric temperature changes in the extra-tropical Northern Hemisphere than elsewhere. There is medium confidence in the rate of warming and its vertical structure in the Northern Hemisphere extra-tropical troposphere and low confidence elsewhere.'

Anthropogenic factors are thought to influence the troposphere and other climate systems in a variety of ways, and many recent studies have focused on the role of GHG emissions (particularly CO_2), ozone depletion and aerosols in climate forcing and tropical expansion.

In 2009, Lu et al. used the height of the tropopause to characterise the tropical zone, and demonstrated that the observed widening of the Tropics can only be accurately replicated by an atmospheric general circulation model that includes direct radiative effects related to human GHG emissions and stratospheric ozone depletion.

More recent studies have attempted to clarify the relative role of GHGs and ozone depletion. A warming of the troposphere raises the height of the tropopause, as does a cooling of the stratosphere (the layer of the earth's atmosphere above the troposphere – approximately 50 km above the earth's surface). An initial report by Santer et al. (2003) provides support for warming of the troposphere and cooling of the lower stratosphere over the last four decades of the 20th century, and indicates that both of these changes in atmospheric temperature have contributed to an overall increase in tropopause height.

Essentially it is thought that the radiative forcing (the difference between energy from sunlight received by the Earth and energy radiated back to space) of GHGs cause upper trophospheric heating, and potentially stratospheric cooling, resulting in a poleward shift in the mid-latitude jetstream and an expansion of the HC (e.g.: Previdi and Polvani 2014). Evidence suggests that stratospheric ozone is being destroyed by a group of manufactured chemicals which contain chlorine and/or bromine. These ozone-depleting substances (ODS) are safe in the lower atmosphere, but float up into the stratosphere where they are broken apart by the intense ultraviolet light, releasing chlorine and bromine (IPCC 2013).

The contribution of aerosols in the expansion of the tropical zone has gained much attention in recent years, and of primary interest has been black carbon (BC); BC is formed by the incomplete combustion of fossil fuels and can cause global warming by absorbing heat in the atmosphere. It is also thought to reduce the ability to reflect sunlight, or albedo, when deposited on snow and ice. Aerosol forcing of the climate may be significant (Lucas et al. 2014), and may occur when heating associated with absorbing aerosols changes relative humidity and impacts the lifetime of clouds.

However, the relative contribution of GHGs, ozone depletion and BC aerosols in the expansion of the tropical zone and associated climatic forcings is still unclear, with studies finding conflicting results. In a recent analysis, Santer et al. (2013) find that warming of the troposphere is mainly driven by anthropogenic GHG emissions, while cooling of

New Britain.
Image:Michael Johnson.

the lower stratosphere is primarily attributable to human-caused stratospheric ozone depletion. Similarly, Lu et al. (2009) found the widening trend in the tropical zone could be attributed entirely to direct radiative forcing, in particular related to greenhouse gases and stratospheric ozone depletion, while Hu et al (2013) found that widening and poleward shift of HC are caused by anthropogenic forcings and particularly increasing GHGs.

Other studies implicate BC, with Rostatyn and Lohmann (2002) finding that the indirect aerosol effect has been found to potentially drive the observed southerly shift in the ITCZ, and BC has been implicated in a northward displacement of the ITCZ and a strengthening of the HC in the Northern Hemisphere (Wang 2007).

In a recent study published in *Nature* (Allen et al. 2012), BC and tropospheric ozone were found, in models, to better explain the observed expansion of the tropical zone in the Northern Hemisphere than were GHGs. The authors note that atmospheric heating in the mid-latitudes from BC and tropospheric ozone has generated a poleward shift of the tropospheric jets.

The role of increasing sea surface temperature (SST), due to climate change, remains unclear, with studies giving conflicting results. For example, Lu et al. (2009) conclude that SST forcing causes no significant change in the width of the Tropics, and even a contraction in some seasons. However, Allen et al. (2014) state that tropical expansion and contraction are influenced by sea surface temperature variability, which is associated with both the Pacific Decadal Oscillation (a long-lived El Niño-like pattern of Pacific climate variability) and anthropogenic aerosols.

Studies have also identified that natural events and natural variation can impact on the expansion of the tropical zone. Volcanic eruptions, which inject sulfur dioxide into the atmosphere, typically result in cooling on the earth's surface and in the lower atmosphere. They thus have the opposite effect of BC aerosols and absorb radiation – warming the lower stratosphere, and cooling and lowering the tropopause, and potentially thus contraction of the tropical zone (Santer et al. 2003; 2014). The IPCC (2013) stated that several small volcanic eruptions have contributed to radiative cooling from 2008-2011.

In summary, there is still no clear consensus on a single primary forcing mechanism behind the observed expansion of the tropical zone (Lucas et al. 2014). To date, studies and modeling indicate that several interacting factors are likely involved, including anthropogenic GHGs, black carbon and warming sea surface temperature. Volcanic eruptions may contribute to temporarily reverse expansion, and cause contraction.

The implications of an expansion of the tropical zone

The Tropics currently occupy approximately forty percent of the Earths land surface and are home to almost half of the world's human population, and account for more than 80% of the Earths terrestrial biodiversity (e.g. Rosenzweig 1995; State of the Tropics 2014). The majority of the world's endemic plants and animals are also found in the Tropics, where they are commonly adapted to the specific climatic conditions found there. Thus, the implications of a poleward expansion of the tropical and subtropical zones are immense and the effects could result in a variety of social, economic and environmental implications (Seidel et al. 2008), which will be discussed in the following sections.

Drought, drying and shifts in climatic zones

In our initial review, we highlighted a number of predicted scenarios from researchers investigating the observed expansion of the tropical zone. At that point in time (2009), the most important predicted consequence was the poleward extension of the subtropical dry zone - bringing drought conditions to regions which currently have a temperate climate with predicable winter rainfall (Seidel et al. 2008). Fu et al (2006) also demonstrated a robust pattern of warming in the mid-latitudinal region, from around 15 to 45° latitude in both hemispheres, indicative of a poleward shift which was predicted to lead to mid-latitude tropospheric warming and contribute to an increased frequency of droughts in both hemispheres (Fu et al. 2006; Seidel et al. 2008). Of particular concern under these predictions were regions bordering the subtropics which currently experience a temperate 'Mediterranean' climate, including heavily populated regions of southern Australia, southern Africa, the southern Europe-Mediterranean-Middle East region, the south-western United States, northern Mexico, and southern South America – all of which were predicted to experience severe drying (Seager et al. 2007; Seidel et al. 2008).

In 2009, the fingerprint of a poleward march of the subtropics into temperate regions was already becoming evident; climate models from the IPCC (2007) were predicting droughts for regions of the Mediterranean and the south-west of the US, while Seager et al. (2007) similarly forecast that southwestern North America would see an imminent shift to a more arid climate. The south-western state of California was, at that time, already in the grip of a multi-year drought (California Department of Water Resources 2008) and significant drying had been observed in the south-west of Western Australia over the previous 50 years, although other Mediterranean climates in Australia (e.g. South Australia) had experienced less significant declines (Bureau of Meteorology, Australia 2009).

More recent studies indicate that some of predictions may indeed be becoming a new reality. Shin et al. (2012) investigated the expansion of areas of dry climate, comprising steppe and desert climates, in relation to the observed intensification of the HC. They find some evidence of an expansion of these climatic zones from 1950 – 2000, concomitant with an enhanced intensity of the HC was enhanced, particularly during the boreal winter (Novermber – March) and conclude an observational linkage that connects desertification with intensification of Hadley Circulation. Polovina et al (2011) further project that the area of the subtropical region will expand by 30% by 2100.

There are also indications of an increase in drought conditions in areas bordering the subtropics. For example, in 2011, the USA state of Texas experienced its worst single-year drought in history, during a drought period beginning in 2010, and currently still continuing (e.g: Seager et al. 2014) – this drought has also affected the neighbouring state of New Mexico to the west. Severe drought conditions are also continuing to impact the state of California (Aghakouchak et al. 2014).

In south-western Western Australia, low rainfall persists and some regions recently experienced the lowest precipitation conditions on record (BOM 2014). Post et al. (2014) also confirm an ongoing expansion of the HC, of 0.5º latitude per decade, leading to a reduction in winter rainfall and run off in southern Australia. Cai et al. (2012) confirm that a poleward shift of the sub-tropical dry-zone explains most of the decline in rainfall in southeastern Australia during April-May. Increasing droughts have been noted also in the Mediterranean Basin (Hoerling et al. 2012), South America (Morales et al. 2012) and China (Ye 2013).

However, how much of this drying can be attributed to the expansion of the subtropical zone remains unclear. Cai et al. (2012) examined the role of tropical expansion on the drying trend apparent in some southern hemisphere regions during austral autumn (March-May). They found rainfall reduction coincided with a poleward expansion of the tropical and subtropical dry zones by around 2°–3° latitude in the same season. However, while their results show that a poleward shift of autumn rainfall may explain most of the southeastern Australia rainfall decline, it explains only a small portion of the southern Africa rainfall trend and none of autumn drying over southern Chile.

