Safe Operating Limits for Humanity - A MAHB Dialogue with Earth System Scientist Will Steffen

Geoffrey Holland

"We are all embedded in exploitative economic systems that are very damaging to our Earth system. We have to change how we operate economically." – Will Steffen

Geoffrey Holland - You have written extensively about the human impact on the safe operating limits of our Earth's living systems. How is it different now than it was a hundred, or even ten years ago?

Will Steffen - The best way to look at this is to look at the phenomenon we call the Great Acceleration. If you go back a hundred years, things were changing. We were in the industrial era. We were using fossil fuels. We were clearing land. But somewhere around the mid-20th century, we really took off. We call this the Great Acceleration, and you can see it in all sorts of parameters. You can see it in population. You can see it in economic activity. You can see it in energy use. You can certainly see it in the global environment. You can see it in the rapid accumulation of greenhouse gases post-1950, as temperatures started moving upward. The

rate of land clearing, particularly in the tropics, increased dramatically. So, this really was a breakpoint in the long history of human modification of environments, which has been going on for thousands of years. But it was only in the mid-20th century that we really started banging into the operating limits of our global environment. More recently, of course, these things are accelerating in very many different ways. I would say in the last 10 or 20 years, probably one of the most dramatic increases we've seen are in things that we call novel entities: new stuff that we are throwing into the Earth System; think of plastics, and a plethora of man-made chemicals. You can think of electromagnetic radiation associated with the digital world, with repeater stations everywhere around the world now. This Great Acceleration is changing in character a bit, but there is no sign that it is slowing down. Just to summarize, we really have entered a very new and different epoch in terms of the human relationship with the rest of the planet. You can definitely see it since the mid-20th century.

GH - What are the biophysical processes that define planetary boundaries?

WS – We see two or three that are really all-encompassing, and then six or seven that support them. Let's start with the big three. One is climate change or the climate system; that's a pretty obvious one that is already seriously destabilized. You're seeing it now in the western United States with the massive wildfires that are all along the US Pacific Coast. We've experienced that here in Australia. You're seeing the Arctic warm, at a very rapid rate. Another process that's equally important is what we call biosphere integrity. We are changing the biosphere, the living part of Earth, at an enormous rate, particularly on the land, but now also in the sea. The third big one is what we call novel entities. These are the new things that we humans are throwing into the system: new types of chemicals, radioactive materials, plastics, and so on. Then we can go to some big geophysical parts of the Earth system, which are very important. One is the ozone layer around the earth that's important because it keeps out very damaging ultraviolet rays from affecting us and other forms of life. Another one that functions under the radar screen is the acidity of the ocean. Normally, that's very well controlled by natural processes and is very important for life in the ocean. We need to maintain that in a very tight range. The third big geophysical planetary boundary is aerosols. These are particles that are emitted into the atmosphere. Some are natural, through dust storms. You're seeing it in the western USA now with big fires, the incredible smoke. These aerosols help to regulate the energy balance at the planetary surface. They also cause direct problems for life on Earth, through pollution and so on. People who live for example in Los Angeles would have been aware of that over the last several decades with the pollution there: that again is aerosols, small particles. The last three processes that we look at to describe how the earth operates are more in terms of the land biosphere. It's very important for us humans because we're land creatures, we live on the land. And that part of the Earth System is exceptionally important. The first is an obvious one. That's

the water cycle. We depend on abundant and timely supplies of freshwater, and so do a lot of other living organisms on Earth. In fact, the water cycle itself is important for the entire operation of the Earth System in many ways. So, having a healthy water system is part of that. Another obvious one, of course, is the land. We have a wide range of very diverse ecosystems on land. For the earth to function properly, we need to have well-functioning land systems. Unfortunately, Earth's landscapes are changing rapidly. Obvious examples now are the Amazon rainforest and some of the large northern forests across Siberia and Canada. The last one is the disruption of the cycling of phosphorus and nitrogen. Those are elements that we need to grow crops. When you put all those together and look at their interactions as well, you can do a pretty good job of describing what we call the Earth System, and how it operates. All of those parameters are changing rapidly. The most important factor driving changes in all of them is human activity. The boundaries for a well-functioning Earth system have been exceeded. That's true for land change. It's true for our planet's phosphorus and nitrogen cycles. It's true for ocean acidity; true for novel entities. And of course, we have the big two: biosphere integrity and climate change. We are now well outside the boundaries of a well-functioning Earth System.

