IMPACTS OF CLIMATE CHANGE

PERCEPTION AND REALITY

Indur M. Goklany

The Global Warming Policy Foundation
Report 46

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About the author

Indur M. Goklany is an independent scholar and author. He was a member of the US delegation that established the IPCC and helped develop its First Assessment Report. He subsequently served as a US delegate to the IPCC, and as an IPCC reviewer.

'The effects of global inaction are startling …Around the world, we are seeing heat waves, droughts, forest fires, floods and other extreme meteorological events, rising sea levels, emergencies of diseases and further problems that are only premonition of things far worse, unless we act and act urgently.'

His Holiness, The Pope[1]

'Climate change is happening now and to all of us. Every week brings a new example of climate-related devastation. No country or community is immune…

Such events are becoming more frequent, more severe and more widespread and will become even worse unless we act urgently, now.

It is clear that climate change threatens decades of development progress and places in jeopardy all our plans for inclusive and sustainable development.

From increased poverty and food insecurity, to growing water stress and accelerated environmental damage, climate change is a clear and present threat.'

UN Secretary General, António Guterres[2]

'Mr Guterres noted that the climate crisis has generated 'turbocharged' hurricanes and storms, which are occurring with greater intensity and frequency.'

UN News[3]

'Climate change is creating catastrophic wildfires.'

Carly Phillips, World Economic Forum[4]

'Now I think America is learning lessons on the importance of ecology…on the east coast, floods, and on the west coast, [forest] fires'.

The Dalai Lama[5]

'2015 was a record-breaking year in the US, with more than 10 million acres burned,' he told DW in an interview. 'That's about 4 million hectares, or an area of the size of the Netherlands or Switzerland'.

Jason Funk, Union of Concerned Scientists[6]

'More than 70 health organisations signed a statement that, among other things, calls for a move away from fossil fuels. The groups cite storm and flood emergencies, chronic air pollution, the spread of diseases carried by insects, and especially heat-related illnesses.'

Inside Climate News[7]

'Mounting evidence points to the fact that climate change is already affecting agriculture and food security, which will make the challenge of ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture more difficult…

Changes in climate are already undermining production of major crops (wheat, rice and maize) in tropical and temperate regions.'

Food and Agriculture Organization of the United Nations (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organization (WHO)[8]

1. The standard narrative

The standard narrative regarding climate change, as represented by the quotes on the opposite page, from some of the world's most influential people and institutions, is that climate change is already increasing the frequency and intensity of extreme weather events (EWEs) and wildfires, reducing available water and crop yields, increasing diseases, hunger, poverty and human mortality, and reducing productivity of the biosphere and the habitat available for species. It is claimed that these and other climate change impacts are diminishing human and environmental wellbeing, and will reduce them further unless 'drastic measures to achieve as quickly as possible zero net greenhouse gas emissions' are taken.[9]

This paper considers whether data on climate-sensitive indicators are consistent with this narrative. Specifically, it examines empirical trends in extreme events, wildfires, water availability, vector-borne diseases, and some indicators of human and environmental wellbeing, such as economic development, poverty rates, life expectancy, biological productivity, and cropland per capita. Since climate change is a global phenomenon, the paper focuses primarily on indicators at the global scale. But it will also examine trends for the US, to a lesser extent China and India (which together comprise over a third of humanity), and, where readily available, aggregated data from developing or low-income countries. However, one should recognise that the existence of a trend in one country (or section of the globe) is not indicative of a global trend.

Moreover, because climate change should not be confused with fluctuations in the weather, the focus will be on long-term trends. Ideally, the temporal record examined should be long enough to, firstly, capture a change in climate. Climate is often defined in terms of 30-year averages. Thus, it should be long enough to define at least two non-overlapping 30-year periods. Secondly, it should also encompass at least one, if not more, full periods encompassing any significant atmospheric or oceanic cycle(s) that could significantly affect the phenomenon for the region under examination. For example, the Atlantic Multidecadal Oscillation, which, it has been theorised, can affect precipitation and droughts on both sides of the Atlantic and hurricane activity in the North Atlantic Basin, has a 60–80 year period.[10] Thus, ideally, the temporal record for determining trends for that region should be long enough to span a few of these periods.

Unless explicitly noted, I will use 'climate change' synonymously with 'greenhouse gas induced climate change'.

2. Extreme weather events

According to the Intergovernmental Panel on Climate Change (IPCC), human activities have warmed the globe about 1°C since preindustrial times.[11] Beyond exacerbating heat waves, climate change, it is claimed, has increased the frequency and/or intensity of various EWEs such as cyclones (known as hurricanes in the Americas, and as typhoons in Asia and the Pacific), which would increase weather-related deaths and economic losses. This section examines empirical trends in:

- the various categories of EWE
- related mortality and economic losses.

Extreme temperatures

According to the latest IPCC assessment,[12] 'since about 1950 it is very likely that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased overall on the global scale, that is, for land areas with sufficient data. It is likely that such changes have also occurred across most of North America, Europe, Asia and Australia'. Thus, heatwaves should have increased for these areas, while cold waves should have declined. However, it has low-to-medium confidence in historical trends in daily temperature extremes in Africa and South America over this period, either because data are insufficient or trends are mixed.[13] It should also have noted that the period from 1950 to the present is only a small sliver of Earth's history.

In some of the regions with longer records and wider coverage, empirical data reveals that heatwaves were more extreme in the past, for example in the US in the 1930s, when atmospheric carbon dioxide concentrations were only 75% of those today (see Figure 1).[14] Moreover, newspaper accounts from Australia from the same period and the 19th century provide evidence of extreme heatwaves whose intensity and extent exceeded the official meteorological records, which are of recent vintage.[15] Also, proxy records for China indicate that although extremely cold winters between 1500 and 1900 were more frequent than those after 1950, 'the intensity of regional heat waves, in the context of recent global warming, may not in fact exceed natural climate variability seen over the last 2000 years'.[16]

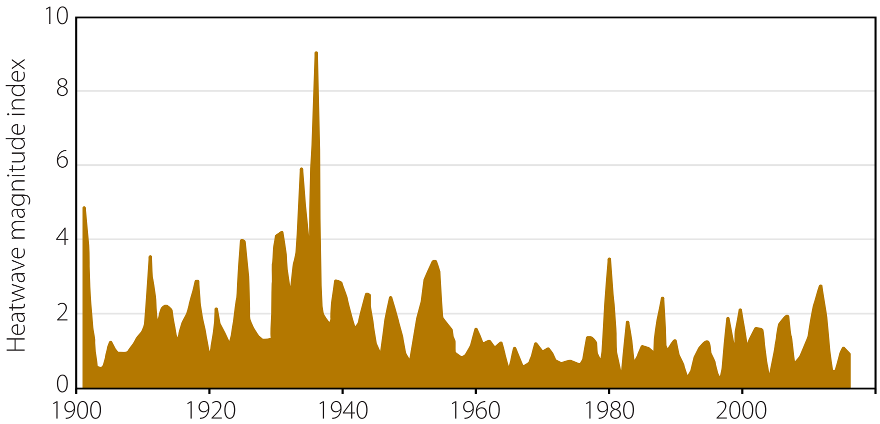


Figure 1: Heatwaves for the USA.

Source: USGCRP (2017), p. 191, Figure 6.4.

Cyclones

Figure 2 is a plot of all hurricanes (top panel) and major hurricanes (bottom panel) hitting the US from 1900 through 2017. Neither shows an increasing trend.

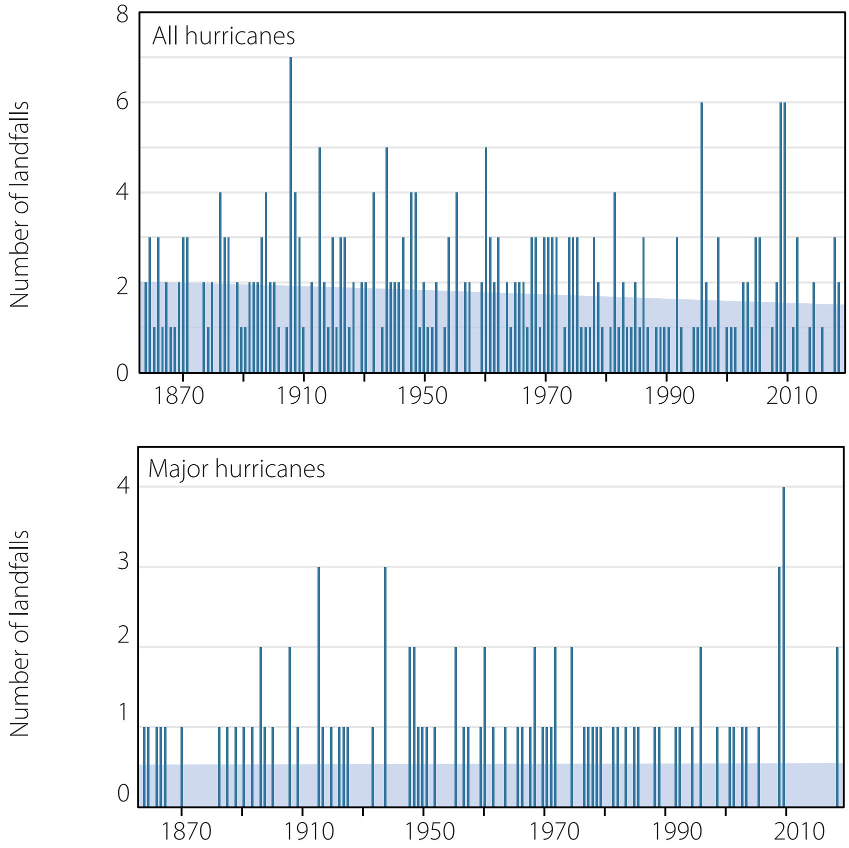


Figure 2: Hurricanes landfalling in the continental USA, 1851–2018.