Eastman and Warren (2013) investigated changes in global cloud cover, and find a small decline of 0.4% per decade. However, the trend is primarily attributed to declining clouds in the middle latitudes – particularly across South America and Australia, which both showed continent-wide decreases in total cloud cover. They link cloud changes to the observed poleward shift of the jet streams in both hemispheres. Similarly, Polade et al. (2014) investigated the future increase in dry days in subtropical regions, concluding that many regions could see up to 30 more dry days per year by the end of this century, and that over most of the subtropics, the change in number of dry days dominates the annual changes in precipitation

A decline in visibility, due to an increase in conditions leading to smog, has also been associated with the intensification and westward extension of the WPSH in eastern China. A decline of 1.4 km of visibility per decade has been estimated, equivalent to 34% over 37 years, linked to more days with stable, hot and humid weather (Qu et al. 2013).

Recent studies also implicate some of the pollutants associated with tropical widening, such as the indirect aerosol effect and black carbon, as drivers of drought. For example, the indirect aerosol effect has been associated with a southward shift in the ITCZ, potentially associated with past Sahelian drought (a climate zone between the African savanna grasslands to the south and the Sahara desert to the north, across West and Central Africa; Rotstayn and Lohmann 2002). Changes in cloud type associated with the Indian monsoon are also consistent with the suggestion that BC could be affecting monsoonal precipitation and causing drought in northern India (Eastman and Warren 2013), while Turner and Annamalai (2012) found that BC could intensify the Asian summer monsoon.

If the dry subtropics belt expands into regions more used to a temperate, wet winter season, there will be consequences for water resources, natural ecosystems and agriculture, with cascading social and health implications (Fu et al. 2006; Seidel et al. 2008). In many tropical regions, more than 90% of the population works in agriculture and, since water dictates tropical agriculture, variability of climate may be responsible for economic weakness in such areas (Balek 1983). The State of the Tropics report (2014) notes that current water use patterns are considered unsustainable in many tropical regions; agriculture accounts for 81% of water withdrawals in the Tropics compared with 69% globally. Historical records show that higher growing season temperatures have dramatic impacts on agricultural productivity, farm incomes, and hence food security (Battisti and Naylor 2009). Thus, increasing drought could lead to large scale human migrations as people search for jobs, which may lead to overcrowding, violence, disease outbreaks and pressure on local resources in neighbouring areas (Matthew 2008). Droughts and global food crises have recently been implicated as a causal factor of riots and violence in a number of regions, including South Africa (Bar-Yam et al. 2013). Studies already demonstrate that climate change related drought in developing countries can result in the loss of human lives to hunger, malnutrition and diseases, the emergence of environmental refugees, and the collapse of national economies (Batterbury and Warren, 2001; Mortimore and Adams, 2001). For example, the Sahal region, which borders the southern edge of the Sahara desert in Africa, has seen a decline in per capita food production following drought, exposing many people to food insecurity and income poverty (Battersby and Warren, 2001).

However, while many regions are predicted to become hotter and drier, some may experience more rain. For example, studies suggested a poleward expansion of the ICTZ may also bring increased precipitation to areas at a greater distance from the equator, while areas close to the equator may receive less rainfall (Sachs et al. 2009) and also that wetter, higher-latitude regions may become wetter still and experience extreme rainfall events (Seager et al. 2007). In 2009, severe flooding affected the normally arid northeastern region of Brazil apparently due to an anomaly in the path of the ITCZ, while Southern Brazil was gripped by drought – events potentially related to the poleward movement of the ITCZ in the northeast and the expansion of the dry subtropics to the south.

Furthermore, due to the apparently simultaneous shift of other climatic events, such as the WPSH, some regions, particularly parts of Asia, actually appear to experience a cooling effect, rather

Bali.
Image: Andy Holt.

than the more widespread warming (Gong and Ho 2002, Hu et al. 2003, Fu et al. 2006). There is some evidence that the severe polar vortex affecting the north east USA - following drought in California - was influenced by GHG emissions and poleward shifts in other climatic phenomena (Wang et al. 2014).

Shifts in tropical cyclone tracks and activity

In 2009, a number of climate scientists were predicting a poleward shift in the paths of extra-tropical and tropical cyclones over the next 100 years (Yin 2005; IPCC 2007; Walsh and Kafney 1999). However, others were arguing that increased vertical wind shear and upper tropospheric warming might negate some effects (e.g.: Vecchi and Soden 2007). Extra-tropical storms, also known as mid-latitude cyclones, occur within the mid-latitudinal band from around 30º to 60º latitude in both hemispheres and studies have documented a poleward shift in the mean latitude of extra-tropical cyclones, by about 2º, over the past 60 years (McCabe et al. 2001; Fyfe 2003).

More recent studies add observational support for a change in storm tracks; for example Bender et al. (2012) find a poleward shift in extra-tropical storm tracks between 1983-2008, while Solman and Orlanski (2013) find an enhancement of the frontal activity shifted to higher latitudes in the northern hemisphere. Similarly, ozone depletion has been associated with a poleward shift in cyclone frequency over the Southern Ocean, but with minimal influence on intensity and lifetime (Grise et al. 2014). Significantly, a very recent study shows a poleward shift in the area of maximum intensity in cyclones in both the Northern and Southern hemispheres, of 53 and 62 km per decade respectively; equivalent to a shift of around 2.5º in latitude per 25 years (Kossin et al. 2014). Shifts in the behavior and tracks of cyclones in Australia have also been noted with tropical cyclone activity is currently at its lowest in Queensland and Western Australia for many centuries (Haig et al. 2014). However, Haig et al. (2014) caution that while there will be fewer cyclones, cyclones that do hit will be of higher intensity.

The shifts in tropical storm tracks have been related to enhanced warming in the tropical upper troposphere and increased tropopause height (Yin 2005); there is also some evidence that the degree of shift is likely to be greater in the mid-latitudes of the southern hemisphere (IPCC 2007; Yin 2005). Predictions were for greater cyclonic activity at higher latitudes in both the tropical and mid-latitude bands (IPCC 2007), increasing flood risk in regions not prepared for extreme precipitation events.

A change in the activity and tracks of tropical cyclones has been noted in some regions. For example, tropical cyclone Gonu tracked unusually far to the northwest into the Gulf of Oman in 2007, hitting landfall in Oman and Iran, a region with no known records of having been hit by a cyclone (WMO 2008). Similarly, in Asia there has been a significant westward shift in typhoon (cyclone) tracks over the past 40 years, resulting in greater storm activity in subtropical East Asia but a decline in typhoons over the South China Sea. 2004 saw a record number of storms hit Japan, while South China faced drought due to a lack of land falling typhoons, and the authors suggest this shift is related to the westward movement of the WPSH (Wu et al. 2005).

More recent studies highlight further changes in cyclone activity; black carbon and other aerosols have been implicated in causing intensification of cyclones in the Arabian Sea region, with significant impacts expected for human health (Evan et al. 2011). In Taiwan, cyclone frequency has almost doubled since 2000, consistent with a northward shift of the typhoon track over the western North Pacific-East Asian region, and an increase of typhoon frequency over the Taiwan-East China Sea; the authors associate these changes with the weakening of the Western North Pacific subtropical high (Tu et al. 2009). Finally, Murakami (2013) finds a decline in typhoon frequency over western Japan and the Korean peninsula, but an increase over eastern Japan, related to the southward shift of the subtropical jet stream.

The economic costs of increasing extreme weather events such as drought, extreme heat waves, flooding and destructive winds, could be considerable. Since the 1950s, the global costs of extreme weather events have risen by around six orders of magnitude, with much of the increase occurring since the late 1980s (UNEP 2005). The total cost of extreme weather events in the USA, in 2011, was estimated to be over US$53 billion, not including health care (NRDC 2011). Extreme weather events resulting in destruction of crops could also be considered a global food security issue (Brown and Funk 2008).

Impacts on biodiversity

Biodiversity is greater in the Tropics across most taxonomic groups, with an equivalently higher proportion of threatened species. For those plants and animals for which there are adequate data, loss of biodiversity is greater in the Tropics compared to the rest of the world (State of the Tropics 2014). The Tropics contains more biodiversity 'hotspots' (Myers 2000) and more endemic species than any other region. In 2009, there was accumulating evidence that many animal and plant species were moving poleward in an attempt to track their preferred climatic conditions (e.g. Parmesan and Yohe 2003) and since then documented range shifts have been reported in many species from many different taxa, including those in the Tropics (e.g.: Chen et al. 2011, Vanderwal et al. 2013).

In 2003, Parmesan and Yohe (2003) estimated that species around the globe had moved 6.1 km per decade towards the poles. Converting this to a 25 year average, in line estimates of the expansion of the Tropics in earlier sections, this means that most species were predicted to move only around 15 km, or 0.13 º in latitude – implying that the poleward movement of most plants and animals would lag behind the movement of climatic zones by at least 207 km, or 1.87º latitude based on the most conservative estimates at that time – which could potentially lead to species loss and extinction in the Tropics.