GH - A decade ago, you wrote that we have already exceeded safe operating limits on climate change, rate of biodiversity loss, and disruption of the planet's nitrogen cycles. How have things changed since then?

WS - That's a very good question. Things are going in the wrong direction on all of those factors. So, when you're looking at the 10 years since we first wrote about these processes, we look at the two most important ones, climate change and biosphere integrity. Greenhouse gas emissions, carbon dioxide emissions are still going up. The concentration of carbon dioxide in the atmosphere, for which we placed the boundary at 350 parts per million, is now rising at two or three parts per million per year, which is enormously fast. Right now, we're sitting at somewhere around 410 to 412 parts per million, way outside the acceptable boundary. The same thing with biosphere integrity, what we're seeing in the rate of biodiversity loss is that it is again actually increasing. Recent estimates are somewhere around perhaps 100 times faster than background levels. Some people are estimating 1000 times the background levels. Our sustainable boundary for that is only 10 times background levels, or even a bit less. One way we can look at this is what we call human appropriation of the productivity of the biosphere. So, if you focus now on the land biosphere, every year, it produces a certain amount of biomass; it cycles elements through and carries out other functions. That's called net primary productivity. So, one metric we can use is how much of that productivity are humans taking off in terms of cropland, in terms of deforestation, and so on. That fraction is rising, and it's somewhere now, up to 30 or 40% of the entire productivity of the terrestrial biosphere that is now being

harvested or co-opted by humans; way above the limit we think is appropriate for a sustainable Earth system. If we look at nitrogen, again we are at least double the amount of nitrogen above sustainable levels, and that is increasing as industrialized agriculture expands to other parts of the planet. So, unfortunately, when we look at the planetary boundaries, and particularly the two important ones, climate change and biosphere integrity, over the past decade, we've been going very much in the wrong direction.

GH - A recent study indicates that 67% of mammalian biomass now consists of just livestock raised for human consumption. What does that tell us about life on Earth being seriously out of balance?

WS - That's a staggering statistic when you just think about it, two-thirds of all the biomass of, in fact, it's all vertebrate creatures, not just mammals, so we've got to throw in reptiles, amphibians. So, anything with a backbone that lives on land, you add up the biomass of all of that, two-thirds is cattle, pigs, chickens, etc. The other thing we need to recognize that another 30% is our own human body biomass. So, when you combine our own human biomass with all of our domesticated animals, that's 97% of all biomass. So, that means that all wild creatures on land, whether it's bison in the US, or kangaroos down here, or giraffes and elephants in Africa, and so on, all of them all together add up to only 3% of the biomass of vertebrates on land. That's just a staggering, staggering statistic. And again, it relates to this biosphere integrity issue in that there is just so little wildlife left on land. We are facing a real extinction crisis. Wild animals are running out of habitat as we clear more and more land. That is made worse by climate change, as more land is damaged by fires, coastal areas being damaged by flooding and storms, and so on. So, there is no doubt that we are headed towards the earth's sixth great extinction event. It's the first extinction event that's actually been driven by a biological species, the human species. Our impact on the planet is undeniable, a really dramatic way of reminding people of just how much we dominate everything now; the land biosphere, and now the oceans, particularly along the coastal zones. When you look at world fisheries, most are hitting their limits or even beyond. So, you can see the imprint of humans just expanding massively around the globe.

GH - The ice sheets at the planet's poles have become seriously destabilized by human-driven climate change. What are the implications of this for life on Earth?