Note in particular the 12-year 'drought' of major hurricanes from 2005–2017. Source: National Hurricane Research Division. See also Klotzbach et al. (2018).

Linear trend

This is consistent with a 2012 review, which found no significant increase in the frequency or intensity of all or major hurricane-strength landfalling cyclones for either the globe or the five major hurricane-spawning basins (North Atlantic, northeastern Pacific, western North Pacific, northern Indian Ocean, and the Southern Hemisphere).[17]

Similarly, as shown in Figure 3, there are no upward trends in hurricanes' accumulated cyclone energy (ACE), an approximate measure of their cumulative energy (or their destructive potential).[18] This is true globally, and also individually for the Northern and Southern Hemispheres.

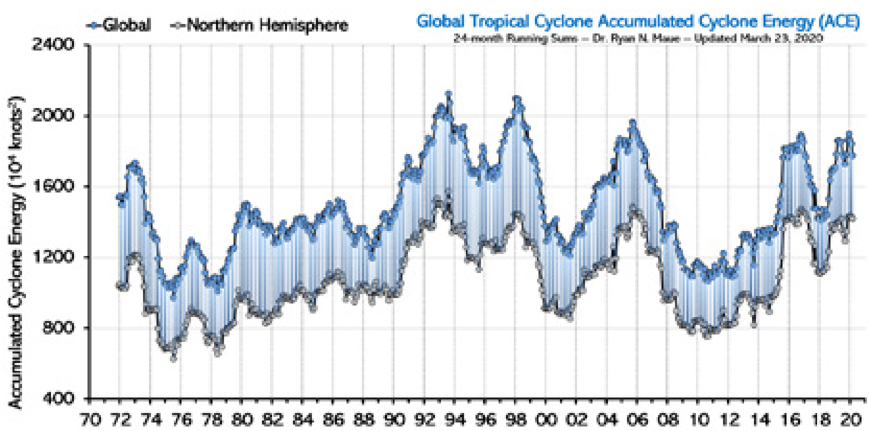


Figure 3: Global and northern hemisphere ACE.

24-month running sums. Global and Northern Hemisphere data are as indicated on the figure. The Southern Hemisphere is effectively the gap between the two lines. Source: https://policlimate.com/tropical/, based on update of Maue (2011).

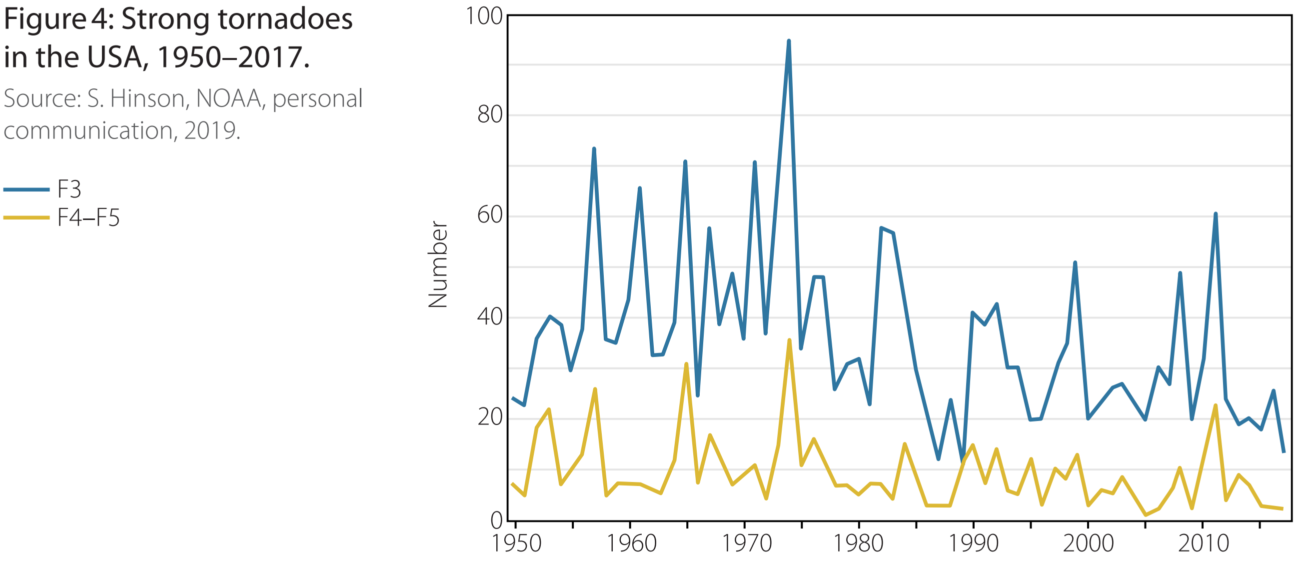
Tornadoes

Over the years, there has been a substantial increase in the number of tornadoes reported and/or observed in the contiguous US. This increase is attributed to a combination of improved detection technologies (e.g. Doppler radar) and an increase in the number of trained observers.[19]

The stronger the tornado, the less the likelihood that it would have escaped detection in earlier times. Therefore, tornado trends are more appropriately based on trends in stronger tornadoes. Figure 4 shows the trend in severe (F3) and devastating or worse (F4 and F5) tornadoes for the contiguous US from 1950 to 2017. Clearly, strong tornadoes have, if anything, been declining over time.

Figure 4: Strong tornadoes in the USA, 1950–2017.

Source: S. Hinson, NOAA, personal communication, 2019.



Floods

It is generally accepted that climate change should increase global precipitation and, indeed, it has. It is a small step to then speculate that floods have become more prevalent. But, as a recent paper – entitled 'If precipitation extremes are increasing, why aren't floods?' – notes, 'evidence for increases in flooding remains elusive. If anything, flood magnitudes are decreasing'.[20]

This statement is consistent with the *Climate Science Special Report*, which notes that 'The IPCC [Fifth Assessment Report] did not attribute changes in flooding to anthropogenic influence nor report detectable changes in flooding magnitude, duration, or frequency'.[21] This is supported by an investigation of annual maximum daily streamflow data from 9213 stations across the globe, which showed that there were more stations with significant decreasing trends than significant increasing trends. Thus evidence for the hypothesis that flood hazard is increasing is limited.[22] There is therefore something of a paradox: increasing precipitation but reduced flooding. The explanations put forward include decreases in antecedent soil moisture, decreasing storm extent, decreases in snowmelt and snow extent, and changes in land cover.[23]

In the United States, 'Trends in extreme high values of streamflow are mixed…Analysis of 200 US stream gauges indicates areas of both increasing and decreasing flooding magnitude but does not provide robust evidence that these trends are attributable to human influences'.[24] This finding is supported by a study of 1204 'minimally altered' catchments in North America and Europe, which found 'no compelling evidence for consistent changes over time in major-flood occurrence'.[25] The same study observed that flood occurrence seemed to have a closer relationship with the the Atlantic Multidecadal Oscillation – a cyclic climatic phenomenon – than with time (which, over the past century or more, may be viewed as a surrogate for carbon dioxide levels or global temperatures).

Droughts

For the contiguous US, the trend in drought from August 1895 to July 2019 has, if anything, been downward (Figure 5).[26] This trend has been associated with long-term precipitation increases.[27]

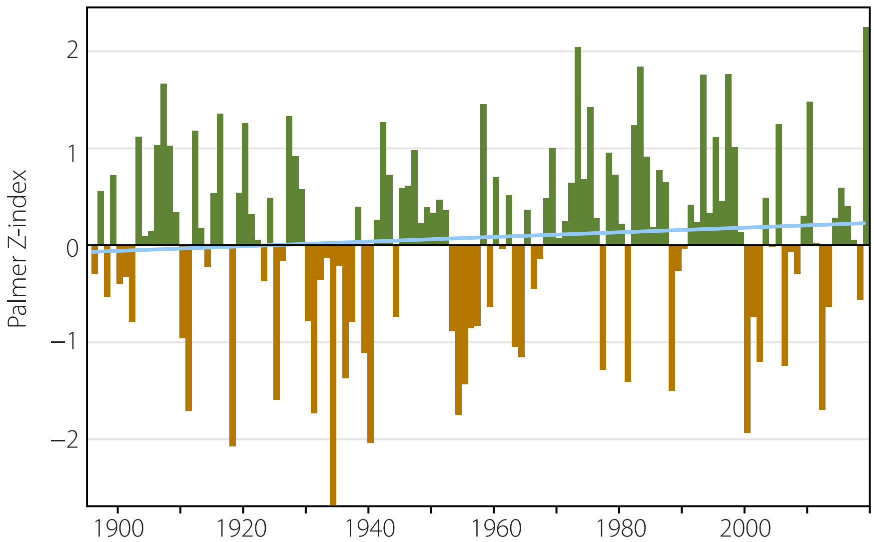


Figure 5: Drought as measured by Palmer Z-index for the contiguous US,12-month averages, August, 1895-July, 2019.

Source: Brown indicates a drought, whereas green indicates no drought (relative to the mean). The blue line is the trend. Source: NOAA, 2019.

