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Essays

Our hunter-gatherer future: Climate change, agriculture and uncivilization★

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ABSTRACT

For most of human history, about 300,000 years, we lived as hunter gatherers in sustainable, egalitarian communities of a few dozen people. Human life on Earth, and our place within the planet's biophysical systems, changed dramatically with the Holocene, a geological epoch that began about 12,000 years ago. An unprecedented combination of climate stability and warm temperatures made possible a greater dependence on wild grains in several parts of the world. Over the next several thousand years, this dependence led to agriculture and large-scale state societies. These societies show a common pattern of expansion and collapse. Industrial civilization began a few hundred years ago when fossil fuel propelled the human economy to a new level of size and complexity. This change brought many benefits, but it also gave us the existential crisis of global climate change. Climate models indicate that the Earth could warm by 3°C-4 °C by the year 2100 and eventually by as much as 8 °C or more. This would return the planet to the unstable climate conditions of the Pleistocene when agriculture was impossible. Policies could be enacted to make the transition away from industrial civilization less devastating and improve the prospects of our hunter-gatherer descendants. These include aggressive policies to reduce the long-run extremes of climate change, aggressive population reduction policies, rewilding, and protecting the world's remaining indigenous cultures.

1. Introduction

Anatomically modern humans, *Homo sapiens*, have inhabited the earth for more than 300,000 years (Stringer & Galway-Witham, 2017). For at least 97 % of this time our hunter-gatherer ancestors lived as many other large predators do, in small groups within the confines of local ecosystems (Diamond, 1987; Gowdy, 1998; Ponting, 2007). Human populations grew and shrank with changes in climate and food resources flowing directly from the natural world—from the hundreds of plants and animals they depended on. Human life on Earth, and our place within that web of life, changed dramatically during the Holocene, a geological epoch that began about 12,000 years ago. An unprecedented combination of climate stability and warm temperatures made possible a greater dependence on wild grains in several parts of the world. Over the next several thousand years, this growing dependence led to agriculture and large-scale state societies (Gowdy & Krall, 2014). It took only a few thousand years after sedentary agriculture began for it to spread and become dominant in the Middle East, South Asia, China, and Mesoamerica. Within that relatively short time period,

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agriculture caused the world human population to explode from 4 to 6 million to over 200 million by the beginning of the Common Era (CE) 2000 years ago (Biraben, 2003).

The adoption of agriculture made the average person worse off for millennia. Physical health declined dramatically and most of the world's people were born into rigid caste systems and lived as virtual or actual slaves. According to Larsen (2006 p. 12): "Although agriculture provided the economic basis for the rise of states and development of civilizations, the change in diet and acquisition of food resulted in a decline in quality of life for most human populations in the last 10,000 years." After agriculture, humans became shorter and less robust and they suffered from more debilitating diseases, from leprosy to arthritis to tooth decay, than their hunter-gatherer counterparts (Cohen & Crane-Kramer, 2007). It is only in the last 150 years or so that the longevity, health, and well-being of the average person once again reached that of the Upper Pleistocene. The average human life span in 1900 was about 30 years, and for Upper Pleistocene hunter-gatherers it was about 33 years.[1] Given the predicted dire economic consequences of climate change and biological annihilation, it is doubtful that these improvements can be maintained. Care must be taken not to see the achievements of the very recent past as representative of the health and well-being consequences of the agricultural revolution.

Agriculture and civilization were possible because of the unusually warm and stable climate of the Holocene. Before then, year-to-year variations in temperature and rainfall made agriculture too undependable to support settled communities with large populations. The Earth's climate has been unusually stable for about 10,000 years. But with the human-caused increase in CO_2 levels we have locked ourselves into a new period of climate instability that scientists predict will be comparable to the conditions of the Pleistocene. During that epoch, climate changes from warm periods to ice ages were triggered by swings in atmospheric CO_2 levels of about 50 ppm around the average of 250 ppm. The temperature variations were about 4 °C from the average. In just the past 70 years human activity has increased atmospheric CO_2 levels by 100 ppm to over 400 ppm, and the Earth's average temperature has warmed by 1 °C. Unless draconian measures are taken to halt the increase in atmospheric CO_2, global temperature will likely increase by at least 3 °C above today's by the year 2100 and could eventually increase by 8 °C or more (the so-called mega-greenhouse). Given the large human population, the likely effects of climate change on economic and social stability, and the potential fragility of the world's industrial agricultural system, it is unlikely that human civilization can survive the coming mega-greenhouse. The prospect of civilization collapse has now entered the mainstream of scientific and popular discourse (BBC, 2019; Diamond, 2019; Spratt & Dunlop, 2019). In the discussion below, the period two to three centuries in the future is used as a general reference point for the ultimate effects of human-caused climate changes. This long-term view avoids the quagmire of the "immediate collapse" versus the "peak and decline" discussions (2012, Randers, 2008) and also gets us close to the likely ultimate business-as-usual peak of temperature and CO_2 levels.