A more recent meta-analysis (Chen et al. 2011) found that - on average - species have moved at 16.9 km per decade, equivalent to 42.24 km or 0.38º latitude in 25 years – more than twice as fast as the estimate from Parmesan and Yohe (2003) in their seminal paper. Combined with the revised lower average estimates of the poleward shift of the tropical zone (see previous section), the lag between species and climate zones is now estimated to be at least 0.87º latitude or 96 km. While this indicates that plants and animals are shifting their range quicker than was previously thought, it still means they are lagging almost 100 km behind potential physical shifts in climate (and, as a result, vegetation) zones. However, the response of species to climate change is likely to be far more complex, and VanDerWal et al. (2013), using 60 years of Australian climatic data and changes in climatic niche space in 464 Australian birds, show that shifts in climatic niche space occur rapidly, and in multiple directions – not just poleward, as has been previously suggested. They suggest multi-directional shifts are related to both changes in temperature and precipitation patterns, and estimate that, if measured only in terms of poleward shifts, the fingerprint of climate change will be underestimated by an average of 26% in temperate regions of the continent, and 95% in tropical regions (VanDerWal et al. 2013).

Potential expansion of pests and disease

A further implication of the potential expansion of the tropical zone is the expansion of associated diseases and pests. Of particular concern has been the potential for an extension in the geographical range of vector-borne diseases such as malaria, dengue fever and Lyme's disease, as temperatures and precipitation patterns become more suitable for disease vectors including mosquitoes and ticks (Githeko et al. 2000; Kovats et al. 2001). In 2010 the Tropics region represented 96% of cases and 99% of deaths from malaria, and approximately 72% of dengue infections occur in the Tropics (State of the Tropics 2014), thus any expansion in the range of these diseases will have significant impacts. Githeko et al. (2000) propose that the greatest impact on transmission rates will occur at the extremes of the range at which transmission now occurs, suggesting an increase in occurrence in the subtropical regions bordering the tropical zone. Patz et al. (1998) modeled the potential spread of dengue carrying mosquitoes and conclude that endemic potential could increase by up to 47% in regions already at risk, and that incidence may increase first in those regions which currently border endemic zones in either latitude or altitude. The greatest increase in the annual epidemic potential of dengue was forecast to occur in subtropical regions, including the southern United States, China and Northern Africa in the northern hemisphere, and South America, southern Africa, and most of Australia in the southern hemisphere.

In 2009, the evidence supporting actual changes in disease transmission rates and geographic range was limited, particularly in the case of malaria (e.g.: Hay et al 2002; Reiter 2005). At that time, many models were predicting an increase in occurrence and the range of disease vectors with increasing temperatures. However, since mosquitoes and ticks can desiccate easily and die under dry conditions (WHO 2003), regions predicted to become more arid as a result of tropical expansion may in fact be less at risk. Despite this, there was some evidence accumulating for an increase in the occurrence of tick-borne disease and dengue fever outside of the normal range - tick-borne encephalitis in Sweden had shown an increase in recent years and had been linked to milder temperatures (Lindgren and Gustafson 2001). Gatewood et al. (2009) also proposed that milder temperatures will result in more virulent strains of Lyme disease in North America while the World Health Organization recorded the extension of dengue fever into 15 new locations, including Hawaii, Nepal and Bhutan, in the period from 2000-2008.

More recent peer-reviewed studies reveal a stronger indication that disease vectors may be expanding their geographical range. For example, Lambrechts et al. (2010) state that the mosquito Aedes albopictus has dramatically expanded its geographic range over the past three decades, with implications for a variety of arthropod-borne viruses that it can carry, including dengue fever. There has also been a reemergence of dengue fever in Florida, since 2009 (Radke et al. 2012). There are also a number of studies which show an increase in range for tick species which carry Lyme disease. For example, the primary tick vector of Lyme disease in North America, *Ixodes scapularis*, has expanded

its range northward from the USA to colonise new regions in southern Canada; the authors state that this expansion is likely related to climatic warming (Leighton et al. 2012). Milder, shorter winters are also favouring the northern expansion of the white-footed mouse in Quebec, which is an important reservoir host for *Borrelia burgdorferi*, the pathogen responsible for Lyme disease (Roy-Dufresne et al. 2013). A similar picture has been found in Europe, where the range of the tick vector *Ixodes ricinus* is predicted to spread across northern Scandinavia, due to climate warming, and eventually encompass most of Sweden, Norway and Finland (Jaenson and Lindgren 2010).

Tonnag et al. (2010) have predicted a redistribution of malaria vectors in Africa based on climate change scenarios, with shifts in species boundaries expected southward and eastward. A recent study also provides evidence for an increase in the altitude of malaria distribution during warmer years in the highlands of Ethiopia and Columbia, implying that warming conditions could result in an increase of malaria in densely population highland regions of Africa and South America (Siraj et al. 2014).

Dengue hemorrhagic fever kills up to 12,000 people a year, mainly children, and the annual economic cost in the Americas and Asia of dengue fever is around US$1.8 billion (Suaya et al. 2009). Githeko et al. (2000) propose that human settlement patterns in different regions will influence disease trends and that health risks will differ between countries that have developed health infrastructures and those that do not.

Conclusions and summary

In 2009, we found there was accumulating evidence for the expansion of the tropical zone in both hemispheres. At that time, the Tropics were estimated to be expanding by between 222 to 533 km per 25 years, taken from studies we reviewed. In the five years since that report, evidence has continued to amass pointing to a tropical expansion, and more robust methodologies have been developed and critiqued. An estimate from more than 30 studies now puts the rate of tropical expansion somewhere between 1.25 – 2.5º, or 138 – 277 km, per 25 years. Thus more recent studies tend to agree on a lower, but nonetheless significant, rate of expansion. However there is still disparity among estimates, most likely due to different methodologies used in estimates.
In our earlier report, the drivers of the tropical expansion were very unclear, but recent research has identified that the primary drivers are likely to be greenhouse gases, black carbon, aerosols and other man-made pollutants, though this is expected to be an area of research that sees further developments in the near future.

The implications of a poleward tropical expansion are significant; subtropical arid, conditions may be seen in regions at higher latitudes which have historically enjoyed a more temperate climate, with implications for management of water resources and agricultural systems. However, some regions which currently border the equatorial zone may experience an increase in extreme rainfall, which could result in flooding, the displacement of communities and increased incidence of disease.

The poleward expansion of the Tropics appears to be linked to a concomitant expansion in the tracks of tropical cyclones, potentially bringing cyclonic activity to regions which have previously not experienced such weather events. Changes to the tracks and activity of cyclones, and other extreme weather events, will impact on human health, biodiversity and the economy. The burden of vector-borne diseases on health and the economy of the Tropics may also increase as more regions become climatically suitable for insect vectors.

The Tropics are the most biodiverse region on earth, with more endemic species and more biodiversity 'hotspots' than anywhere else. However research suggests that although many species are tracking climate changes, species in the Tropics may be lagging behind the rate of tropical expansion – meaning some species may not be able to sufficiently track their preferred environment and climate and may potentially risk extinction.

Steenbok, Kalahari.
Image: Frank Vassen.

References

AghaKouchak A, Feldman D, Stewardson MJ, Saphores JD, Grant S, Sanders B. (2014) Australia's drought: lessons for California. *Science*, **343** (6178), 1430-1431.

Arbuszewski JA Cléroux C, Bradtmiller L, Mix A. (2013) Meridional shifts of the Atlantic intertropical convergence zone since the Last Glacial Maximum. *Nature Geoscience,* **6**(11), 959-962.

Allen RJ, Sherwood SC, Norris JR, Zender, CS (2012) Recent Northern Hemisphere tropical expansion primarily driven by black carbon and tropospheric ozone. *Nature* **485:**350–354.

Balek J. (1983) *Hydrology and water resources in tropical regions.* Elsevier Press.

Bar-Yam T, Lagi M, Bar-Yam Y. (2013) South African riots: Repercussion of the global food crisis and US drought. arXiv preprint arXiv:1307.5268.

Batterbury S, Warren A. (2001) The African Sahel 25 years after the great drought: assessing progress and moving towards new agendas and approaches. *Global Environmental Change* **11:** 1-8.

Battisti DS, Naylor RL. (2009) Historical warnings of future food insecurity with unprecedented seasonal heat. *Science* **323**(5911), 240-244.

Bender FA, Ramanathan V, Tselioudis G. (2012) Changes in extratropical storm track cloudiness 1983–2008: observational support for a poleward shift. *Climate Dynamics* **38**(9-10), 2037-2053.

Birner T. (2010) Recent widening of the tropical belt from global tropopause statistics: sensitivities. *Journal of Geophysical Research*, 115: D23109.

Bureau of Meteorology - http://www.bom.gov.au/climate/drought/

Brown MEE, Funk CC. (2008) Climate: food security under climate change. *Science*, 5863, 580-581.

Cai W, Cowan T, Thatcher M. (2012) Rainfall reductions over Southern Hemisphere semi-arid regions: the role of subtropical dry zone expansion. *Scientific Reports,* 2.

California Department of Water Resources (2008) *California drought: an update.*

Choi J, Son SW, Lu J, Min SK. (2014) Further observational evidence of Hadley cell widening in the Southern Hemisphere. *Geophysical Research Letters*, **41**(7), 2590-2597.

Chen IC, Hill JK, Ohlemüller R, Roy DB, Thomas CD. (2011) Rapid range shifts of species associated with high levels of climate warming. *Science*, **333**(6045), 1024-1026.

Davis NA, Birner T. (2013) Seasonal to multi-decadal variability of the width of the tropical belt. *Journal of Geophysical Research.* **118**:7773–7787.