Moreover, 'by geographical scale and duration, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record'.[28]

At the global scale, the IPCC notes that there is low confidence in any trends in drought.[29] This suggestion was confirmed by an analysis of precipitation data from 1980 to 2012, which found a significant positive trend in the land area under drought in the Southern Hemisphere but no significant trend in the Northern Hemisphere or, more importantly, the entire globe.[30] A similar study found no increase in global area under drought from 1982 to 2012.[31] Figure 6 shows total global area under drought from 1950–2018.[32] It suggests phase or instrumental changes in the early 1980s, but no subsequent increase in the drought area.

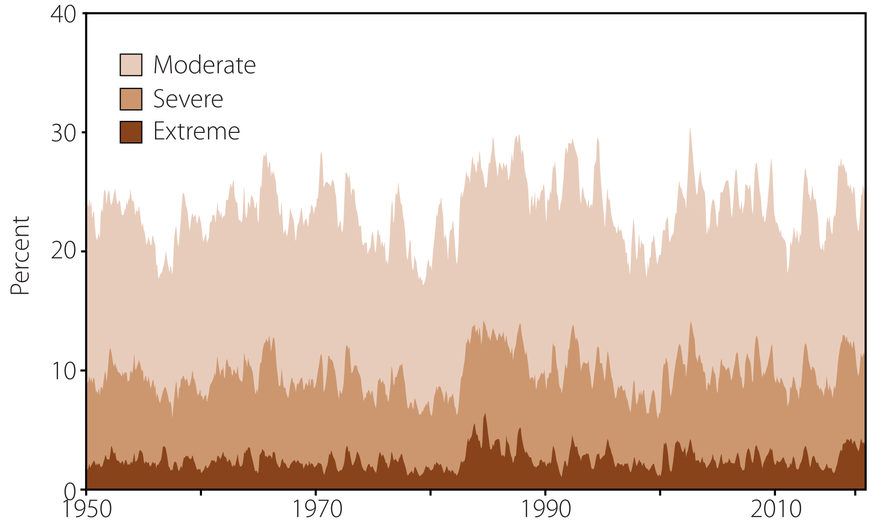


Figure 6: Global drought 1950–2018.

Percentage of global land area (excluding ice sheets and deserts) in drought, by severity, based on self-calibrating Palmer Drought Severity Index. Inset: each month of 2018. Source: Barichivich et al. (2019, S40).

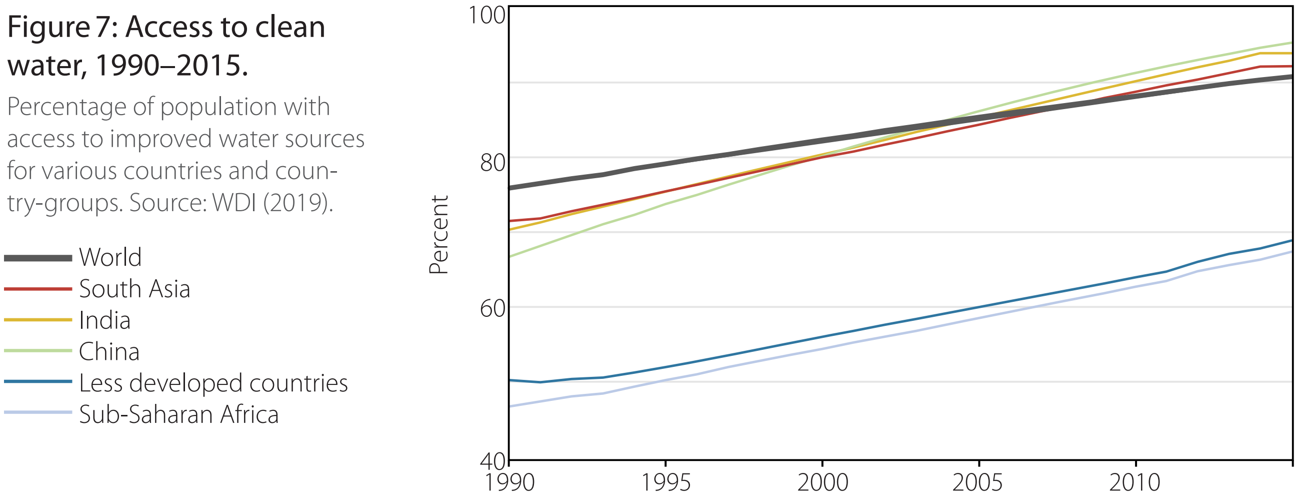
It has also been hypothesised that the intensification of the hydrological cycle due to climate change would lead to dry areas becoming drier and wet areas wetter. However, an analysis of global data sets for evapotranspiration, precipitation and potential evaporation from 1948 to 2005 found that 'over about three-quarters of the global land area, robust dryness changes cannot be detected.[33] Only 10.8% of the global land area shows a robust 'dry gets drier, wet gets wetter' pattern, compared to 9.5% of global land area with the opposite pattern, that is, 'dry gets wetter, and wet gets drier.' In other words, the hydrological cycle is not obviously becoming more intense.

Moreover, a review of paleoclimate data shows that today's droughts are not particularly remarkable when placed in historical context. The paper says, 'megadroughts reconstructed over north-central Europe in the 11th and mid-15th centuries reinforce other evidence from North America and Asia that droughts were more severe, extensive, and prolonged over Northern Hemisphere land areas before the 20th century'.[34]

More importantly, concerns about drought are driven by concerns that people will run out of water to drink, grow crops and meet other human and environmental needs. These worries are magnified by the fact that populations continue to grow. Nevertheless, access to safer water has actually increased (Figure 7),

Figure 7: Access to clean water, 1990–2015.

Percentage of population with access to improved water sources for various countries and country-groups. Source: WDI (2019).



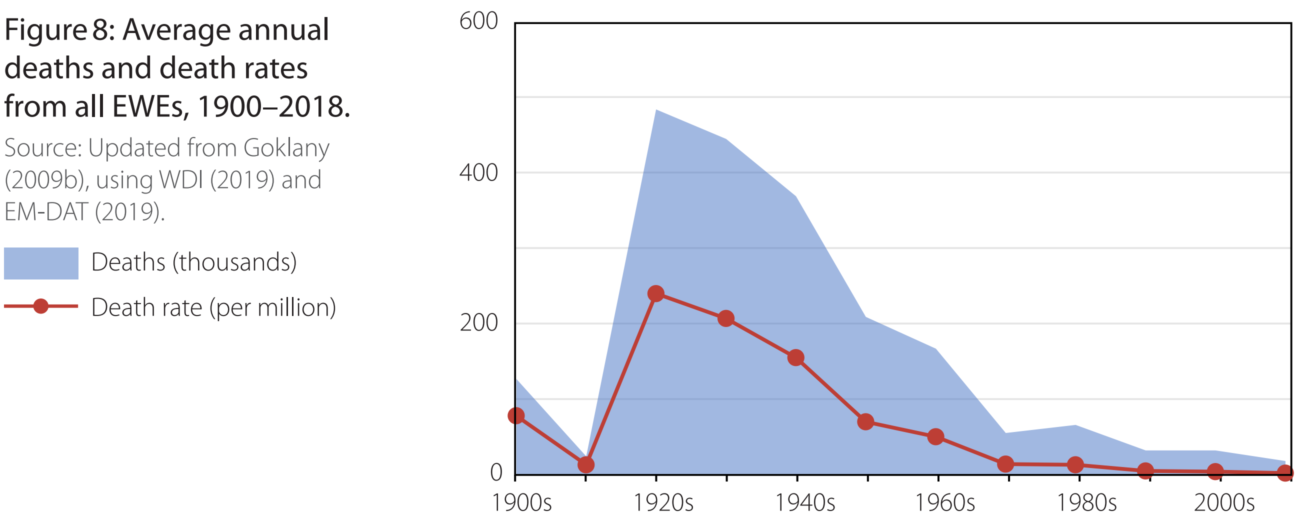
as have crop yields worldwide (Section 5). In other words, notwithstanding increasing pressures on water supplies, society's ability to provide the services humans demand directly or indirectly from water has, paradoxically, increased, probably because of technological improvement, driven by economic development, which makes better technologies more affordable.[35] This suggests that analyses of the impacts of climate change should go beyond climate's biophysical effects and consider human adaptability.

Mortality

Since, as we have just seen, the frequency, duration and intensity of EWEs has not increased, one might expect global death rates from all such events to be more or less constant. But in fact, as Figure 8 shows, since the 1920s, global death rates from all EWEs have declined by 98.9%. More remarkable is the fact that annual deaths from such events have decreased by 96.1% over this period despite a more-than-tripling of the population. Notably, the vast majority of these reductions occurred before climate change became a concern for the public and policymakers (arguably no earlier than the signing of the 1992 Rio Declaration). This suggests that autonomous adaptation driven by wealth and technological change is a natural human response to perceived threats, and should be incorporated into estimates of future climate change impacts.[36]

Figure 8: Average annual deaths and death rates from all EWEs, 1900–2018.

Source: Updated from Goklany (2009b), using WDI (2019) and EM-DAT (2019).



To put this into context, the average annual death toll from all EWEs in 2010–2018 was 19,021. This is only 0.035% of the current global all-cause annual death toll of about 55 million (WHO, 2016). Despite this, EWEs clearly receive a disproportionate share of publicity.