2. Climate stability and the origin of agriculture

Evidence suggests that the unique climate stability of the Holocene made agriculture possible and that before then the climate instability of earlier epochs made it impossible (Richerson, Boyd, & Bettinger, 2001: Feynman & Ruzmaikin, 2018). Fig. 1 shows the unique warmth and stability of the Holocene compared to the previous 45,000 years of the Pleistocene. The vertical scale shows the surface temperature of Greenland ice, and the horizontal scale is years before present.

During the Pleistocene there were several episodes when the earth's climate was as warm as today's, but these were brief compared to the Holocene. Climate instability held sway for the entire 2.5 million years of the Pleistocene. Changes in average world temperatures as great as 8^0C occurred over time spans as short as two centuries (Bowles & Choi, 2012).

Unpredictable year to year climate fluctuations before the Holocene made any incipient attempt at large-scale agriculture impossible to sustain. An example is the Natufian culture that started down the path to agriculture as the Earth warmed and stabilized just before the Holocene but abandoned it during the Younger Dryas abrupt cooling event that began about 13,000 years ago (Munro, 2004). Another factor inhibiting agriculture was that plant productivity in the late Pleistocene was low because of reduced CO_2 levels, about 200 ppm compared to 250 ppm at the beginning of the Holocene. Evidence suggests that the total amount of stored organic land carbon was 33–60 % lower in the Late Pleistocene compared to the Holocene (Beerling, 1999; Bettinger, Riche, rson & Boyd, 2009).

Agriculture came about because of the convergence of a number of seemingly unrelated phenomena that drove the evolution of a complex and expansionary economic system. These include the unprecedented climate stability of the Holocene, the evolution of human sociality, and our ability to cooperate with unrelated others. Once agriculture began to take hold, natural selection operating on diverse populations, driven by the economic requirements of surplus food production, favored those groups that could best take advantage of economies of scale in production, larger group size, and a complex division of labor. Human society was transformed into a unified, interdependent and highly complex economic machine (Gowdy & Krall, 2013, 2014, 2016).

3. Vulnerability to climate change after the agricultural revolution

The archeological and historical record of early agricultural state societies shows a common pattern of rapid expansion, followed

[1] The Upper Pleistocene number is based on estimates by Kaplan, Lancaster, and Hurtado, (2000)) for contemporary hunter-gatherers. Life expectancy estimates are notoriously difficult to compare because of differences in infant mortality, the effects of wars and epidemics, and other local factors.

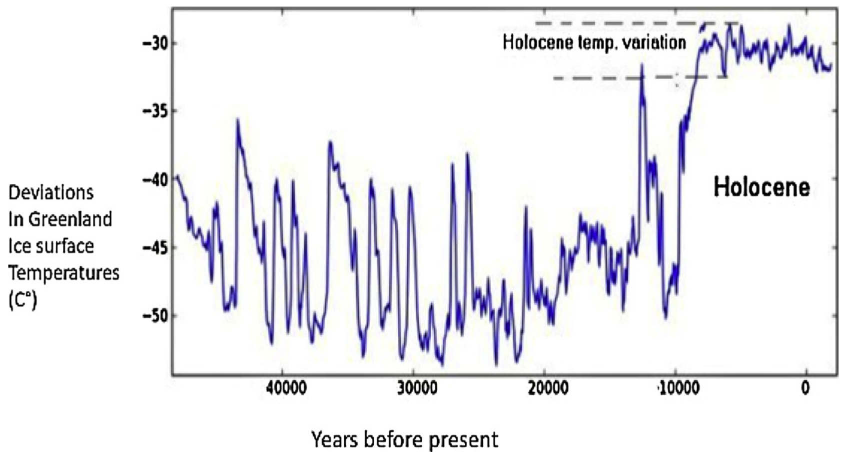

Fig. 1. Temperature deviations during the past 45,000 years as shown in Greenland ice cores.
Source: History of Earth's Climate 7.-Cenozoic IV-Holocene http://www.dandebat.dk/eng-klima7.htm. The vertical scale shows the temperature of Greenland ice surface (C^{o}) in the Holocene compared to the previous Weichsel ice age (115,000–11,700 years ago).

by collapse and loss of complexity (BBC, 2019; Diamond, 2005; Ponting, 2007; Tainter, 1988). Examples include the Akkadian empire, Old Kingdom Egypt, the Classic Maya, and the Harappan of the Indus valley. These civilizations disintegrated due to a variety of factors including the loss of soil fertility, erosion from reliance on annual plants, soil salinization, water mismanagement, and the inability to withstand prolonged droughts. Climate change is increasingly accepted as a major driver of past societal collapse (Diamond, 2005; Weiss & Bradley, 2001). Agricultural societies have also been plagued by instability driven by the destabilizing effects of inequality based on castes (the hereditary control of economic surplus) and overexploitation of the natural world (Scheidel, 2017; Scott, 2017).