Davis SM, Rosenlof, KH (2012) A multi-diagnostic intercomparison of tropical width time series usingreanalyses and satellite observations. *Journal of Climatology,* **25**, 1061-1078.

Eastman R, Warren SG. (2013) A 39-Yr Survey of Cloud Changes from Land Stations Worldwide 1971-2009: Long-Term Trends, Relation to Aerosols, and Expansion of the Tropical Belt. *Journal of Climate,* **26**(4).

Evan AT, Kossin, JP, Ramanathan V. (2011) Arabian Sea tropical cyclones intensified by emissions of black carbon and other aerosols. *Nature,* 479 (7371), 94-97.

Fu Q, Johanson CM, Wallace JM, Reichler T. (2006) Enhanced mid-latitude tropospheric warming in satellite measurements. *Science* **312**, 1179.

Fu Q, Lin P. (2011) Poleward shift of subtropical jets inferred from satellite-observed lower-stratospheric temperatures. *Journal of Climatology* **24**:5597–5603.

Fyfe, JC. (2003) Extratropical Southern Hemisphere cyclones: Harbingers of climate change? *Journal of Climate,* **16**, 2802-2805.

Gatewood AG, Liebman KA, Vourc'h G, et al. (2009) Climate and Tick Seasonality Are Predictors of Borrelia burgdorferi Genotype Distribution. *Applied and Environmental Microbiology*, **75**, 8, 2476-2483.

Githeko AK, Lindsay SW, Confalonieri UE, Patz JA. (2000) Climate change and vector-borne diseases: a regional analysis. *Bulletin of the World Health Organization,* **78**(9), 1136-1147.

Gong D, Ho C. (2002) Shift in the summer rainfall over the Yangtze River valley in the late 1970s, *Geophysical Research Letters*, 29(10), 1436,

Grise KM, Son SW, Correa GJ, Polvani L M. (2014) The response of extratropical cyclones in the Southern Hemisphere to stratospheric ozone depletion in the 20th century. *Atmospheric Science Letters*, 15(1), 29-36.

Hay SI, Cox J, Rogers DJ et al (2002) Climate change and the resurgence of malaria in the East African highlands. *Nature,* **415**(6874), 905-909.

Ho CH, Baik JJ, Kim JH et al. (2004) Interdecadal changes in summertime typhoon tracks. *Journal of Climate,* 9, 1767-1776.

Hoerling M, Eischeid J, Perlwitz J, Quan X, Zhang T, Pegion P. (2012) On the Increased Frequency of Mediterranean Drought. *Journal of Climate,* **25**(6), 2146-2161.

Hu ZZ, Yang S, Wu RG (2003) Long-term climate variations in China and global warming signals. *Journal of Geophysical Research – Atmospheres,* **108**, 4614.

Hu Y, Fu Q. (2007) Observed poleward expansion of the Hadley circulation since 1979. *Atmospheric Chemistry and Physics.* **7a**, 5229–5236.

Hu Y, Tao L, Liu J. (2013) Poleward expansion of the Hadley circulation in CMIP5 simulations. *Advances in Atmospheric Sciences,* **30**, 790-795.

Hu Y, Zhou C, Liu J. (2011) Observational evidence for the poleward expansion of the Hadley circulation. *Advanced Atmospheric Science* **28**:33–44.

Hudson RD (2012) Measurements of the movement of the jet streams at mid-latitudes, in the Northern and Southern Hemispheres, 1979 to 2010. *Atmospheric Chemistry and Physics* **12**:7797–7808.

Hudson RD, Andrade MF, Follette MB, Frolov AD. (2006) The total ozone field separated into meteorological regimes – Part II: Northern Hemisphere mid-latitude total ozone trends. *Atmospheric Chemistry and Physics.* **6**, 5183–5191.

References | Continued

Intergovernmental Panel on Climate Change (2007) *Climate change 2007: the physical science basis.* Contribution of working group I to the fourth assessment report of the IPCC.

Intergovernmental Panel on Climate Change (2013) *Climate change 2013: the physical science basis.* Contribution of working group I to the fifth assessment report of the IPCC.

Intergovernmental Panel on Climate Change (2014) *Climate change 2014: Impacts, Adaptation and Vulnerability.* Contribution of working group II to the fifth assessment report of the IPCC.

Jaenson TG, Lindgren E. (2011) The range of *Ixodes ricinus* and the risk of contracting Lyme borreliosis will increase northwards when the vegetation period becomes longer. *Ticks and Tick-Borne Diseases,* **2**(1), 44-49.

Kossin JP, Emanuel KA, Vecchi GA. (2014) The poleward migration of the location of tropical cyclone maximum intensity. *Nature,* **509**, 349-352.

Kovats RS, Campbell-Lendrum DH, McMichael AJ, Woodward A , St H, Cox J. (2001) Early effects of climate change: do they include changes in vector-borne disease? *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences,* **356**, 1057-1068.

Lambrechts L, Scott TW, Gubler DJ. (2010) Consequences of the expanding global distribution of Aedes albopictus for dengue virus transmission. *PLoS Neglected Tropical Diseases.* **4**(5), e646.

Lindgren E, Gustafson R. (2001) Tick-borne encephalitis in Sweden and climate change. *Lancet,* **358**, 16-18.

Lu J, Deser C, Reichler T. (2009) Cause of the widening of the tropical belt since 1958. *Geophysical Research Letters,* **36**, L02803.

Lucas C, Nguyen H, Timbal B. (2012) An observational analysis of Southern Hemisphere tropical expansion. *Journal of Geophysical Research* **117**:D17112.

Nguyen H, Evans A, Lucas C, Smith I, Timbal B. (2013) The Hadley circulation in reanalyses: climatology, variability and expansion. *Journal of Climatology* **26**:3357–3376.

Leighton PA, Koffi JK, Pelcat Y, Lindsay, LR, Ogden NH. (2012) Predicting the speed of tick invasion: an empirical model of range expansion for the Lyme disease vector Ixodes scapularis in Canada. *Journal of Applied Ecology,* 49(2), 457-464.

Lucas C, Timbal B, Nguyen H. (2014) The expanding tropics: a critical assessment of the observational and modeling studies. *WIREs Climate Change,* **5**, 89-112.

Matthew, R. (2008) "Threat Assessment." In *Global Climate Change National Security Implications.* Carolyn Pumphrey, ed. The Strategic Studies Institute, U.S. Army War College.

McCabe GJ, Clark MP, Serreze, MC (2001) Trends in Northern Hemisphere surface cyclone frequency and intensity. *Journal of Climate*, **14**, 2763-2768.

Morales, M. S., Christie, D. A., Villalba, R., Argollo, J., Pacajes, J., Silva, J. S., Alvarez, C.A., Llancabure, J.C., Gamboa, C. C. (2012) Precipitation changes in the South American Altiplano since 1300AD reconstructed by tree-rings. *Climate of the Past,* **8**(2), 653-666.

Mortimore MJ, Adams WM, (2001) Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change* **11**: 49–57.

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, **403**(6772), 853-858.

NRDC (2011) http://www.nrdc.org/health/climate/extreme-weather.asp

Patz AP, Martens WJM, Focks DA, Jetten TH. (1998) Dengue fever epidemic potential as projected by general circulation models of global climate change. *Environmental Health Perspectives,* 106, 147-153.

Parmesan, C., Yohe, G. (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature,* **421**(6918), 37-42.

Polade PD, Pierce DW, Cayan DR, Gershunov A, Dettinger MD. (2014) The key role of dry days in changing regional climate and precipitation regimes. *Scientific reports,* **4**.

Post DA, Timbal B, Chiew FHS, Hendon HH, Nguyen H, Moran R. (2014) Decrease in southeastern Australian water availability linked to ongoing Hadley cell expansion. *Earths Future,* **2**, 231-238.

Polovina JJ, Dunne JP, Woodworth PA, Howell EA. (2011) Projected expansion of the subtropical biome and contraction of the temperate and equatorial upwelling biomes in the North Pacific under global warming. *ICES Journal of Marine Science: Journal du Conseil,* **68**(6), 986-995.

Previdi M, Polvani LM. (2014) Climate system response to stratospheric ozone depletion and recovery. *Quarterly Journal of the Royal Meterological Society.*

Qu W, Wang J, Gao S, Wu T. (2013) Effect of the strengthened western Pacific subtropical high on summer visibility decrease over eastern China since 1973. *Journal of Geophysical Research: Atmospheres,* **118**(13), 7142-7156.

Radke EG, Gregory CJ, Kintziger KW, Sauber-Schatz EK., Hunsperger EA, Gallagher GR. Blackmore CG. (2012) Dengue outbreak in key west, Florida, USA, 2009. *Emerging Infectious Diseases,* **18**(1), 135.

Reiter P. (2005) Climate change and mosquito-borne disease. *Environmental Health Perspectives,* **109,** (S1), 141-161.

Rosenzweig, ML. (1995) *Species diversity in space and time.* Cambridge University Press.

Rotstayn LD, Lohmann U. (2002) Tropical rainfall trends and the indirect aerosol effect. *Journal of Climate,* 15, 15, 2103.