The above estimate (0.035%) also represents only a small fraction of deaths attributable to abnormal temperatures. Each location appears to have an optimum temperature at which mortality is a minimum,[37] and this appears to vary between the 60th percentile of the average daily temperature for some tropical countries to more than the 90th percentile in some temperate countries.[38] Figure 9 shows that most of the optimum temperatures are clustered between the 78th and 93rd percentiles.

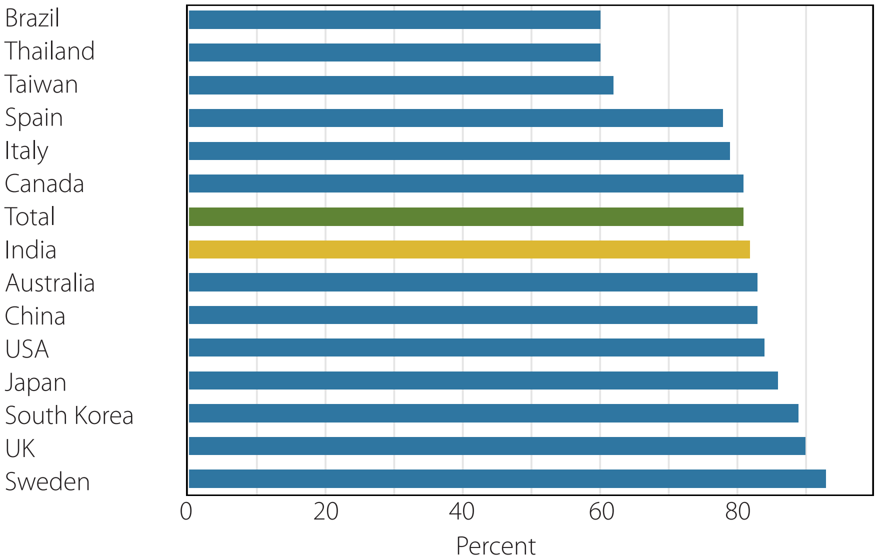


Figure 9: Optimum average daily temperature at which mortality is minimized, expressed as a percentile of the average daily temperature distribution.

From Gasparrini et al. (2015), except for India, from Fu et al. (2018). The total bar is based on the aggregate deaths for countries in blue.

Many more deaths are attributable to abnormally cold than to abnormally warm days (see Figure 10). An analysis of over 74 million deaths at 384 locations in 13 countries suggested that deaths from abnormal cold are 17 times more common than deaths from abnormal heat. Even in a warm country like India, the ratio is nearly 14.[39] It has also been estimated that *extreme* cold and hot temperatures are together responsible for less than 1% of total mortality, nine times *less* than abnormal temperatures.[40]

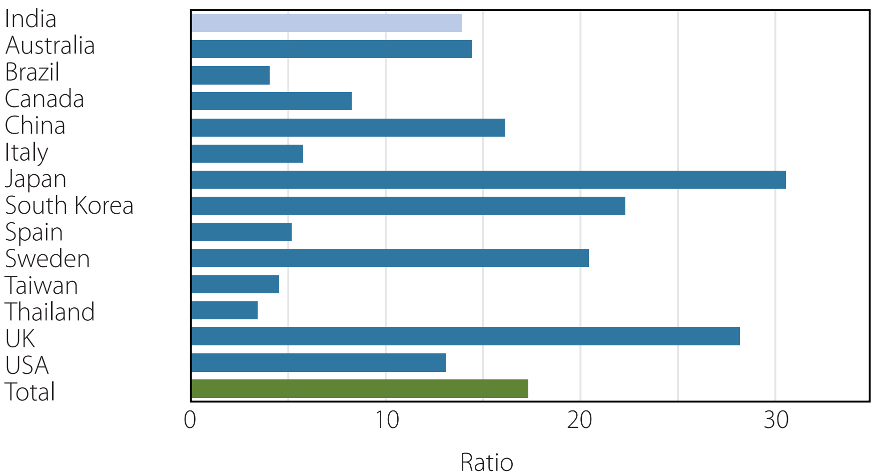


Figure 10: Ratio of deaths attributable to colder-than-optimum versus those attributable to warmer-than-optimum temperatures.

From Gasparrini et al. (2015), except India, from Fu et al. (2018). The total bar is based on the aggregate deaths for countries in dark blue.

There is substantial evidence of a decline in mortality from heat in several countries in recent years, suggesting adaptation and/or acclimation. The relative risk associated with high temperatures declined significantly between 1993 and 2006 in the US, Japan, and Spain;[41] the decline in Canada was not significant, and in certain other countries the changes have been small or of low statistical power. Interestingly, the authors found that risk to the US population 'seems to be completely abated in 2006 for summer temperatures below their 99th percentile'. Another study found that, notwithstanding any urban heat island effect, there was a 80% decline in US mortality rates on hot days during the 20th century.[42]

Societies may adapt better to heat rather than cold. A study of 53 communities in Japan and Korea found that the relative risk of mortality declined over time for heat waves, but apparently *increased* for cold waves.[43] And an analysis of trends in country-specific temperature-attributable mortality fractions not only confirmed that cold-related mortality substantially exceeds heat-related mortality,[44] it also found that despite warming trends, heat-related deaths decreased over the study period in 7 of the 10 countries studied. The trends in cold-related mortality were less consistent, with 5 countries showing a decrease, and 1 an increase.

Finally, it has been shown that winter is warming faster than the other seasons, and that nighttime temperatures have warmed more than daytime.[45] These changes are consistent with expectations of climate change and suggest that, *ceteris paribus*, in the future, the reduction in deaths from cold should exceed the increase in deaths from heat.

Economic losses

Figure 11 shows that global economic losses from EWEs as a proportion of GDP from 1990–2018 have been declining. For the US, once data have been adjusted to account for growth in population, assets at risk and GDP, there is apparently no long-term increase in economic losses from hurricanes,[46] floods,[47] or tornadoes.[48] An analysis of losses from weather-related disasters in China between 1985 and 2014 tells a similar story.[49]

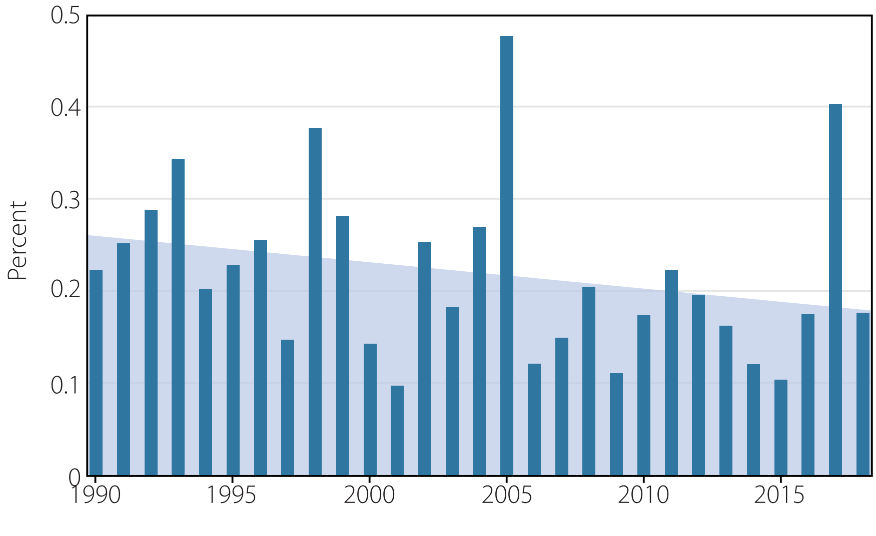


Figure 11: Global weather losses as percent of global GDP, 1990–2018.

Source: Pielke, Jr (2019), available at https://rogerpielkejr.com/2019/01/10/tracking-progress-on-disasters-2018-update/

Linear trend

3. Area burned by wildfires

One of the risks of climate change is that it might exacerbate wildfires. This would then affect forests, other ecosystems, human health, and water quality, among other things.[50] However, it appears that wildfires probably burned more area in the past – both before 1930 and in the pre-industrial era.[51] Analyses of charcoal in ice cores, lake and marine sediments, and tree-rings suggest that levels of fire activity vary greatly over the centuries, but 'generally fire occurrence increased to a peak around 1850 before declining to [present day] levels'.[52] It also appears that the current acreage burned in wildfires is substantially smaller for California specifically, and the globe generally:

> On longer timescales Mallek et al. suggest that [present day] burned area is just 14% of [pre-industrial] burned area in California, and Arora and Melton suggest an overall global decline of 25–30% in burned area since the [preindustrial era]. This decline in fire is a result of human activity: e.g., passive fire suppression from landscape fragmentation limits the spread of fires, while active fire suppression management and legislation aimed to improve air quality offset any potential anthropogenic increase in accidental fire ignitions.[53]

A recent review of satellite data found that the global burned area declined by between 16 and 33% between 1998 and 2015.[54]

With respect to the USA, Figure 12 indicates more land area was burned by wildfires from the 1920s through the 1950s than at present, peaking at four to five times current levels during the 1930s, which also saw the worst heatwaves in the US over the past century (see Figure 1). This suggests that, while weather may have an influence, factors such as land management and fire suppression may be more important in determining the area consumed annually by wildfire.