After the initial establishment of agriculture there was a period of several thousand years of small, settled communities—"stateless" societies that practiced a combination of agriculture and foraging. Scott (2017) argues that, in the Near East, along the Indus river, coastal China, and the Valley of Mexico, these early agricultural societies were based in riverine wetlands with alluvial floodplains making agriculture relatively easy and easily supplemented by a variety of fish, aquatic plants, and animals. Wetland societies were "environmentally resistant to centralization and control from above." Several factors were responsible for the demise of wetland societies and the later phase of rapid population growth and the emergence of centralized state societies, including grain agriculture and warfare as an economic policy of the state, but a key driver was climate change.

The connection between agriculture, climate destabilization, and civilization collapse is well-established (Weiss, 2017). The collapse of the Akkadian empire was triggered by a severe, centuries long drought (Kerr, 1998; Weiss et al., 1993). Several civilizations in China disintegrated because of extraordinary floods that were part of a climatic upheaval around 4200 years ago (Huang, Pang, Zha, Su, & Jia, 2011). The collapse of the Mayan civilization has been attributed to a severe drought (Haug et al., 2001). The collapse of the Harrapan civilization was driven by a prolonged drought. In the Middle East, the period 5,500- 4500 years ago was marked by increasing aridity and a sharp decline in sea level and water flow in the Euphrates (Nissen, 1988). The surrounding marshes shrank and provided less subsistence for the population. Increasing soil salinity reduced the amount of arable land. The increasing scarcity of alternatives to agriculture increased the dependence on grains. The negative consequences of a shrinking subsistence base promoted concentrations of populations and the concentration of political and economic power. Scott (2017 p. 121) writes:

> The shortage of irrigation water confined the population increasingly to well-watered places and eliminated or diminished many of the alternative forms of subsistence, such as foraging and hunting…Aridity proved the indispensable handmaiden of state making by delivering, as it were, an assembled population and concentrated cereal grains in an embryonic state space that could not, at that epoch, have been assembled by any other means.

Climate change may have also played an important role in the transition to state societies in the Nile Valley. The flow of the Nile river decreased significantly around 5300 years ago resulting in an increased concentration of populations and more centralized control to manage increasingly scarce resources. The increasingly arid climate concentrated the population in larger settlements and necessitated the intensification of agricultural production to offset the reduction in wetland resources. With the concentration of populations, greater dependence on storage of grains, and without the protection of the marshes, cities became a target of looting. Looting and warfare became another subsistence choice on the world stage (Turchin, Currie, Turner, & Gavrilets, 2013).

After agriculture, a second sea-change in economic and social organization came with the massive influx of fossil fuel energy that triggered the industrial revolution. Economic life was transformed from being predominantly agricultural to one dominated by manufacture, trade and finance (Hall & Klitgaard, 2011). Fossil fuel energy is flexible, storable and transportable and it transformed every aspect of human society from an individual's capacity to perform work to global population size. Fossil fuel has also transformed the climate and locked us into ever more complex and fragile agricultural, industrial and financial systems. Modern industrial agriculture depends on fossil fuels increasingly costly to assess in terms of energy return on energy invested (Hall & Klitgaard, 2011). It also depends on the stability of global markets and economic institutions, and on the ability of complex technologies to respond quickly to a variety of climatic and biological threats. Our industrial agriculture system is dependent on the relative climate stability of the Holocene and on abundant and readily accessible fossil fuels, the main source of climate destabilizing CO_2.

4. The coming mega-greenhouse

Most statements about climate change use a phrase something like "since the industrial revolution the earth's temperature has increased by 1 °C." This is true but the alteration of the earth's atmosphere by human activity is a very recent and rapid phenomenon. Most of the 1 °C increase in the earth's average temperature since pre-industrial times has occurred since 1980. Most of the increase in atmospheric CO_2 (from about 310 ppm–410 ppm) has occurred since 1950. 75 % of fossil fuel burning and anthropogenic CO_2 in the atmosphere has occurred since 1970. The effects of anthropogenic CO_2 emissions are just beginning to be felt.