WS - People don't tend to think much about these big ice sheets because they're at the poles. Nobody lives down there. Only a few scientists go down there. But the fact that they are changing so rapidly has implications for the entire planet. One obvious one is sea-level rise. If we keep going in the direction we're going now, we could have up to a meter, a bit over three

feet, of sea level rise by the end of the century. That's really important for us humans because a large proportion of the human population actually lives along the coastlines. You can already see it in some of the big cities. In America, for example, New York City, Los Angeles, the two that are well known internationally. Both are on the coastlines. But when you look at some of the big Asian cities, like Bangkok, like Dhaka, like Kolkata, cities like that have their very large populations, and they are sitting right at sea level. It also means that when storms come along the coast, and we are starting to see more intense tropical cyclones and hurricanes coming on shore, a higher sea level makes them much more damaging. In the United States, the Gulf of Mexico is a classic example. Areas around Texas and Louisiana are getting hit by massive storm surges. It's happening in South Asia off the Indian Ocean as well. We're seeing the polar ice is melting, and that means the sea level is rising. The fact that the sea is rising means storms are becoming more damaging. But there's a more subtle way to look at it, and that is that one of these big polar ice sheets, the northern one on Greenland, is melting at an accelerating rate. That is dumping a lot of freshwater on the North Atlantic Ocean as that ice sheet melts. And that is actually now starting to change the ocean circulation in the Atlantic; the north-south circulation, which goes all the way down toward the south pole. So, these big polar ice sheets are melting, and that is beginning to change ocean circulation. That has a lot of impacts that are reverberating around the planet.

GH - Methane is massively more potent as a greenhouse gas than carbon dioxide. Trillions of tons of methane are trapped in high-latitude permafrost and shallow, ocean floor sediments. Human-induced atmospheric warming is greatest at the Earth's poles. What should we make of this? In your opinion, why have we not seen this issue more critically raised?

WS - Well, the issue of methane release, I think, has been overshadowed obviously by the direct emissions of carbon dioxide, which is the primary greenhouse gas, and the more important one overall. However, it's a real concern that methane concentration in the atmosphere has been rising over the last decade after a multiyear period of being relatively stable. There's a lot of investigation now going on as to why that methane rise is occurring. We think that most of it is still due to direct human activities; that is cattle production. Cattle, through the digestive system, emit methane to the atmosphere. Our fossil fuel development is also a factor as more and more natural gas is being developed for energy systems. But the big-ticket item is the methane that is stored in the northern high latitudes, basically in two places. One is in the so-called permafrost, which is frozen, very moist soil. But in the high latitudes where it's frozen, methane tends to be locked away from the atmosphere. It's also in the shallow ocean sediments in the Arctic Ocean. What we're seeing now is higher methane emissions as the Arctic suffers excessive heating. It's heating at about twice the global average. We're starting to see temperatures up above the Arctic Circle that are pushing 90 or 100

degrees in Fahrenheit. These are really excessively warm temperatures for that part of the planet. And we're starting to see the first erosion and melting of permafrost. We're seeing methane bubbling out. Fortunately, that's at fairly small rates at the moment, but there is a real concern that over the next decade or two, the rate could increase drastically. And there's a self-reinforcing feedback system. In Siberia, the reaction that occurs when permafrost melts releases methane, and also carbon dioxide. In chemistry, that is what we call an exothermic reaction; the reaction itself produces heat. So, you start getting an internal heating, as well as the external heating. The concern is, we may reach an internal tipping point where the whole system becomes self-reinforcing. In other words, the melting of the permafrost itself generates enough heat, that even if we could stabilize the climate, it would continue to melt. So, there's a real concern that we have an internal mechanism here that could allow the permafrost melting to really take off. There's probably even more methane stored in the shallow ocean floor sediments in the Arctic Sea, and the Arctic sea ice is melting again at an increasing rate. We think that about 55 or so million years ago, there was a massive outgassing of methane and CO_2 from the Arctic Sea. And that warmed the earth by four or five degrees. So, there is a historic paleo-precedent for massive methane emissions from the northern high latitudes. The concern is that we are now activating a so-called tipping point and that once we hit that point-of-no-return, we're going to release a massive amount of methane into the atmosphere, and that's going to warm the earth at an accelerating rate. That's going to probably cause other tipping points to change, including perhaps the irreversible melting of Greenland. We really worry that we could trigger a so-called tipping cascade, where you get tipping points like the North Atlantic ocean circulation, like the Amazon forest. The melting permafrost could actually lead to deforestation in the Amazon. It could occur in this way. The methane increasingly is emitted by the melting permafrost, which obviously is warming the earth. That increases the melt of the Arctic sea ice, which exposes a darker ocean of ice-free water, that absorbs more sunlight and increases warming, particularly in the northern high latitudes. That's one of the reasons why we see double the rate of warming up in the northern high latitudes. Greenland is in the northern high latitudes too. So, this effect would increase the ice melt from Greenland, increasing freshwater flow to the Atlantic Ocean. That tends to slow down the Atlantic circulation. That in turn, decreases rainfall over the Amazon forest. About half the rainfall over the Amazon forest is sourced from the Atlantic Ocean. So here you can see this melting permafrost, this tipping cascade as we call it, actually leading to reduced rainfall over the Amazon basin. And that, coupled with deforestation, could cause a tipping point whereby drought and fires take over and transform much of the Amazon forest into a drier savanna or a woodland. So basically, the release of frozen methane could lead to a vastly warmer climate and could push the climate system beyond human control. This issue has not gotten the attention it deserves. The big reason it's not getting much attention is that we still view the climate system as a linear system. In other words, the temperature rise, and the CO_2 rise are