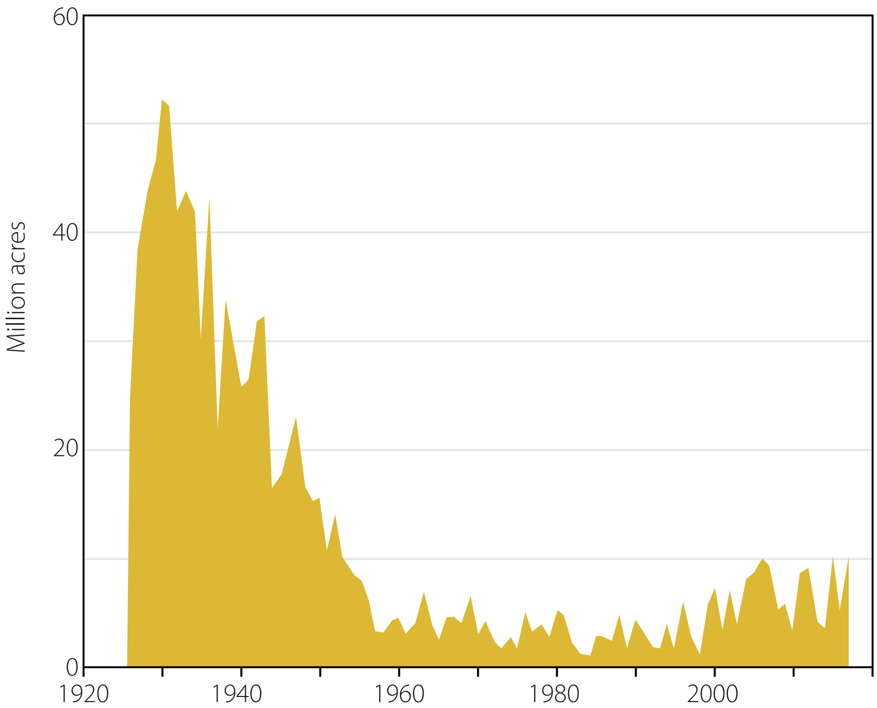


Figure 12: Area burned by wildfire, US, 1926–2017.

Source: US National Interagency Fire Center (2018), https://www.nifc.gov/fireInfo/fireInfo_statistics.html.

4. Disease

Warming, it is claimed, could increase the impact of climate- and weather-sensitive diseases. These include diarrheal diseases, as well as diseases transmitted or mediated by organisms whose life-cycles are sensitive to temperature, the presence of water or other climatic/weather factors.

The impact of diseases is measured in two different ways: mortality, and the global burden of disease (GBD), which is a measure of useful life lost due to being ill. GBD is measured in disability-adjusted life years lost, or DALYs.

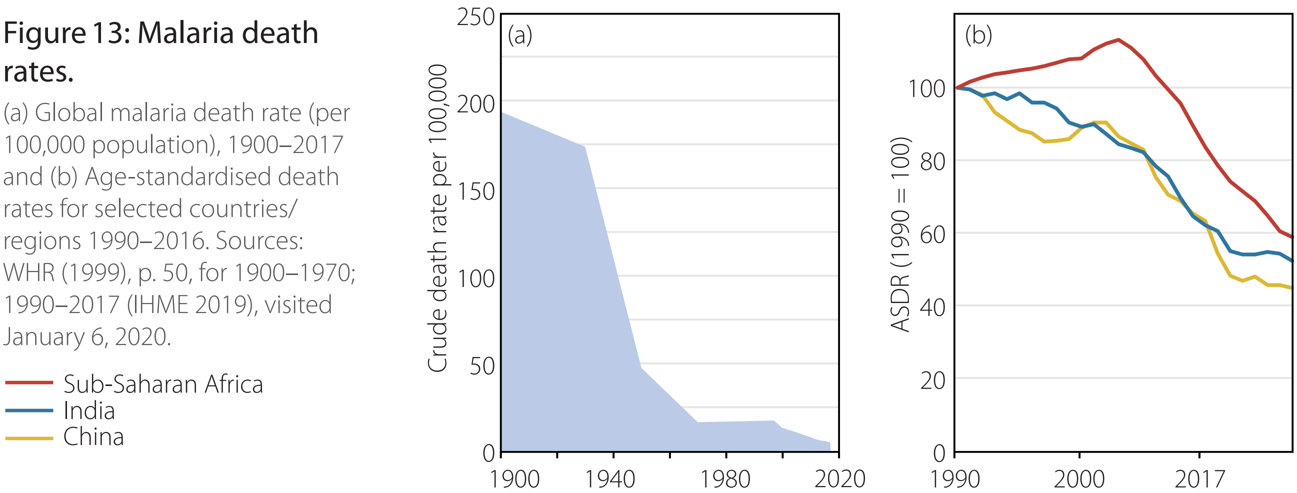
Parasitic and vector-borne disease

In the period 2000–2016, GBD for parasitic and vector-borne diseases declined by 42%.[55] Of the 13 diseases listed under this category by the WHO,[56] only dengue bucked the trend, but it is a relatively uncommon illness, representing just 6% of the category total in 2016. It is noteworthy that Zika, another dread disease frequently linked with climate change, does not even merit an entry on the WHO breakdown of the diseases in the category.

Malaria accounted for approximately 72% GBD of the category in 2016, and 76% in 2000,[57] so it is a reasonable surrogate for such diseases. In 2017, it accounted for 1.1% of global deaths, 23% below its rate in 1990.[58] Figure 13 indicates that the global crude death rate for malaria declined by 96% from 1900 to 2017. The decline for the US (not shown) was even more spectacular. In 2016, there were 5 malaria deaths in the US,[59] a rate of 0.0016 deaths per 100,000 population. In 1900, the rate was 7.9, so there has been a reduction of 99.8%.[60] Figure 13 shows that there have also been remarkable improvements elsewhere: the age-standardised death rates for China, India and Sub-Saharan Africa have declined by 55%, 48% and 41% respectively, from 1990–2017.[61] These improvements can be attributed to improved public health, the result of economic development, better science and technology, and its wide dissemination. Similar to death rates from EWEs (Figure 8), most of the improvements predate concern about climate change. They testify to humanity's ability to adapt to and reduce the impact of adversity.

Figure 13: Malaria death rates.

(a) Global malaria death rate (per 100,000 population), 1900–2017 and (b) Age-standardised death rates for selected countries/regions 1990–2016. Sources: WHR (1999), p. 50, for 1900–1970; 1990–2017 (IHME 2019), visited January 6, 2020.



Moreover, the prevalence of malaria is far more sensitive to the quality of public health systems and socioeconomic conditions than to climate, as demonstrated by the recent upsurge in malaria in Venezuela, even as it fell in the rest of South America.[62] During the first decade of the 21st century, malaria prevalence in that country had stabilised at around 1.5 per 1000 inhabitants; by 2017 it had increased sixfold,[63] representing more than half of the cases in the Americas, and 20 times its share in 2000.[64]

Diarrheal diseases

Diarrheal diseases accounted for 5.6% of global deaths in 1990 and 2.8% in 2017: a halving. Figure 14 shows that between 1990 and 2017, the age-standardised death rate for these diseases decreased everywhere. Going further back, crude US death rate from 'diarrhea and enteritis' was 133.2 per 100,000 in 1900,[65] and 2.7 per 100,000 in 2017 from diarrheal diseases.[66,67] Notwithstanding minor differences between the two classification schemes, the numbers indicate a large decline in deaths since the start of the 20th century.

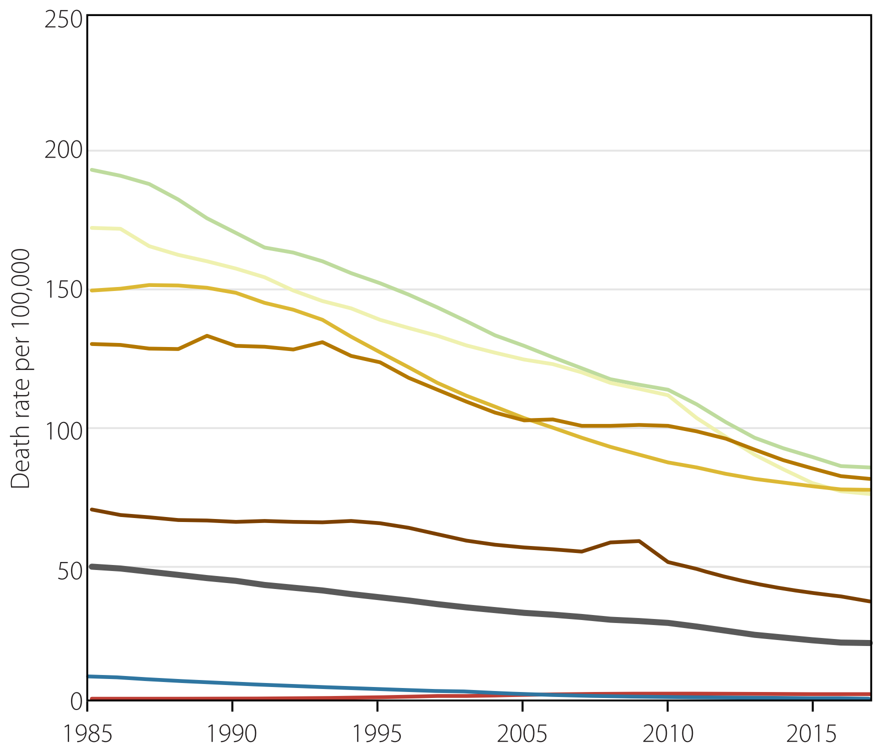


Figure 14: Death rates from diarrheal diseases, 1985–2017.