Climate change projections are increasingly alarming as they become more accurate by, for example, refining the effects of sunlight reflected by clouds as the earth warms, and modifying projections using past warming events to calibrate the interactions among CO_2, temperature, sea level rise, and feedback effects.[2] Brown and Caldeira (2017) suggest that there is a 93 % change that temperature increases will exceed 4 °C by the end of this century. A report by the World Bank (2012 p. xiii) warns:

> Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3 °C above the preindustrial climate. Even with the current mitigation commitments and pledges fully implemented, there is roughly a 20 percent likelihood of exceeding 4 °C by 2100. If they are not met, a warming of 4 °C could occur as early as the 2060s. Such a warming level and associated sea-level rise of 0.5–1 meter, or more, by 2100 would not be the end point: a further warming to levels over 6 °C, with several meters of sea-level rise, would likely occur over the following centuries.

The IPCC (2014) median no-aggressive-policies, high emissions projection for 2100 is a warming of 4 °C (RCP8.5). The current lack of effective policies to deal with climate change, even in the face of increasingly dire warnings, suggests that high emission projections provide the most accurate climate change scenarios (Gabbatiss, 2017). The IPCC optimistic scenarios (RCP2.6, RCP4.5) assume not yet feasible geoengineering schemes to remove atmospheric CO2. Annual emissions have increased significantly since the Kyoto Protocol twenty years ago. No major industrial country is on track to meet the commitments of the (very modest) Paris agreement (Wallace-Wells, 2017). It seems unlikely that the policies required to keep warming at manageable levels will be implemented in time to avoid catastrophic climate change.

The very long-term consequences of climate change have received relatively little attention (Bala, Caldeira, Mirin, Wickett, & Delire, 2005; Gowdy & Juliá, 2010; Kasting, 1998). Most projections of global warming focus on either the year 2100 or the effects of a doubling of CO_2 (from the pre-industrial level of 275 ppm–550 ppm). The lack of attention to the very long run is a serious shortcoming, since integrated carbon-climate models project that if CO_2 from current *in situ* fossil fuel resources continues to be released into the atmosphere, the peak concentration of atmospheric CO_2 could exceed 1400 ppm by the year 2300 and the average global temperature could warm by 8 °C or more (Bala et al., 2005; Kasting, 1998). A CO_2 level of 1400 ppm would increase the risk of a rise in temperature as high as 20 °C which will certainly have catastrophic consequences for all life on Earth. It is sobering to consider that current levels of CO_2 are higher than at any time in the last 15 million years (World Bank, 2012 p. xiv).

The main policy-relevant variable for the Earth's temperature is the amount of CO_2 in the atmosphere. The human contribution to CO2 increases is largely the result of fossil fuel burning. Unless coupled with policies to leave fossil fuels in the ground, other energy sources will merely supplement, not replace fossil fuels. Future increases in total atmospheric CO_2 depend primarily on the total amount of fossil fuel carbon burned. Accessible fossil fuel carbon—mostly coal—is so vast that if burning continues, currently feasible mitigation options such as moderately reducing CO_2 emission rates, limited sequestration, and re-forestation will have a negligible effect on the ultimate atmospheric concentration of CO_2 (Caldeira & Kasting, 1993; Matthews & Caldeira, 2008). Even if climate change mitigation policies reduce CO_2 emission rates, atmospheric CO_2 concentrations will continue to rise until emissions fall to the natural removal rate. Much of the emitted CO_2 remains in the atmosphere centuries or even millennia after its release. Archer (2005) suggests that 300 years is a good average lifetime number for CO_2 and that 17–33 % of the CO_2 will remain in the atmosphere 1000 years after it is emitted. Montenegro, Brovkin, Eby, Archer, and Weaver (2007) suggest that released carbon may stay in the atmosphere an average of 1800 years or longer. According to Archer & Brovkin (2008 p. 283): "Ultimate recovery takes place on time scales of hundreds of thousands of years." The effects of fossil fuel burning are irreversible on a time scale relevant to humans.