linearly related or smoothly related to the emissions from fossil fuel combustion, and that has been the case up until now. So, the big focus, and it's an important focus, is on getting greenhouse gas emissions down. But that means we have neglected, or haven't given enough attention to these internal tipping points, that once they are triggered, like the permafrost melting that we've been talking about, once they are triggered, they are very difficult or impossible to stop. That could basically put climate beyond human control and could drive the system toward a much hotter state. We've done some research on this, we call it Hothouse Earth, which appears to be a stable state, four or five degrees hotter than pre-industrial, that could be triggered by these internal feedbacks. We need to give much more attention to the evidence that this is a nonlinear system, that it has its tipping points, it has abrupt shifts, irreversible shifts built into it. Once we trigger this, these phenomena will become as important or perhaps even more important than the human emission of greenhouse gases. So, issues like the permafrost melting deserve much more attention than they have received up till now.

GH - Culturally, humans have long functioned like we are above and superior to nature, rather than a part of it. Is that kind of thinking a dead-end for humanity?

WS - We have developed cultures and societies, particularly since the Industrial Revolution, that are increasingly disengaged or disconnected from nature, or from what we say is the rest of the Earth System. Unfortunately, this means we think we can operate independently from the earth; that we can just leave a few remnants in terms of national parks; that our economies can operate without limits, with the rest of the earth viewed mainly as resources, simply to be exploited. What we're seeing now clearly is that there are limits, what we call planetary boundaries. We have to change fundamentally how we view our place in the natural world. In other words, instead of building an economy where we look at the rest of the planet, as something external to us, as the economists like to call an externality... that's totally wrong. In fact, it's so simplistic, I think even kindergarten children can understand that we humans are part of our living planet. So, we have to change our way of viewing our place in nature. We ourselves are embedded in, and part of the biosphere. We evolved in the biosphere. We're still a wholly-owned subsidiary of the biosphere. If we fail to become effective and wise stewards of the biosphere and the rest of the planet, we can see the consequences already. We can see the sixth great extinction event unfolding. We can see our disruption of the big element cycles. We can certainly see our disruption of the climate system. So, our human cultures have put us in direct conflict with our own life support system. One of the interesting things about Australia is that we have one of the oldest living cultures on the planet. I'm talking about Indigenous Australians. In the last decade or so, there's more and more interest now in how the indigenous people have lived sustainably for a minimum of 65,000 years on the toughest continent on the planet for humans to live on, outside of Antarctica. One of the things we're learning is that our