Death rates per 100,000 population, age-standardised. CSSA, ESSA, SSSA, WSSA are central, eastern, southern and western SSA, respectively. Source: OWID, https://ourworldindata.org/grapher/diarrheal-disease-death-rates, visited April 16, 2019.

- India
- Sub-Saharan Africa: West
- Sub-Saharan Africa: East
- Sub-Saharan Africa: Central
- Sub-Saharan Africa: South
- China
- USA
- World

5. Food and hunger

Among the numerous concerns regarding climate change is that it could reduce crop yields and therefore global food supplies, which, in turn, could increase hunger and malnourishment. However, cereals, excluding what is used to make beer, provide 45% of global food calories,[68] and data from the UN show that at least from 1961 onwards, cereal yields increased in every geographical area of concern: China, India, the Least Developed Countries, and the Low-Income Food Deficit Countries (Figure 15a). This has, over the long term, helped increase food supplies per capita (Figure 15b) and reduced the prevalence of chronic hunger or undernourishment (Figure 15c). While there may be year-to-year fluctuations (due to weather, not climate change), none of these figures suggest a sustained decline in food security, despite steady increases in carbon dioxide and any warming.

Overall changes in yields and food supplies over what might be considered to be approximately the period of global warming are summarised in Table 5.1. Global cereal yields have tripled, and food supplies per capita have increased by 31% since 1961. The table also shows more recent changes in the prevalence of chronic hunger. These have declined markedly.

Figure 15: Improving food situation since 1961

(a) Cereal yields, 1961–2016;
(b) food supply, 1961–2013;
(c) prevalance of hunger, 2000–2016 (3-year centred moving average). LDC = Least Developed Countries; LIFDC = Low Income Food Deficit Countries. Source: FAOSTAT (2019).

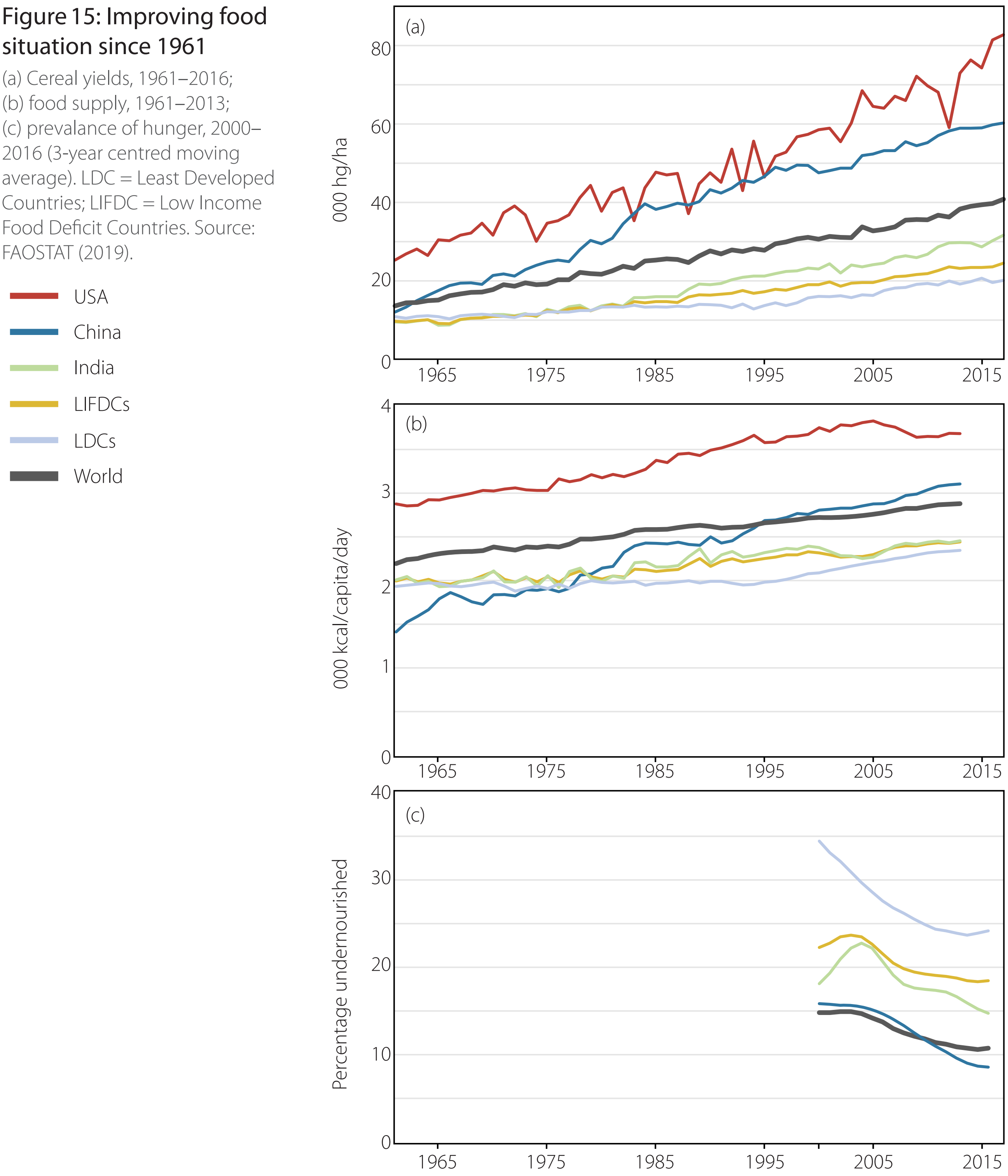


Table 1: Improvements in cereal yields, food supplies and hunger

Change in:	China	India	US	LDC	LIFDC	World
	% change					
Cereal yield, 1961–2017	405	234	228	87	155	201
Food supplies per capita, 1961–2013	120	22	28	21	22	31
Proportion chronically hungry, 1989–1991 to 2015–2016	–45	–19	NE	–30	–17	–28

NE = no estimate provided. Source: FAOSTAT (2019).

Most of the increase in yields is due to the use of fossil fuel dependent technologies. First, nitrogenous fertilisers are derived directly or indirectly from the Haber-Bosch process, which uses natural gas – or in China, coal – as its energy source. It has been estimated that the Haber-Bosch process is responsible for 48% of the world's food production.[69] Second, synthetic pesticides, which also use fossil fuel products as their feedstocks, are vital. Without them crop yields would be reduced by 26–40%.[70] These two technologies alone have increased food production by over 150%.[71]

6. Sea-level rise and land loss

Another concern is that seas will rise and inundate coastal areas, severely affecting, if not endangering, coastal and island populations through floods, storm surges, contamination of water supplies, and loss of living space and agricultural lands. And, indeed, the seas have been rising for much of the twenty centuries since the last ice age. However, virtually all of this rise – over 120,000 mm – predates human fossil fuel use. Sea-level rise (SLR) is normal during an interglacial, like the period we are in. One should expect, therefore, that climate change would accelerate SLR.

It is suggested that global mean sea level (GMSL) has been rising at a rate of around 3 mm per year since 1993, with an acceleration of 0.084 ± 0.025 mm/year^2.[72] The IPCC's Fifth Assessment notes that the current rate of SLR is higher than the mean rate during the 20th century, but this may be a fluctuation rather than a real acceleration because:

- The records are very short, especially compared to the length of oceanic cycles that could affect SLR.
- GMSL 'rose between 1920 and 1950 at a rate comparable to that observed since 1993'
- There have been 'previously reported multi-decadal variations of mean sea level'.[73]

Nevertheless, one should expect that beaches and low-lying islands would have shrunk because of SLR. However, a study of the state of the world's beaches indicates that only 24% of them are eroding at rates exceeding 0.5 m per year, while 28% are growing and 48% are stable.[74] It also found that erosion rates exceed

5 m per year along only 4% of the world's sandy shorelines, whereas 6% are growing at more than 5 m per year. This finding is consistent with a recent analysis that found that 'Earth's surface gained…33,700 km^2 of land in coastal areas'.[75] While this is a miniscule increase relative to the global land area, it is inconsistent with the notion that land (in aggregate) is disappearing.

Other counterintuitive results include the recent finding that coral atolls do not seem to be shrinking either. An analysis of 30 Pacific and Indian Ocean atolls, including 709 islands, revealed that no atoll larger than 10 ha was becoming smaller and that the vast majority of islands were either stable or increasing in area. Only 11% were contracting.[76] It has also been shown that the 101 islands of the atoll nation of Tuvalu have expanded in area by 3% between 1971 and 2014, despite the fact that local sea level rose at twice the global average rate.[77]

Finally, Bangladesh is frequently cited as a country that is threatened by SLR. However, a study of its coastline using 30 years of Landsat (satellite) images revealed that the rate of accretion was slightly higher than the rate of erosion, resulting in a net gain of 237 km^2 between 1985 and 2015. The rate of increase is small, but quite a contrast to received wisdom.[78]

7. Human wellbeing

Climate change is said to be a threat to human wellbeing.[79] The previous sections have shown that trends in many of the factors that might directly affect human wellbeing have, contrary to the standard narrative, actually improved. In this section, I consider some of the broader indicators of human wellbeing to see if these have worsened, as would be expected per the standard climate narrative. The indicators concerned cover the areas of economic development, life expectancy, health, poverty, human development, and access to amenities such as electricity, the Internet, and mobile phones.