5. Agriculture will be impossible in the post-Holocene climate

With the future climate instability already locked into the system by recent human activity we will most likely return to the climate volatility of the Pleistocene. Climate change will adversely affect agriculture in a number of ways including sea level rise, higher average temperatures, heat extremes, changes in rainfall patterns, and the loss of pollinators. Less understood changes include the effects on agricultural pests, soil composition, and the growth response of crops to rising CO_2 levels. Fig. 2 shows the possible

[2] "Alarmist" scenarios should not be dismissed out of hand. The MIT climate model predicts a 10% chance of a 7°C warming with no aggressive climate change policy. This low probability does not mean "zero chance" and the possibility should be considered in prudent climate change policies. https://globalchange.mit.edu/research/research-tools/risk-analysis/greenhouse-gamble

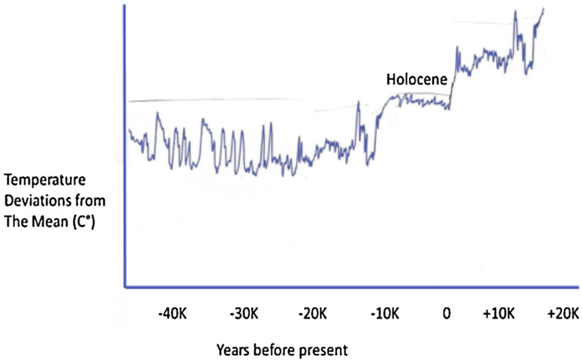

Fig. 2. Past temperature deviation from the mean and future projections.
Source of Earth's Climate 7.- Cenozoic IV-Holocene http://www.dandebat.dk/eng-klima7.htm.

volatility in climate if the Earth returns to the climate regime of the last few thousand years of the Pleistocene. Future volatility will not, of course, follow exactly the same pattern but Fig. 2 represents a rough guess as to what might occur. Agriculture was impossible in the past because of climate/weather instability and it is likely to again be impossible if similar conditions return.

Increased climate volatility could occur quite soon. According to Batissti (Quoted in Wallace-Wells, 2017):

> By 2050, under a typical middle-of-the-road emissions scenario, you're looking at a doubling of the volatility for grains in the mid-latitudes. In places like China, the U.S., Europe, Ukraine—the breadbasket countries of the world—the volatility from year-to-year just from natural climate variability at a higher temperature is going to be much higher. The impact on crops is going to be greater and greater.

The ability of agriculture to adapt to climate change will depend on the rapidity of changes as well as their severity. Intensively growing high-tech crops on the massive scale required to support billions more people will be prohibitively expensive just in terms of the energy required. The feasibility of massively moving crops North to avoid warmer temperature is limited because of poor quality soils in places like northern Canada and Russia. Also, temperature fluctuations will be greater toward the poles. Much of the evidence is anecdotal, but there are already indications of climate instability more than offsetting the advantages of longer growing seasons in northern regions, For example, although longer summers in Greenland have increased the growing season by two weeks, they are becoming drier and rainfall has become more unpredictable with adverse effects on crops and livestock (Kintisch, 2016).

Sea level rise will be a major stress factor on agricultural output with the loss of agricultural land and increasing salinity from storm surges. According to Hansen et al. (2016): during the last interglacial, about 140,000 years ago, the earth was about 1 °C warmer than today and sea levels were 6–9 meters higher with evidence of extreme storms. Their modelling implies that a 2 °C warming would cause an eventual shutdown of the North Atlantic current, an ice melt in the North Atlantic and Southern oceans causing increased temperature gradients and more severe storms, and sea level rise of several meters within a very short time span of 50–150 years. Fischer et al. (2018 p. 474) write:

> A global warming average of $1-2$ °C with strong polar amplification has, in the past, been accompanied by significant shifts in climate zones and the spatial distribution of land and ocean ecosystems. Sustained warming at this level has also led to substantial reductions of the Greenland and Antarctic ice sheets, with sea-level increases of at least several meters on millennial timescales.

Wallace Broecker has called the ocean conveyer belt "the Achilles' heel of the climate system" He estimates that were it not for the belt's current course, average winter temperatures in Europe would drop by 20 degrees or more. According to him:

> There is surely a possibility that the ongoing buildup of greenhouse gases might trigger yet another of these ocean re-organizations, and thereby the associated atmospheric changes. Were this to happen a century from now, at a time when we struggle to produce enough food to nourish the projected population of 12 billion to 18 billion, the consequences could be devastating. (quoted in Smith, 2019).

Another threat to agriculture partially due to climate change, the loss of pollinators, is already underway (United Nations, FAO, 2019).

Increasing temperatures will have a devastating effect on agricultural productivity, especially given the sensitivity of grains to temperature extremes. It is estimated that 60 % of the calories consumed by humans come from just three grains, maize, rice and wheat. Modeling by Battisti & Naylor (2009 pp. 240-241) indicates a greater than 90 % probability that average growing season temperatures will exceed the most extreme seasonal temperatures recorded between 1900 and 2006 for most of the tropics and subtropics. During the record heat in Europe in Summer 2003, maize production fell by 30 % in France and 36 % in Italy. A 2008 study found that southern Africa could lose 30 % of its maize crop by 2030 due to the negative effects of climate change. Losses of maize and rice crops in South Asia could also be significant (Lobell et al., 2008).