Roy-Dufresne E, Logan T, Simon JA, Chmura GL, Millien V. (2013) Poleward expansion of the white-footed mouse (Peromyscus leucopus) under climate change: Implications for the spread of lyme disease. *PloS one*, 8(11), e80724.

Sachs J, Stege M, Keju T. (2009) Recent movements of the ITCZ in the tropical Pacific and ramifications for the Marshall Islands. *IOP Conference Series: Earth and Environmental Sciences,* **6**, 072010.

Santer BD, Painter JF, Bonfils C et al. (2013) Human and natural influences on the changing thermal structure of the atmosphere. *Proceedings of the National Academy of Sciences.* **110**, 17235-17240.

Santer BD, Bonfils C, Painter JF. et al. (2014) Volcanic contribution to decadal changes in tropospheric temperature. *Nature Geoscience.* **7**, 185-189.

Santer BD, Wehner MF, Wigley TML et al., (2003) Contributions of anthropogenic and natural forcing to recent tropopause height changes, *Science*, **301**, 479-483.

Seager R, Godard, L., Nakamura, J., Henderson, N., Lee, D.E. (2014) Dynamical causes of the 2010/11 Texas-Northern Mexico drought. *Journal of Hydrometeorology,* **15**, 39-68.

Seager R, Ting MF, Held I et al.(2007) Model projections of an imminent transition to a more arid climate in southwestern North America. *Science,* **316**, 1181-1184.

Seidel DJ. Fu Q. Randel WJ. Reichler TJ. (2008) Widening of the tropical belt in a changing climate *Nature Geoscience* **1**, 21 – 24.

Seidel DJ, Randel WJ. (2007) Recent widening of the tropical belt: evidence from tropopause observations. *Journal of Geophysical Research – Atmospheres,* **112** (D20), D20113.

Shin SH, Chung IU, Kim HJ. (2012) Relationship between the expansion of drylands and the intensification of Hadley circulation during the late twentieth century. *Meteorology and Atmospheric Physics,* **118**(3-4), 117-128.

Siraj AS, Santos-Vega M, Bouma MJ, Yadeta D, Carrascal DR, Pascual, M. (2014) Altitudinal changes in malaria incidence in highlands of Ethiopia and Colombia. *Science,* **343**(6175), 1154-1158.

Solman SA, Orlanski I. (2013) Poleward shift and change of frontal activity in the Southern Hemisphere over the last 40 years. Journal of the *Atmospheric Sciences,* **71**, 539–552.

State of the Tropics (2014) *State of the Tropics 2014 report.* James Cook University, Cairns, Australia.

Suaya JA, Shepard DS, Siqueira JB. et al. (2009) Cost of Dengue Cases in Eight Countries in the Americas and Asia: A Prospective Study. *American Journal of Tropical Medicine and Hygiene.* **80**, 846-855.

Thorne PW, Lazante JR, Petrson TC, Seidel DJ, Shine KP (2010) Tropospheric temperature trends: history of an ongoing controversy. *WIREs Climate Change,* **2**, 66-88.

Tonnag HEZ, Kangalawe RYM, Yanda PZ (2010) Predicting and mapping malaria under climate change scenarios: the potential redistribution of malaria vectors in Africa. *Malaria Journal,* **9**, 111.

Tu JY, Chou C, Chu PS (2009) The Abrupt Shift of Typhoon Activity in the Vicinity of Taiwan and Its Association with Western North Pacific–East Asian Climate Change. *Journal of Climate,* **22**(13).

Turner AG Annamalai H. (2012) Climate change and the South Asian summer monsoon. *Nature Climate Change,* **2**(8), 587-595.

VanDerWal J, Murphy HT, Kutt A, Perkins G, Bateman B, Perry J , Reside A. (2013) Focus on poleward shifts in species' distribution underestimates the fingerprint of climate change. *Nature Climate Change,* 3, 239 – 243.

Vecchi GA, Soden BJ. (2007) Global warming and the weakening of the tropical circulation. *Journal of Climate,* **20**(17).

Walsh KJE, Katzfey J. (1999) The impact of climate change on the poleward movement of tropical cyclone-like vortices in a regional climate model. *Journal of Climate,* **13**, 1116-1132.

Wang C. (2007) Impact of direct radiative forcing of black carbon aerosols on tropical convective precipitation. *Geophysical research letters,* **34**(5), L05709.

Wang S-Y, Hipps L, Gillies RR, Yoon J-H. (2014) Probable causes of the abnormal ridge accompanying the 2013–2014 California drought: ENSO precursor and anthropogenic warming footprint. *Geophysical Research Letters.*

Webster PJ. (2004) The elementary Hadley circulation, In – *The Hadley Circulation: Present, Past and Future* (ed. HF Diaz & RS Bradley). Kluwer Academic Press.

Williams SE, Shoo LP, Isaac JL, Hoffman AA, Langham G. (2008) Towards and integrated framework for assessing vulnerability of species to climate change. *PLoS Biology,* 6, 2621-2626.

World Health Organization (2003) *Climate Change and Human Health: Risks and Responses* (Ed. A. J. McMichael et al).

World Meteorological Organization (2008) *World Climate News,* No.33.

Wu L, Wang B, Geng S. (2005) Growing typhoon influence on East Asia. *Geophysical Research Letters,* **32**, L18703.

Ye J-S. (2013) Trend and variability of China's summer precipitation during 1955-2008. *International Journal of Climatology,* **34**, 3, 559-566.

Yin, JH. (2005) A consistent poleward shift of the storm tracks in simulations of 21st century climate. *Geophysical Research Letters,* **32**, L18701.

Zhou WJ, Head MJ, Deng L. (2001) Climate changes in northern China since the late Pleistocene and its response to global change. *Quaternary International,* **83-5**, 285-292.

Zhou YP, Xu K-M, Sud YC, Betts AK. (2011) Recent trends of the tropical hydrological cycle inferred from Global Precipitation Climatology Project and International Satellite Cloud Climatology Project data. *Journal of Geophysical Research.* **116**:D09101.

Mandalay.
Patrik M Loeff.

Mandalay.
Image: Dieter Zirnig.w

Appendices

Appendix A: Data sources for each indicator, including temporal coverage (in years) and additional notes regarding data coverage and limitations

The Ecosystem

Domain	Indicator	Data Source	Data coverage (years)	Notes
Atmosphere	Carbon dioxide emissions (CO_2)	World Resources Institute's Climate Analysis Indicators Tool (CAIT). European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency.	1950 - 2008	CO_2 totals are emissions from fossil fuels and cement manufacture. The latest version of the dataset includes greenhouse gas data for 1990 to 2005 for most countries of the world.
	Greenhouse gas emissions (GHG)	World Resources Institute's Climate Analysis Indicators Tool (CAIT). European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency.	1990 - 2005 for most countries of the world.	GHG emissions are a sum of data from individual sectoral emissions but it's Important to note that GHG exclude emissions associated with land use, land-use change, the forestry sector due to high levels of data uncertainties. Missing nations include Somalia, Fed States Micronesia, Hong Kong, New Caledonia, Puerto Rico, French Polynesia, Tuvalu, Macau and Timor Leste, Reunion, Palau.
	Energy supply from fossil fuels	Energy Information Administration – International Energy Statistics	1980 - 2010	Due to distribution networks of power supply, power supply was apportioned by population.
	Air pollution	World Bank Development Indicators For sub-national data for those countries that straddle the tropic / temperate divide data from the World Bank, (Development Economics Research Group Estimates) and WHO (Urban Outdoor Air Pollution Database)	1990 - 2010	At sub-national level for tropical straddlers is the PM_{10} concentration weighted by the proportion of city population relative to total population. For intervening years – data is year weighted between 1999 and 2008. Pre- & post- 1999 and 2008 data is used. For the non-tropical proportion of the straddlers, the national concentration is used.
Land and Water	Land degradation	World Soil Information	1981 - 2003	No degradation was noted for the following places, probably due to resolution of the data derived from satellite imagery: Fiji, French Polynesia, Hawaii, Kiribati, Marshall Islands, Micronesia, Palau, Samoa, Tonga, Tuvalu, Antigua & Barbuda, Barbados, Saint Kitts & Nevis, Saint Lucia, St Vincent & Grenadines, Maldives, Mauritius, Seychelles
	Agricultural land	Food and Agricultural Organisation of the United Nations – FAO Stat	1980 - 2009	There are no data for cattle and sheep/goat for American Samoa, British Virgin Islands, Cayman Islands, Cook Islands, French Guiana, Guadeloupe, Guam, Martinique, Montserrat, Netherlands Antilles, Niue, Reunion, United States Virgin Islands, Wallis and Futuna Islands
	Renewable water resources (RWR)	Food and Agricultural Organisation of the United Nations – Aquastat database	Long term average.	RWR data divided by population data. Straddling nations were calculated based on RWR by tropical population.
Oceans	Wild marine catch	FAO – Fishstat	1950 - 2010	No data available for: Mayotte, Reunion, Anguilla, Aruba, British Virgin Islands, Caymans Islands, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos Is., US Virgin Islands, French Guiana, American Samoa, Cook Islands, Guam, Nauru, Niue, Northern Mariana Is., Tokelau, Wallis and Futuna Islands
	Aquaculture	FAO – Fishstat	1950 - 2010	Due to difficulties in discriminating data at sub-national levels to marine and inland waters, data are aggregated to total aquaculture only.
	Coral	Bryant et al. (1998); Burke et al (2011)	1998 & 2010	The data for 1998 Reefs at Risk and 2010 Reefs at Risk Revisited assessed integrated threat slightly differently. In the 2011 data set reefs assessed at very high risk were aggregated with reefs at high risk to allow direct comparison with 1998 data. Both assessed the integrated local threats to reefs from coastal development, marine-based pollution & damage, watershed-based pollution and overfishing or destructive fishing practices (eg cyanide, explosives). See the data source publications for more detail.
	Mangroves	Food & Agriculture Organisation (2007). The world's mangroves 1980-2005. FAO Forestry paper 153, Rome.	1980 - 2005	Nations excluded due to limited data availability: Wallis & Futuna Is, American Samoa, Aruba, Bahamas, Cayman Islands, Turks & Caicos Islands, US Virgin Islands, British Virgin Islands, Guam, Nauru, Niue, Northern Mariana Is, Tokelau, Mayotte, Guadeloupe, Martinque, Montserrat, Netherlands Antilles, French Guiana, Grenada. No mangroves in Hawaii according to Spalding (2010)
Biodiversity	Biodiversity & Threatened Species	International Union for the Conservation of Nature – Red List of Threatened Species 2012.2. International Union for the Conservation of Nature – Summary Statistics	2012	Regional data downloaded with straddlers dealt with at a national level. At the sub-national level for straddlers, efforts made to determine distribution from IUCN website or other relevant websites.
	Terrestrial & marine protected areas	United Nations – Millennium Development Goals. International Union for the Conservation of Nature, United Nations Environment Programme and the World Conservation Monitoring Centre – the World Database on Protected Areas	2012	Only designated areas were included (proposed & inscribed areas were excluded).
	Extent of primary forests	Food and Agricultural Organisation of the United Nations – Global Forest Resource Assessment 2010. Australia data from Australia's State of the Forests Report 2008. Bangladesh data from National Forest and Tree Resources Assessment 2005-2007.	1990 - 2010	The Russian Federation is excluded from the time series analysis because there was a large difference in the reported change rate (from +1.6 million hectares per year in the 1990s to -0.5 million hectares per year in the period 2000–2005) related to a modification to the classification system introduced in 1995 rather than actual changes in primary forest area.