Economic development and life expectancy

Two of the broadest indicators of human wellbeing are economic development and life expectancy. Notably, these were two of the three measures used in the UN's original Human Development Indicator. Economic development, for which I will use GDP per capita as a surrogate, is a measure of material wellbeing and standard of living. Equally importantly, increases in GDP per capita correlate with improvements in a wide range of other indicators of human wellbeing:

- income and wealth
- declines in infant, child and maternal mortality
- reductions in involuntary hunger, child labour, and poverty
- improvements in health status as well as educational status and achievement
- expenditures on health, and research and development.[80]

Meanwhile, life expectancy, probably the single most important indicator of human wellbeing, reflects changes in:

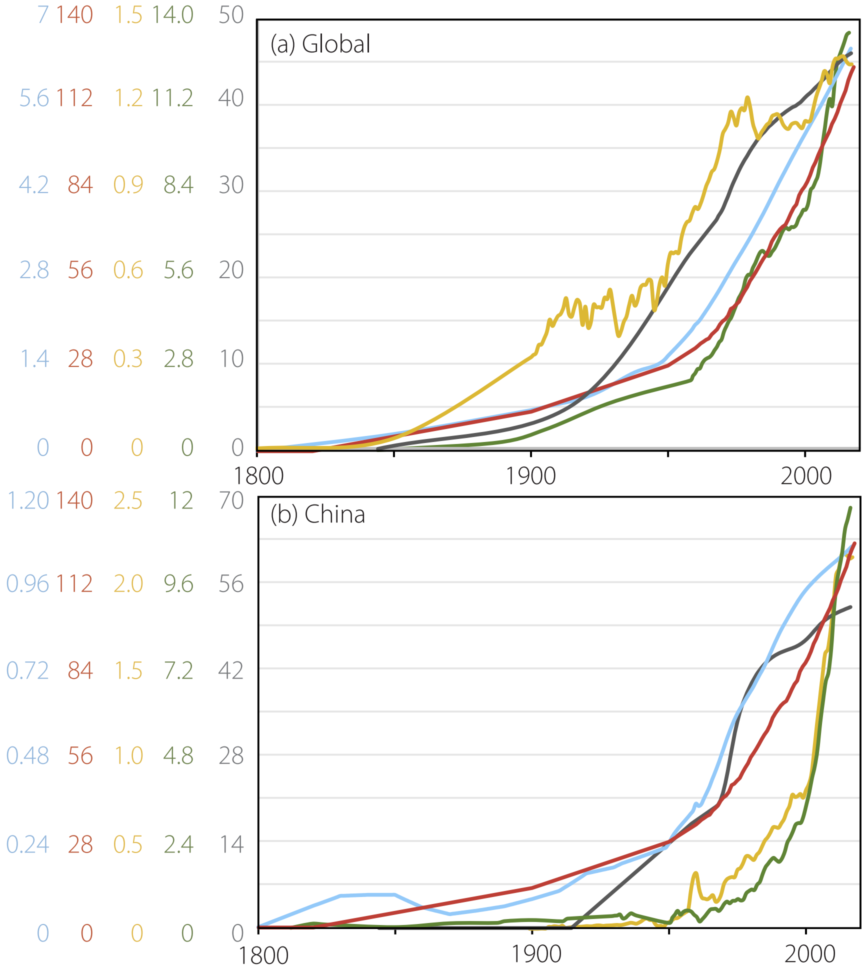
- infant, child, and maternal mortality
- health (and healthcare)
- sanitation
- access to clean water.

However, because it is theoretically possible for it to increase even as health status deteriorates, I also consider a measure in which life expectancy is discounted for years spent in poor health. However, these so-called 'health-adjusted' life expectancy (HALE) values are based on subjective determinations regarding the severity of different diseases so the values for HALE should be treated cautiously.

Figure 16a shows changes during the fossil fuel era in GDP per capita, life expectancy, population, and annual carbon dioxide emissions per capita – an approximate surrogate for fossil fuel use per capita – for the world.[81] The latter can be used as an approximate[82] marker to identify when industrialisation commenced in earnest for the geographic area under consideration (the whole world in this figure). Global atmospheric carbon dioxide concentration is also shown because it is an indicator for the amount of climate change that has (or should have) occurred. It helps the reader determine whether wellbeing indicators have declined as

Figure 16: Carbondioxideand human welfare.

(a) World and (b) China. Updated from Goklany (2012a). Indicators of human welfare are: changes in GDP (per capita at PPP in 2011 USD), population and life expectancy. Carbon dioxide is represented by changes in emissions per capita and global concentration. All changes versus 1800 value, or nearest alternative date. Note that in 1800, emissions per capita were negligible.Sources citation in main text.



Changes in carbon dioxide:
- Concentration (ppm)
- Emissions per capita (t carbon)

Changes in human welfare:
- Life expectancy
- Per-capita GDP (000 2011$)
- Population (billions)

global carbon dioxide concentrations (and, presumably, temperatures) have increased.[83]

Figure 16a also shows that human wellbeing has increased in parallel with the increase in fossil fuel use. Moreover, both life expectancy and GDP per capita increased despite a ramp-up of the population. This observation undermines the fundamental premise underpinning demands to reduce carbon dioxide emissions, namely, that those emissions are reducing wellbeing in multiple ways: improving wellbeing and increasing population are the very definition of a species' success, so long as a habitable environment is maintained (see Section 8). The corresponding graph for China (Figure 16b) affirms these findings, as do the graphs for the US, UK, France, India, the Less Developed Countries, and sub-Saharan Africa (not shown). The increases in life expectancy and GDP per capita for China in the late 20th and early 21st centuries, which roughly parallel increases in carbon dioxide per capita, are particularly dramatic.

Curiously, given the large estimates of the death toll associated with *outdoor* air pollution, one may have expected that air pollutants in combination with carbon dioxide would have reduced life expectancy during the period of high carbon dioxide growth for a nation, that is, from the late 1990s to the present. It has been estimated that in 2010, outdoor air pollution, mostly from PM2.5, led to 1.36 million deaths in China and 645,000 deaths in India.[84] If these estimates, which are based on statistical associations rather than hard cause-of-death data from death certificates, are accurate, then for 2010, 14.8% of all deaths in China and 7.0% in India were due to outdoor air pollution.[85] Nevertheless, there is no hint of any decline in life expectancy during the period when fossil fuel use and therefore presumably outdoor air pollution were growing rapidly (see Figure 16b).

Table 2 indicates that, despite substantial increases in PM2.5 exposures, life expectancies in both countries increased substantially. This indicates that deaths from outdoor air pollution do not substantially decrease life expectancy, are overestimated, or they are more than overwhelmed by all the factors associated with eco-

Table 2: Life expectancy, PM2.5 exposure and CO_2 concentrations, 1990–2010.

		1990	2010	% increase
China	PM2.5 exposure* (μg per m^3)	57.8	69.5	20
	Life expectancy, total (years)	69.3	75.2	9
India	PM2.5 exposure* (μg per m^3)	81.3	95.8	18
	Life expectancy, total (years)	57.9	66.6	15
CO_2	Atmospheric concentration (ppm)	354	390	10

* population-weighted mean annual exposure. Source: World Development Indicators, April 24, 2019.

nomic development and energy use that improve life expectancy, or some combination of these factors.

Further support for this observation comes from the fact that comparing a list of Chinese cities ranked by the Air Quality Index versus rankings by life expectancies (both for 2018) reveals no correlation between the two lists. For example, Shanghai, Suzhou and Nanjing are ranked 1st, 2nd and 3rd by life expectancy but 10th, and 13th and 12th by AQI.[86] Notably, Beijing is 10th by life expectancy but 28th by AQI. In fact, of the top 20 cities in terms of life expectancy, 11 are not even listed among the top 45 cities in terms of AQI. According to Wikipedia's list of Chinese cities by life expectancy, 'Most cities with high life expectancy are located in the Yangtze River Delta, Pearl River Delta and Beijing-Tianjin region'. These are among the most industrialised (and urbanised) areas, not just in China, but anywhere in the world.

Poverty rate

As economic development has advanced around the world, absolute poverty has declined. Figure 17 shows that in 1820, a billion people – 84% of the global population – lived in absolute poverty.[87] By 2015, this had dropped to 10%. Thus fewer people live in absolute poverty today than in 1820, despite a sevenfold increase

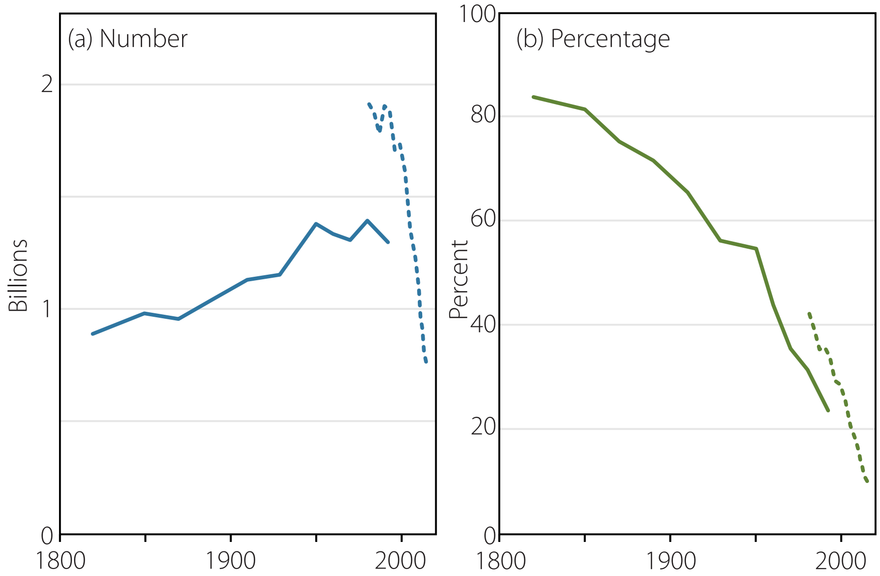


Figure 17: Trends in global poverty, 1820–2015.