Climate change will exacerbate social and political instability. It is difficult to establish a direct cause-and-effect relationship between climate change and social conflict, but the correlations are suggestive (Burke, Hsiang, & Miguel, 2015). The wars in Dafur and Syria and the massive migrations out of North Africa have been linked to droughts. The climatologist Michael Mann observed: “The Syrian uprising was driven by another drought that was the worst drought on record—the paleo record suggests the worst in 900 years. Drought is a big one, it’s behind a lot of the conflict we see” (quoted in Wallace-Wells, 2017). As climate change accelerates, migrations will be driven not only by drought, but also by sea level rise and the uninhabitability of much of South Asia and the Middle East because of extreme temperatures. Clark et al., 2016 p. 363) write: “Given that deglacial warming led to a profound transformation of Earth and ecological systems, the projected warming of 2.0–7.5 °C above the already warm Holocene conditions (at much faster rates than experienced during deglaciation) will also reshape the geography and ecology of the world.” Mass migration and the resulting conflicts over water and food will most likely destabilize future societies.

6. Our hunter-gatherer future

Will the transition to hunting and gathering result from a catastrophic collapse of civilization or a semi-orderly contraction? A strong case can be made for a sudden catastrophic collapse and a massive dieoff of *Homo sapiens* (Ehrlich & Ehrlich, 2013; Morgan, 2009; Spratt & Dunlop, 2019). A BBC report on civilization collapse (BBC, 2019) states:

> Societies of the past and present are just complex systems composed of people and technology. The theory of “normal accidents” suggests that complex technological systems regularly give way to failure. So collapse may be a normal phenomenon for civilisations, regardless of their size and complexity. We may be more technologically advanced now. But this gives little ground to believe that we are immune to the threats that undid our ancestors. Our newfound technological abilities even bring new, unprecedented challenges to the mix. And while our scale may now be global, collapse appears to happen to both sprawling empires and fledgling kingdoms alike. There is no reason to believe that greater size is armour against societal dissolution. Our tightly-coupled, globalized system is, if anything, more likely to make crisis spread.

Collapse is not a necessary pre-requisite to a hunter-gatherer future for our species. Our species may avoid collapse and have some sort of semi-orderly contraction of the human population and our impact on the biosphere. One way or another, with the environmental stress on agriculture from future climate change and the inevitable decline in food production, the number of humans on the planet will be drastically reduced over the coming centuries. As human populations shrink, and grain production becomes problematic, state societies as we know them will become increasingly difficult to maintain. This will be good for the planet and for individual human well-being. Scott (2017) makes a strong case that the average person was better off after past state societies collapsed. He argues that the period from the first appearance of states until their complete hegemony some 5000 years later was a “golden age of barbarians.” Barbarians had the autonomy to pursue limited agriculture, foraging and hunting, and they had the opportunity to take some of the spoils of the state through raiding and pillaging. The barbarians, according to Beckwith (2009 p. 76, quoted in Scott pp. 232-233):

> were in general much better fed and led easier, longer lives than the inhabitants of the large agricultural states. There was a constant drain of peoples escaping from China to the realms of the eastern steppe, where they did not hesitate to proclaim the superiority of the nomad lifestyle. Similarly, many Greeks and Romans joined the Huns and other Central European peoples, where they lived better and were treated better than they had been back home.

One can envision a relatively slow decline in food production as climate change becomes more and more pronounced, and a decline in population and economic output. The decrease in economic surplus will increasingly constrain the ability of states to maintain their monopoly on violence and their ability to control the population. It may be unlikely, but if the effects of climate change are gradual enough, a soft landing to a non-agricultural economy may be possible.

Will we be too stupid to be hunter-gatherers?

The human brain has been shrinking rapidly since agriculture, (from 1500cc to 1350cc). This fact is well-documented and is independent of race, gender and geographical location. For example, Henneberg (1988, p. 395) writes of the decline in cranial capacity in Europe and North Africa during the Holocene:

For both males and females the decrease through time is smooth, statistically significant and inversely exponential. A decrease of 157 cc (9.9% of the larger value) in males and of 261 cc (17.4%) in females is a considerable one, of the order of magnitude comparable to the difference between averages for H. erectus and H. sapiens sapiens.