contemporary human cultures have lost this idea that we are part of nature, that we're embedded in nature, and that we interact with the natural world all the time. My indigenous colleagues say their primary goal in life is to 'look after Country'. That means to maintain a well-functioning biosphere, and that it will in turn look after them. That's been their 65,000-year journey. Australia's indigenous culture is the only culture I know that's come through the transition from the last ice age into the Holocene with their culture pretty much intact. They did that by always understanding they are embedded in the natural world; they are part of it; they have to be custodians of it. The bigger picture shows that most humans have lost this, since the Industrial Revolution, probably even before that. That's the real challenge that humanity faces now. We have to reconnect with the biosphere, with the living planet, with the entire system. Unless we find our place in that, we're going to have trouble dealing with human-caused problems like climate change, and biodiversity loss, and living within sustainable planetary boundaries. Destabilizing the planet is driven by a single root cause, and that is humans have lost our connections with the rest of the living world. We've got to restore those connections. That really is our primary 21st-century challenge.

GH - Humans are entrenched in market-based economics that put profit ahead of nature, people, and planet. How does the way we do business have to change?

WS – Market-driven economies have to change fundamentally. They are the root of the problem. Or, I should say, our value system, and our cultures that drive market economics are the root of the problem. On the positive side, there are some really innovative solutions that are now emerging. One of the most interesting ones is called doughnut economics. It's been developed by an economist named Kate Raworth at Oxford University in the UK. She uses the word 'doughnut'. Visually, you have an inner circle of your doughnut that's called social wellbeing. Economies should be organized and designed to promote and maintain human wellbeing. Economics shouldn't be just about individuals getting wealthier. In fact, there's a lot of evidence now that simply getting wealthier and more individualistic is destructive to human welfare. We need to look at social values, poverty, social inclusiveness. We need to look at emotional wellbeing along with physical wellbeing. We have a whole range of these equity issues, gender equity, equity across races, and social classes. Kate Raworth defines the inner circle of the doughnut as social equity. But the earth is not limitless. Human activities are destabilizing our planetary life support systems. So, the outer ring of the doughnut is our environmental ceiling, or our planetary ceiling. Kate Raworth uses the nine planetary boundaries as a framework for guiding how we maintain a well-functioning Earth system. We need to bring our activities back within sustainable planetary boundaries. So, the doughnut is a very different way of looking at economics. A well-functioning economic system should not be about ever-increasing wealth. It needs to provide social wellbeing for humans within safe

operating limits for the planet. We can call this a wellbeing economy. Our current brand of market economics is ill-equipped to support a finite planet that is being destabilized at an increasing rate. We need to get away from old-school market economics. We need to get away from that as fast as we can. In fact, some countries are already starting to do that. One is New Zealand, where they are embarked on a wellbeing economy. They're using different indicators to measure the wellbeing of New Zealanders, their environment, and so on. New Zealand is a good model for how we can take a contemporary modern society and start to move it in a direction that delivers a higher quality of life in a more stable and sustainable environment.

GH - The technologies needed to forge a sustainable future for humanity seem to already be in place. Can we get past human tribalism to a place where the planetary consensus puts common survival first?

WS - Well, that indeed, is the critical question, and I gotta say, I don't have a clear answer for that. Because I don't think we know whether humanity can actually do this or not. There are some arguments that even in our basic genetic makeup, we can't do that. I actually don't quite subscribe to that. And again, I give you the example of Indigenous Australians who have lived for 65,000 years sustainably on this continent. When Europeans arrived here, two or three hundred years ago, they found a well-functioning climate, rich biodiversity, and also well-functioning indigenous human societies. So, it can be done. But again, I think we have to go back to the core value systems that drive our societies. Indigenous Australians are driven by the number one mandate to look after Country, to keep a well-functioning environment around them. They understood if they didn't do that, they weren't going to survive. That's the number one goal that we humans must have. Now, we're in the 21st century. We don't live as indigenous Australians. We live in a very high-tech contemporary society. We're are pushing our Earth System to its limits. How are we going to deal with this? There are some really interesting new ideas out there. One of the most fascinating has been put forth by a legal expert in Portugal. His name is Paolo Magalhaes. He has developed a concept called Our Common Home for Humanity. Paolo says that part of the reason why we can't forge a sustainable future for humanity is we don't have a legal framework that allows us to do that. When you look at a map of the world, what you see is a bunch of different colors with lines around them that identify nation-states. But when you get up in space, like an astronaut, you don't see that. You see this beautiful blue marble. You see a single system. Paolo's legal breakthrough was to recognize the earth system. Not the physical Earth, but the software, the functioning interface of the planet, the ocean circulation, the atmosphere circulation, the movement of materials, carbon, nitrogen, phosphorus energy around the planet. Our natural Earth-scale systems don't recognize or respond to national boundaries. They act together to form a single Earth system. So, the hope is that if we change the way we think, the fact that we