Appendix A: Data sources for each indicator, including temporal coverage (in years) and additional notes regarding data coverage and limitations

The Human System

Domain	Indicator	Data Source	Data coverage (years)	Notes
Poverty	Population below $1.25/day	World Bank – PovcalNet	1981 - 2008	No data are reported for Afghanistan. This approach was less successful when looking at the East Asia & Pacific region. This covers five UN sub-regions (Eastern Asia, South Eastern Asia, Melanesia, Micronesia and Polynesia), and probably reflects the heterogeneity of nations in this region. PovcalNet does not 'explicitly' report data for North Korea and Mongolia (UN Eastern Asia), Burma/Myanmar (UN South Eastern Asia), Solomon Islands and Vanuatu (UN Melanesia), Kiribati, Marshall Islands, Northern Mariana Islands, Palau and Samoa (UN Micronesia), and American Samoa and Tonga (UN Polynesia).
	Undernourished population	Food and Agriculture Organisation of the United Nations – Food Security Indicators	1990 - 2012	Insufficient data for the following nations: Equatorial Guinea, Mayotte, Reunion, Saint Helena, Anguilla, Aruba, British Virgin Islands, Cayman Islands, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos Islands, Virgin Islands (U.S.), American Samoa, Cook Islands, Guam, Midway Islands, Nauru, Niue, Northern Mariana Islands, Tokelau, Wake Island, Wallis and Futuna Islands, French Guiana, Singapore, Bhutan, Oman, Qatar
Urbanisation	Urban population	World Bank – World Development Indicators (UN, Department of Economic & Social Affairs, Population Division)	1980 - 2010	Of nations to be reported, this data set does not include data for Curacao, Kosovo, Serbia, St Martin, Western Sahara, Gibraltar, Vatican, Falkland Islands, Saint Pierre & Miquelon, Occupied Palestinian Territory
	Slum population	World Bank – World Development Indicators	2001, 2005	Data are reported for 2001 and 2005. No data available for: Curacao, Kosovo, Serbia, St. Martin, Western Sahara, Gibraltar, Holy See, Falkland Islands (Malvinas), Saint Pierre and Miquelon, Occupied Palestinian Territory (West Bank and Gaza)
Health	Life expectancy	United Nations – World Population Prospects	1950 - 2010	Of nations to be reported, this data set does not include data for: Seychelles, South Sudan, Antigua and Barduba, Dominica, Saint Kitts and Nevis, Kiribati, Marshall Islands, Palau, Tuvalu
	Maternal mortality	Maternal Mortality Estimate Inter-Agency Group	1990 - 2010	Reported data on maternal and child mortality are limited as only one-third of nations have a complete civil registration system with good attribution of cause of death (WHO 2012b). Estimates are produced using a combination of civil registration and census data, and household surveys.
	Under-five mortality	United Nations – World Population Prospects	1950 - 2005	Reported data on maternal and child mortality are limited as only one-third of nations have a complete civil registration system with good attribution of cause of death (WHO 2012b). Estimates are produced using a combination of civil registration and census data, and household surveys.
	Obesity and Non-Communicable Diseases	World Health Organisation – Global Burden of Disease	2002 - 2010	Data not included for China (Hong Kong, Macao), Puerto Rico, Saint Kitts & Nevis, French Polynesia, New Caledonia, Western Sahara. Occupied Palestine Territory, Channel Islands, Isle of Man, Faeroe Islands, Gilbraltar, Holy See, Montenegro, Bermuda, Falkland Islands, Greenland, Saint Pierre and Miquelon, Leichtenstein, Serbia, Seychelles, Antigua & Barbuda, Dominica, Kiribati, Marshall Islands, Palau, Tuvalu, Andorra, San Marino, Monaco.
Health	HIV & AIDS	World Bank – World Development Indicators. World Health Organisation – Global Burden of Disease	1990 - 2010	Data are for population aged 15-49 years old. Based on nations for which the World Bank or WHO report data. By population, China is the largest nation for which data are unavailable. The following exclusions are made in the Tropics (expressed as a percentage of the 2010 regional population): 15% of Oceania (11 nations); 11% of Caribbean (6 nations); 22% of South East Asia (3 nations; less than 1% if China is not included); 13% of North Africa & Middle East (2 nations); and 9% of Central & Southern Africa (2 nations). Nations in the Rest of the World for which data were unavailable represent 40% of the population, with China, Russian Federation, Algeria, Uzbekistan, Iraq and Argentina accounted for the greatest proportion.
	Tuberculosis	World Health Organisation – TB burden estimates	1990 - 2010	TB burden estimates are calculated using models that consider the number of notifications, the estimated degree of underreporting, mortality data and trends in neighbouring nations. Population was used to estimate TB burdens at sub-national levels for nations that straddle the Tropics.
	Malaria	World Health Organisation – World Malaria Report 2012	2010	Proportion of cases in tropical zone within straddling countries derived from Cibulkis et al. (2011). Nations in the tropics that are excluded from analyses based on data availability: Mayotte, Reunion, Saint Helena, Anguilla, Aruba, British Virgin Islands, Cayman Islands, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos Islands, United States Virgin Islands, American Samoa, Cook Islands, Guam, Midway Islands, Nauru, Niue, Northern Mariana Islands, Tokelau, Wake Island, Wallis and Futuna Islands, French Guiana.
	Dengue and other neglected tropical diseases	Bhatt et al (2013) The global distribution and burden of Dengue. Center for Disease Control – Neglected Tropical Diseases. World Health Organisation – Global Burden of Disease	2010	There are no time series data for dengue. Data presented are for 2010. No data for Central & Southern Africa and Northern Africa & Middle East. Information presented are based on estimates by Bhatt et al (2013). Nations with no estimate data include Botswana, Namibia, Sao Tome and Principe, South Sudan, Hong Kong, Macau, Australia and USA.