If our bodies had shrunk at the same rate as our brains the average human would be 4' 6" and weigh 64 pounds (http://superscholar.org/shrinking-brain/). According to Hawks (2011) the decrease in brain size during the last 10,000 years is nearly 36 times the rate of increase during the previous 800,000 years. There is no evidence that we are just as smart, or even smarter, because our brains have become streamlined to be more efficient. There is no evidence that the human brain became more complex as it shrank.

Too make matters worse, there is evidence that high levels of CO_2 result in a decline in cognitive ability. A recent study found a 15% decline in cognitive ability when CO_2 levels reached 950ppm and a 50% decline when they reached 1400ppm. https://www.yaleclimateconnections.org/2016/07/indoor-co2-dumb-and-dumber/ Ambient CO_2 levels will most likely reach 1000ppm sometime in the next century.

6.1. Maintaining agriculture will be unlikely after the climatic transition and the end of fossil fuels

Without the fossil fuel bonanza of the twentieth century, and given future climate instability, water shortages, and degraded soils, large-scale grain agriculture will be impossible within the next 100–200 years. The major crops we depend on are already showing signs of stress due to climate change. About half the world's population depends on rice as the major source of calories (Nguyen, 2005). Rice production will be affected by sea level rise and an increase in average temperature. Higher temperatures result in increased sterility of rice plants and a larger net energy loss at night because plants are more active then at higher temperatures. Kucharik and Serbin (2008) estimated that each additional 1 °C increase in summer temperature would cause a decline in the output of maize and soybeans by 13 % and 16 %, respectively. Wheat is also being adversely affected by climate change. A simulation model by Asseng, Foster, and Turner (2011) using Australian data found that variations in average growing season temperatures of 2 °C can cause reductions in grain production of 50 %.

Suppose there is a precipitous decline in the human population and our species is once again characterized by isolated bands of hunter-gatherers. Would agriculture eventually return? Probably not. (1) temperatures would be too instable to support major grain crops, (2) currently grown varieties of rice, wheat, and maize could not survive without human help and would disappear, and (3) human hunter-gatherers in the Pleistocene did not "choose" agriculture and would be unlikely to do so in the future (Gowdy & Krall, 2014).

6.2. The environment will recover as the human domination of the Earth ceases

Several "natural" experiments have occurred in the wake of the unintended consequences of human abandonment of large areas. The contaminated land around Chernobyl and Fukushima, Japan, is now abundant with wildlife as is the demilitarized no man's land between North and South Korea. When the human domination of nature ends, the biological world has an amazing ability to heal itself. What will be left of nature in the 22nd century and beyond? Probably enough to support a population of human hunter-gatherers. Rapid evolution will occur in "new" territories. The recovery of plants and animals will depend on the severity of climate change impacts on the biological world, for example, the amount of inhabitable land after sea level rise and increases in lethal regional temperatures. Given nature's resilience when human pressure is removed, there is reason to be optimistic. There will be some wildlife slaughter in the period of the contraction—there is a massive number of guns on the planet–but the limiting factor will be ammunition which will run out quickly. Most of it will be used on other humans if history is any guide.

7. Can we do anything? Some policy initiatives implied by a long-run perspective on climate change

Standard economic analysis is of no use in policy valuations of the very long-term effects of climate change. Its valuation perspective is that of a self-regarding individual making decisions in the immediate present. Any positive discount rate will reduce the calculated long-term benefits of climate change mitigation (avoided costs) to near zero. Furthermore, standard theory and policy recommendations based on surveying human "preferences" are almost always based on the preferences of Western people living in market economics. Henrich et al. (2010) documented the biases of preference surveys and concluded that people in WEIRD societies (western, educated, industrial, rich, and democratic) hold world views that are outliers in terms of most human cultures. If we are so bad at determining the preferences of humans living today, how can we possibly know the preferences of those living hundreds of years in the future? Economics, or indeed science, cannot be used to answer questions of ethics and value judgments. As Clark et al. (2016 p. 366) put it: "An evaluation of climate change risks that only considers the next 85 years [to 2100] of climate change impacts fails to provide essential information to stakeholders, the public and the political leaders who will ultimately be tasked with making decisions about policies on behalf of all, with impacts that will last for millennia."

Several widely discussed initiatives could reduce the human impact on the natural world and improve our long-term chances for survival after collapse or gradual decline. If we revert to hunting and gathering at some point in the future these policies will make the transition easier and improve the survival prospects for our descendants.