live in nation-states, but we share one life support system, and we have now as humans become so numerous and so technologically powerful, we are seriously damaging our own life support system. We know that quite well in science, but Paolo's innovation here is to say, we need a legal framework for this. And that will help us reorganize how we operate our economies and our societies. We need to see the earth system, not the earth, the system to be recognized legally as the intangible natural heritage of all humans. When you ask, how can the legal system deal with this, Paolo Magalhaes says there are precedents. A good example is copyright. All right, I've got some nice books on my shelf. I open them up. What are they physically? They are paper with ink imprinted on them. But that's not worth much. It's the concept of my being able to read the symbols on those pages and make sense of them and, and you get all sorts of emotions and feelings and all sorts of things from that. That's the value. So, we recognize that legally through copyright. Paolo has a number of examples of this, where we actually do have legal recognition of intangible goods, intangible services. So, he's starting a movement that's now getting a lot of traction in the United Nations. The world of nations needs a treaty that recognizes the Earth System as the common intangible heritage of all living things on the planet, including humans. Once we do that, we can start legally recognizing and penalizing actions that damage this common life support system for all humans. We can also start rewarding people who are regenerating ecosystems, people who are removing CO_2 from the atmosphere. This can be recognized economically as something that has value. Right now, it is assigned no value. So, we need new innovative thinking that gets us past some of the tribalism that has plagued us. Tribalism is a big problem. Look at what's happening with the current administration in the United States, but not only there, when you look at many countries like the United Kingdom, when you look at Russia, when you look at our present government in Australia, it's all about human societies, and how they can manipulate the global system to extract more and more wealth. It's not cooperative. So how are we going to get to something like planetary citizenship? Well, we can have social tipping points that change human societies fairly quickly. Human social tipping points are hard to predict, hard to see coming. Now, maybe there are enough strands, enough movements, like student strikes for climate action, that can power the idea of recognizing the earth system legally. There are all sorts of these things starting to bubble up. My hope is that we can reach a social tipping point, where we change the way we view ourselves, the way we view our relationship to each other, and the way we view our relationship to our planetary home, the Earth system. We've got to get past our tribalism. That's something that's plagued us in the past. There is no room anymore for that. If we don't wake up very soon, we will become a failed species on a trashed planet. That's not a future that would be good for anyone.

GH - What can each of us do as individuals to make sure that the bio-physical processes we all depend on are operating within safe and sustainable limits?

WS – That's really a collective action problem. Individually, we can change our lifestyles a bit, but we are all embedded in exploitative economic systems that are very damaging to our Earth System. We have to change how we operate economically. Fortunately, many of us live in democratic systems. Some of them aren't operating as well as they should be these days. But still, we have the opportunity to change the system. We can do that through trying to change who's running our governments. We can do that through peaceful demonstrations. We can do that by putting pressure on finance systems to shift money into less damaging economic activities. There are multiple pressure points on failing economic systems and we're starting to see a lot of those pressure points being highlighted. My advice to individuals is, do whatever you are comfortable doing… find ways to apply pressure to save precious areas of ecosystems, or to stop other damaging activities. Systems are made up of large groups of people. We need to understand where the pressure points are. We need to apply grassroots pressure from the bottom up to get our Earth System to operate in a more sustainable direction.

Will Steffen was the executive director of the Australia National University (ANU) Climate Change Institute, and a member of the Australian Climate Commission until its dissolution in September 2013. From 1998 to 2004, he was the executive director of the International Geosphere-Biosphere Programme, a coordinating body for global change research based in Stockholm, Sweden.

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Questions should be directed to joan@mahbonline.org