Appendix A: Data sources for each indicator, including temporal coverage (in years) and additional notes regarding data coverage and limitations

The Human System

Domain	Indicator	Data Source	Data coverage (years)	Notes
Education	Mean years of schooling of adults	Barro and Lee (2010) Educational Attainment in the World 1950-2010	1980 - 2010	Nations in the Tropics excluded from analysis: Angola, Burkina Faso, Cape Verde, Comoros, Equatorial Guinea, Ethiopia, Guinea, Guinea-Bissau, Madagascar, Nigeria, Sao Tome and Principe, Seychelles, Djibouti, Chad, Eritrea, Somalia, South Sudan, Timor-Leste, Antigua and Barbuda, Dominica, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, French Polynesia, Kiribati, Marshall Islands, Micronesia (Fed. States of), New Caledonia, Palau, Samoa, Solomon Islands, Tuvalu, Vanuatu. For straddling nations: • No data at subnational level was located for Bangladesh - an assumption was made that MYS for Tropical and non-tropical Bangladesh are the same • Australia, China, India, Saudi Arabia and United States report data at subnational level by the highest level of education achieved.
	Youth literacy	United Nations Educational, Scientific and Cultural Organisation – Institute for Statistics Data Tables - Education	1980 - 2010	Nations in the Tropics excluded from analysis: : Angola, Congo, Guinea-Bissau, Sierra Leone, Djibouti, Mali, Somalia, Timor-Leste, Antigua and Barbuda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Belize, Suriname, French Polynesia, Kiribati, Marshall Islands, Micronesia, New Caledonia, Palau, Solomon Island,s Tonga and Tuvalu.
	Adult literacy	United Nations Educational, Scientific and Cultural Organisation – Institute for Statistics Data Tables - Education	1980 - 2010	UNESCO Adult (15+) Literacy dataset (1975-2011) is quite fragmented, particularly it does not have much data prior to 1995. For developed countries, for which data on literacy (in terms of literacy as it is defined by UNESCO) are not collected, an assumed 99% literacy rate was used in the data analysis.
Work	Unemployment rate	International Labour Organisation – Global Employment Trends	2000 - 2011	Nations in the Tropics excluded from analysis: : Sao Tome and Principe, Seychelles, Djibouti, South Sudan, Antigua and Barbuda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, French Polynesia, Kiribati, Marshall Islands, Micronesia, New Caledonia, Palau, Samoa, Tonga, Tuvalu and Vanuatu.
Economic Output	GDP per capita	World Bank – World Development Indicators	1980 - 2010	In the World Bank dataset there are a number of nations for which data are not reported, and for a large number of countries, gaps in the times series. Nations that don't have 80% of their data points reported by the World Bank were excluded from the analysis (in the Tropics these countries include Zimbabwe, Somalia, Cuba, Puerto Rico, French Polynesia, Marshall Islands, New Caledonia, Tuvalu).
Government	Public sector debt service burden	World Bank – World Development Indicators	1980 - 2010	There are no data available for Oceania. The Caribbean only includes data for the Dominican Republic. Other large economies omitted from analysis due to data availability are Tanzania, Nigeria, Saudi Arabia, Hong Kong, and Singapore.
International Trade & Investment	Exports of goods and services (% of GDP)	World Bank – World Development Indicators	1980 - 2010	The following nations in the Tropics were excluded from analyses because no data were available: Mayotte, Reunion, Saint Helena, Anguilla, Aruba, British Virgin Islands, Cayman Islands, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos Islands, Virgin Islands (U.S.), American Samoa, Cook Islands, Guam, Midway Islands, Nauru, Niue, Northern Mariana Islands, Tokelau, Wake Island, Wallis and Futuna Islands, French Guiana
	Imports of goods and services (% of GDP)	World Bank – World Development Indicators	1980 - 2010	Nations in the Tropics excluded from analyses because no data available were as for 'Exports of goods and services (% of GDP)'
	Foreign direct investment, net inflows	World Bank – World Development Indicators	1980 - 2010	Nations in the Tropics excluded from analyses because no data available were as for 'Exports of goods and services (% of GDP)'
Science & Technology	Research and development (% of GDP)	World Bank – World Development Indicators	2000 - 2008	Data for this indicator are very poor. Data are particularly limited for nations in Africa, the Middle East, the Caribbean and Oceania.
	Tertiary Enrolments	United Nations Educational, Scientific and Cultural Organisation – Institute for Statistics Higher Education Statistics	1950 - 2010	Estimates do not include India, China or Hong Kong
	Scientific & technical journal articles	US National Science Federation – Science and Engineering Indicators	1990 - 2009	Nations in the Tropics excluded from analysis: Cape Verde, Comoros, South Sudan, Timor Leste, Antigua and Barbuda, Dominca, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and Grenadines, French Polynesia, Kiribati, New Caledonia, Tuvalu. Estimates from Hong Kong and Macao are reported as China.
Human Security	Refugees	World Bank – World Development Indicators	1990 - 2010	Nations omitted from the analysis include South Sudan, Marshall Islands, Micronesia (Fed States of) New Caledonia, Channel Islands, St Pierre & Miqueleon, Isle of Man, Faeroe Islands, Gibraltar Holy See, Lichtenstein, Falkland Islands, Greenland, Occupied Palestinian Territory

Appendix A: Data sources for each indicator, including temporal coverage (in years) and additional notes regarding data coverage and limitations

The Human System

Domain	Indicator	Data Source	Data coverage (years)	Notes
Crime & Corruption	Homicide rate	World Bank – Criminal Justice Sources; World Bank – International Public Heath Sources	2004	The analysis was restricted to the 2004 year due to the difficulty in sourcing time series data for most nations. Dataset does not include French Polynesia, New Caledonia, Tuvalu, Western Sahara, Occupied Palestine Territory, Channel Islands, and Montenegro.
	Corruption	World Bank – World Development Indicators	2006 - 2011	The analysis was restricted to the period from 2006 to 2011 inclusive due to the large data gaps in the years from 1995 to 2005, in the majority of the tropical regions. Nations excluded from analysis due to no data in Transparency International dataset include: Tropical Nations: Saint Kitts & Nevis, Antigua & Barbuda, South Sudan, Marshall Islands, Micronesia (Fed States of), New Caledonia, Palau, French Polynesia, Tuvalu, Rest of the World:, Channel Islands, St Pierre & Miqueleon, Isle of Man, Faeroe Islands, Gibraltar, Holy See, Liechtenstien, Falkland Islands, Greenland, Bermuda, Monaco, San Marino, Occupied Palestinian Territory, Andorra and Western Sahara.
Gender Equality	Ratio of female to male adults with at least secondary education	Barro and Lee (2010) Barro-Lee Educational Attainment Dataset	1950 - 2010	Nations excluded from analysis: Angola, Burkina Faso, Cape Verde, Comoros, Cote d'Ivoire, Equatorial Guinea, Ethiopia, Guinea, Guinea Bissau, Madagascar, Nigeria, Sao Tome and Principe, Seychelles, Djibouti, Chad, Eritrea, Somalia, South Sudan, Timor-Leste, Antigua and Barbuda, Dominica, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, French Polynesia, Kiribati, Marshall Islands, Micronesia (Fed. States of), New Caledonia, Palau, Samoa, Solomon Islands, Tuvalu, Vanuatu
	Women in national parliament	Inter-Parliamentary Union – Women in National Parliament Statistical Archive	1997 - 2011	Nations excluded from analysis: Mayotte, Reunion, Saint Helena, Anguilla, Aruba, British Virgin Islands, Cayman Islands, Grenada, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos Islands, Virgin Islands (U.S.), American Samoa, Cook Islands, Guam, Midway Islands, Nauru, Niue, Northern Mariana Islands, Tokelau, Wake Island, Wallis and Futuna Islands, French Guiana
Infrastructure	Gross capital formation (% of GDP)	World Bank – World Development Indicators	1980 - 2011	Nations excluded from analysis: Angola, Equatorial Guinea, Guinea, Liberia, Nigeria, Sao Tome and Principe, Seychelles, Tanzania, Djibouti, Eritrea, Niger, Somalia, South Sudan, Yemen, Maldives, Brunei Darussalam, Cambodia, Laos, Burma/Myanmar, Timor-Leste, Haiti, Jamaica, Saint Kits and Nevis, Saint Lucia, Saint Vincent and the Grenadines, El Salvador, Suriname, Kiribati, French Polynesia, Marshall Islands, Micronesia, New Caledonia, Palau, Samoa, Solomon Islands Tuvalu.
	Access to improved water source	United Nationals Children's Fund/World Health Organisation Joint Monitoring Program	1990 - 2010	Nations excluded from analysis: Bahrain, Bermuda, Channel Islands, Faeroe IslandsIsle of Man, Falkland Islands (Malvinas), Liechenstein, Poland, San Marino, Western Sahara; and nations in the Tropics: Brunei Darussalam, China, Hong Kong SARChina, Macao SAR, New Caledonia, Puerto Rico, Saint Vincent and the Grenadines, Seychelles, South Sudan
	Access to improved sanitation	United Nationals Children's Fund/World Health Organisation Joint Monitoring Program	1990 - 2010	Nations excluded from analysis: Bahrain, Bermuda, Channel Islands, Falkland Islands (Malvinas), Faeroe Islands, Gibraltar, Holy See, Isle of Man, Italy, Liechenstein, New Zealand, Saint Pierre and Miquelon, Saudi Arabia, San Marino, Western Sahara; and nations in the Tropics: Brunei Darussalam, China, Hong Kong SAR China, Macao SAR, New Caledonia, Puerto Rico, Saint Vincent and the Grenadines, Saudi Arabia, Seychelles, South Sudan
Communication	Mobile phone subscriptions	International Telecommunications Union - Statistics	1993 - 2010	Nations excluded from analysis: Western Sahara, Channel Islands, Gibraltar, Holy See, Isle of Man, Falkland Islands (Malvinas), Saint Pierre and Miquelon. Nations excluded due to large number of missing data points: Macedonia, Serbia. Of nations to be reported with missing data points for which an assumption has been made that there were nil mobile cellular mobile subscribers in specific years:, Antigua & Barbuda: 1993-1995, Democratic Republic of Congo: 1993-1994, Liechtenstien: 1993-1997, Palau: 1993-2001, Saint Kitts & Nevis: 1993-1995, Saint Lucia: 1993, Timor-Leste: 1993-2002, Occupied Palestinian Territory: 1995-1999. Of nations to be reported with a missing data point for which a mid point calculation has been used to calculate number of mobile cellular subscribers: Bahamas: 1994, Congo: 1997. Of nations to be reported with missing data points for which av. annual growth rate has been used to calculate number of mobile cellular subscribers: Sierra Leone: 2004-2006
	Fixed broadband internet subscribers	International Telecommunications Union - Statistics	2000 - 2010	Nations excluded from analysis: Western Sahara, Channel Islands, Gibraltar, Holy See, Isle of Man, Falkland Islands (Malvinas), Kosovo, Saint Pierre and Miquelon, South Sudan. Nations excluded due to large number of missing data points: TFYR Macedonia, Montenegro, Occupied Palestinian Territory, Serbia and Turkmenistan. [also many nations for which assumption was made that data were nil for specific years]
	Internet users	International Telecommunications Union - Statistics	1993 - 2010	Nations excluded from analysis: Western Sahara, Channel Islands, Gibraltar, Holy See, Isle of Man, Falkland Islands (Malvinas), Kosovo, Saint Pierre and Miquelon, South Sudan. Nations excluded due to large number of missing data points: Liechenstien, Macedonia, Monaco, Palau, Serbia