7.1. Rewilding

The goal of the "rewilding" project is to protect and restore large, core ecosystems and existing wilderness areas and to establish corridors between them (MacKinnon, 2013; Monbiot, 2014). Projects include the Yellowstone to Yukon conservation initiative, the European Green Belt along the former Iron Curtain boundary, and the Buffalo Commons initiative for the American great plains. The beauty of these projects is that, for the most part, they require little investment except for regulations and easements and scientific information gathering and monitoring. Once established, nature takes care of the details. An example of nature's resilience is the cascading effect of the introduction of wolves in Yellowstone Park in 1995, seventy years after they had been exterminated. Numerous unanticipated positive "ecological cascades" occurred including increases in beaver populations which created habitats for birds, otters, and moose. The presence of wolves reduced coyote populations causing a rise in the number of small mammals which in turn increased the numbers of owls, foxes and badgers.

Whenever the conversation turns to keeping nature wild, some people immediately go on the attack with "What about people? You care about nature more than humans!" But rewilding is not about keeping out humans, it's about keeping out markets and the industrial economy. The inherent conflict is between nature and economic exploitation, not between nature and people.

Reconnecting with the natural world makes us more human, not less.

7.2. Rapidly reduce the human population

The human population now approaches 8 billion people. It is growing at an annual rate of 1.1 %, adding about 83 million people per year. Longer-term projections are highly speculative and show everything from runaway growth to a population crash down to 2.3 billion in 2300.[3] The most widely accepted view of population growth is the "demographic transition." If incomes continue to rise in most countries and richer people have fewer children, then world population should peak at 9–11 billion around the year 2100. But some recent statistics suggest that his view could be wrong. In Europe during the past 10 years or so fertility rates have been increasing. Fertility rates fell in Africa for a few years but they have now levelled off at around 4.6 instead of continuing to drop as the demographic transition predicts. Of course, the effect of human population growth on the natural world is complicated and depends not only on sheer numbers of people, but also energy and material use and technology. As Paul and Anne Ehrlich, Herman Daly and other advocates of population control have long argued, population, overconsumption and destructive technologies are all to blame for the destruction of the natural world as we know it (Daly, 2012; Ehrlich & Ehrlich, 1990). Decreasing the human population should be a coordinated strategy of family planning, female empowerment, and economic equality. However, all the problems we face are exacerbated by a growing population. As Paul Ehrlich puts it:

> Solving the population problem is not going to solve the problems of racism, of sexism, of religious intolerance, of war, of gross economic inequality. But if you don't solve the population problem, you're not going to solve any of those problems.

7.3. Protect the world's remaining traditional cultures

The long-run survival of a species depends on its ability to adapt as environmental conditions change. Because evolution works on populations, not individuals, adaptability depends on having sufficient variety within populations. Although it may seem to us that human diversity is increasing as many more different cultures and races are present in specific locations. Globally, however, human cultures are becoming more homogenized as the rest of the world adopts the values and way of life of WEIRD (Western, Educated, Industrial, Rich, Democratic) society (Henrich, Heine, & Norenzayan, 2010). In view of the looming social and environmental changes we face, this makes it even more important to support and protect the world's remaining indigenous cultures that still have the ability to live beyond the confines of modern civilization. Human societies still exist that have little contact with the outside world. These groups may be the only humans having the necessary skills to survive a climate/social/ technological apocalypse.

8. Summary and conclusion

Climate change has been a major driver in the biological and social evolution of the human species. For some 97 % of our existence we lived as hunter-gatherers in the Pleistocene, a geological epoch characterized by extreme climate swings from ice ages to warm periods. Agriculture, perhaps the major social evolutionary transition in our history, was made possible by the unusually warm and stable climate of the Holocene. That climate stability is already being undermined by the fossil fuel CO_2 injected into the atmosphere by the industrial economy. The climate system will be overwhelmed if we continue to burn fossil fuels for just a few more decades. Without climate stability and the cheap, abundant energy of the 20^{th} century it is unlikely that agriculture will be possible in the 21^{st} century and beyond. Civilization will either collapse or gradually disappear over the coming centuries.

The fact that civilization is likely to end does not mean that we should give up on climate change mitigation, radically changing the world's industrial agriculture system, social justice or the rest of a progressive political agenda. Our prospects for survival will dramatically improve if we hold temperature increases to 3 °C, rather than 6 − 8 °C, by instituting social and environmental policies to reduce the worst climate change impacts. In the long run, the vision of returning to a hunting and gathering way of life is wildly optimistic compared to the technological dystopias envisioned by many science fiction authors and social philosophers. Every characteristic that defines us as a species—compassion for unrelated others, intelligence, foresight and curiosity—evolved in the Pleistocene (Shepard, 1998). We became human as hunters and gatherers and we can regain our humanity when we return to that way of life.

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