Appendix B – Nations of the Tropics

	Tropical population 2010 (millions)	% of population in the Tropics	% of Regional population in the Tropics
Central & Southern Africa			
Angola	19.55	100.0%	2.8%
Benin	9.51	100.0%	1.3%
Botswana	1.97	51.5%	0.2%
Burkina Faso	15.54	100.0%	2.4%
Burundi	9.23	100.0%	1.2%
Cameroon	20.62	100.0%	2.9%
Cape Verde	0.49	100.0%	0.1%
Central African Republic	4.35	100.0%	0.6%
Comoros	0.68	100.0%	0.1%
Congo, Democratic Republic of	62.19	100.0%	9.7%
Congo, Republic	4.11	100.0%	0.6%
Cote d'Ivoire	18.98	100.0%	2.9%
Equatorial Guinea	0.70	100.0%	0.1%
Ethiopia	87.10	100.0%	12.2%
Gabon	1.56	100.0%	0.2%
Gambia	1.68	100.0%	0.3%
Ghana	24.26	100.0%	3.6%
Guinea	10.88	100.0%	1.5%
Guinea-Bissau	1.59	100.0%	0.2%
Kenya	40.91	100.0%	5.9%
Liberia	3.96	100.0%	0.6%
Madagascar	21.08	91.8%	2.8%
Malawi	15.01	100.0%	2.2%
Mauritius	1.23	100.0%	0.2%
Mozambique*	23.97	80.3%	2.8%
Namibia*	2.18	80.3%	0.3%
Nigeria	159.71	100.0%	23.3%
Rwanda	10.84	100.0%	1.6%
Sao Tome & Principe	0.18	100.0%	0.0%
Seychelles	0.09	100.0%	0.0%
Sierra Leone	5.75	100.0%	0.9%
Tanzania	44.97	100.0%	6.6%
Togo	6.31	100.0%	0.9%
Uganda	33.99	100.0%	4.9%
Zambia	13.22	100.0%	1.9%
Zimbabwe	13.08	100.0%	1.8%

	Tropical population 2010 (millions)	% of Population in the Tropics	% of Regional population in the Tropics
North Africa & Middle East			
Djibouti	0.83	100.0%	0.6%
Chad	11.72	100.0%	7.3%
Eritrea	5.74	100.0%	3.4%
Mali*	13.99	99.9%	10.0%
Mauritania	3.61	99.3%	2.2%
Niger	15.89	100.0%	10.1%
Saudi Arabia*	11.16	41.3%	7.4%
Senegal	12.95	100.0%	8.1%
Somalia	9.64	100.0%	6.1%
South Sudan	9.94	100.0%	6.0%
Sudan	35.65	100.0%	22.4%
Yemen	22.76	100.0%	15.7%
Caribbean			
Antigua and Barbuda	0.09	100.0%	0.2%
Barbados	0.28	100.0%	0.7%
Cuba	11.28	100.0%	27.3%
Dominica	0.07	100.0%	0.2%
Dominican Republic	10.02	100.0%	24.0%
Haiti	9.90	100.0%	24.2%
Jamaica	2.74	100.0%	6.6%
Puerto Rico (United States)	3.71	100.0%	9.1%
Saint Kitts & Nevis	0.05	100.0%	0.1%
Saint Lucia	0.18	100.0%	0.4%
St Vincent & the Grenadines	0.11	100.0%	0.3%
Trinidad and Tobago	1.33	100.0%	3.2%

* These nations have large populations and area and straddle the Tropics. Sub-national calculations were used and these nations divided into tropical and non-tropical regions for the analyses. See Appendix C.

	Tropical population 2010 (millions)	% of Population in the Tropics	% of Regional population in the Tropics
Central America			
Belize	0.31	100.0%	0.2%
Costa Rica	4.67	100.0%	3.6%
El Salvador	6.22	100.0%	4.7%
Guatemala	14.34	100.0%	11.0%
Honduras	7.62	100.0%	5.8%
Mexico*	91.72	77.7%	67.5%
Nicaragua	5.82	100.0%	4.4%
Panama	3.68	100.0%	2.7%
Oceania			
Australia*	1.27	5.7%	10.0%
Fiji	0.86	100.0%	6.8%
French Polynesia	0.27	100.0%	2.2%
Kiribati	0.10	100.0%	0.8%
Marshall Islands	0.05	100.0%	0.4%
Micronesia, Federated States of	0.10	100.0%	0.9%
New Caledonia (France)	0.25	100.0%	2.0%
Palau, Republic of	0.02	100.0%	0.2%
Papua New Guinea	6.86	100.0%	54.5%
Samoa	0.19	100.0%	1.5%
Solomon Islands	0.53	100.0%	4.3%
Tonga	0.10	100.0%	0.8%
Tuvalu	0.01	100.0%	0.1%
Unites States (Hawaii)*	1.38	0.4%	10.8%
Vanuatu	0.24	100.0%	1.9%
South Asia			
Bangladesh*	54.99	36.6%	7.4%
India*	690.68	54.0%	89.7%
Maldives	0.33	100.0%	0.0%
Sri Lanka	20.76	100.0%	2.8%

	Tropical population 2010 (millions)	% of Population in the Tropics	% of Regional population in the Tropics
South East Asia			
Brunei	0.40	100.0%	0.1%
Cambodia	14.36	100.0%	2.0%
China*	161.39	7.9%	14.9%
China – Hong Kong SAR	7.05	100.0%	1.0%
China – Macau SAR	0.53	100.0%	0.1%
Indonesia	240.68	100.0%	33.9%
Laos	6.40	100.0%	0.9%
Malaysia	28.28	100.0%	4.0%
Burma/Myanmar	51.93	90.8%	6.1%
Philippines	93.44	100.0%	13.2%
Singapore	5.08	100.0%	0.7%
Thailand	66.40	100.0%	9.8%
Timor-Leste	1.08	100.0%	0.2%
Vietnam	89.05	100.0%	12.4%
South America			
Bolivia	10.16	100.0%	3.4%
Brazil*	167.18	82.4%	54.9%
Colombia	46.44	100.0%	15.8%
Ecuador	15.00	100.0%	4.9%
Guyana	0.79	100.0%	0.3%
Peru	29.26	100.0%	9.9%
Suriname	0.52	100.0%	0.2%
Venezuela	29.04	100.0%	9.9%

Appendix C – Sub-national regions/states/provinces used for large nations that straddle the Tropics

Australia		
Queensland • Central West • Far North • Fitzroy • Mackay • Northern • North West	Western Australia • Kimberley • Pilbara	Northern Territory

Bangladesh		
Barisal	Chittagong	Kulna

Brazil		
Acre	Goias	Pernambuco
Alagoas	Maranhoa	Rio de Janeiro
Amapa	Mato Grosso	Rio Grande di Norte
Amazonas	Mato Grosso do Sul	Rondonia
Bahia	Minas Gerais	Roraima
Ceara	Para	Sao Paulo
Distrito Federal	Paraiba	Sergipe
Espirito Santo	Piaui	Tocantins

China		
Guangdong	Guangxi	Hainan

India		
Andaman & Nicobar Islands	Gujarat	Mizoram
Andhra Pradesh	Jharkhand	Orrisa
Chhattisgarh	Karnataka	Pondicherry
Dadra & Nagar Haveli	Kerala	Tamil Nadu
Damon	Lakshadweep	West Bengal
Dui	Madhya Pradesh	
Goa	Maharashtra	

Mexico		
Aguascalientes	Jalisco	Quintana Roo
Campeche	Mexico	San Luis Potosi
Chiapas	Michoacan	Tabasco
Colima	Morelos	Tlazcala
Federal District	Nayarit	Veracruz
Guanajuato	Oaxaca	Yucatan
Guerrero (Warrior)	Puebla	Zacatecas
Hidalgo (Noble)	Queretaro	

Saudi Arabia		
Asir	Jizan	Najran
Baha	Makkah	

United States		
Hawaii		

Palau.
Image: Lux Tonnerre.

STATE OF THE TROPICS

2014 REPORT