(a) Number and (b) percentage of people in 'absolute' poverty. Sources: Bourguignon and Morrisson (2002; solid lines); WDI (2019; dotted lines).

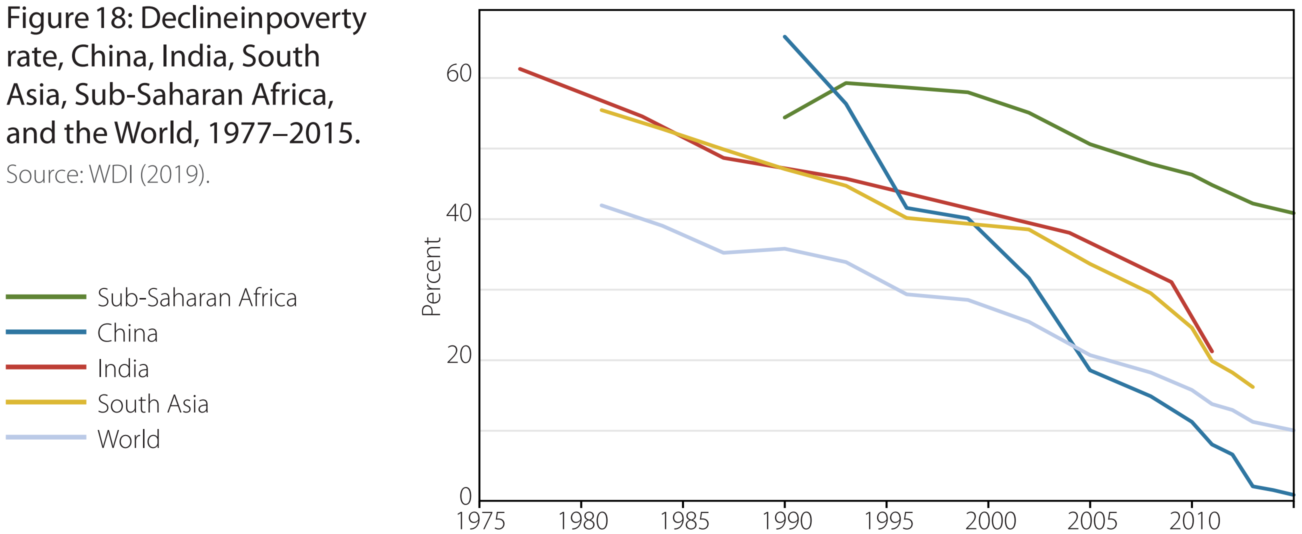


Figure 18: Declineinpoverty rate, China, India, South Asia, Sub-Saharan Africa, and the World, 1977–2015.

Source: WDI (2019).

in population. Figure 18 shows poverty rates declined across most of the world from 1977 onward.

Notably, the fastest declines in the global poverty rate occurred in the past three decades, coinciding with rapid increases in atmospheric carbon dioxide, due mainly to the explosion in fossil fuel use in China (Figure 16b) and, to a lesser extent, India. Consistent with the notion that economic development and energy consumption are positively correlated, these two countries also saw a more rapid reduction in their poverty rates than the world as a whole during this period (Figures 17 and 18).

Health-adjusted life expectancy

Health-adjusted life expectancy (HALE) accounts for the fact that a longer life does not necessarily equate to a healthier life. HALE is calculated by adjusting life expectancy (LE) downward to account for the amount of time people spend in a diseased or disabled condition, taking into account the severity of the disease or disability. However, in contrast to LE, HALE estimates are rather subjective, in particular with regards to the weight assigned to each

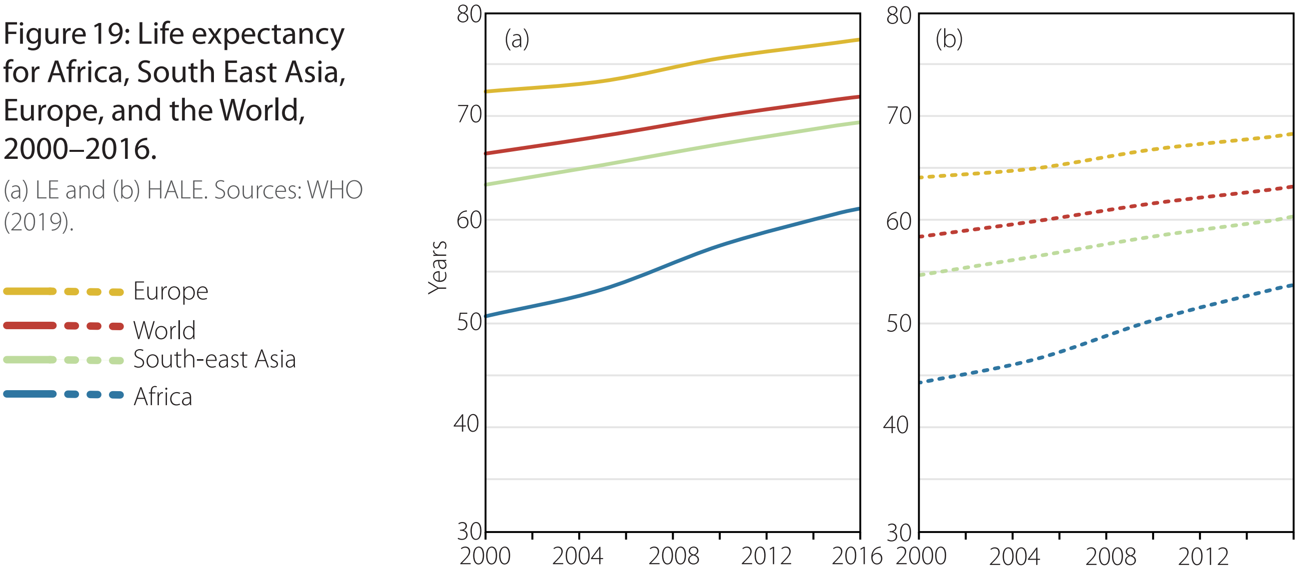


Figure 19: Life expectancy for Africa, South East Asia, Europe, and the World, 2000–2016.

(a) LE and (b) HALE. Sources: WHO (2019).

disease condition or disability. Figure 19 shows that LE and HALE have been increasing, more or less monotonically, since 2000.[88]

In fact, HALE in virtually every area today exceeds unadjusted life expectancy from a generation or two ago (Table 3).

Table 3: HALE in 2016 versus LE in 1950.

	LE in 1950	HALE in 2016	2016 HALE above LE of
China	41.0	68.7	1986
India	32.0	59.3	1992
US	68.2	68.5	1951
World	49.0	63.3	1981
CO_2 concentration (ppm)	311	404	

Sources: Figures 6.1–6.4, WHO (2019).

Notably, there was a marked LE inequality between Africa and the rest of the world in 2000, but the difference, of 15.7 years, had shrunk to 10.8 years by 2016. Similarly, the inequality in HALE decreased from 14.1 to 9.5 years over this period,[89] confirming earlier findings that human wellbeing has been globalised.[90]

7.4 Human development index

The human development index (HDI) is a measure developed by the UN Development Programme to compare levels of human development in different geographical areas; it aggregates values for GDP per capita, life expectancy, and level of education, so as to emphasise that there is more to human wellbeing than wealth.

Figure 20 illustrates the trend in HDI for the world, USA, China, India, the LDCs and sub-Saharan Africa between 1990 and 2017.

Figure 20: Trends in HDI, 1990–2017.

Source: UNDP, at http://hdr.undp.org/sites/default/files/2018_human_development_statistical_update.pdf, visited May 12, 2019.

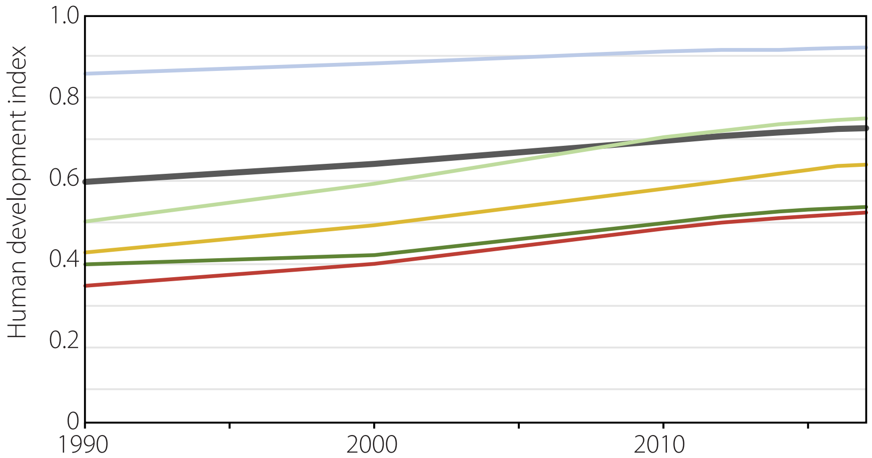


Table 4 indicates the percentage increase in HDI for various countries and country groups over the same period. Contrary to what might be expected if climate change is a significant, and negative, determinant of human wellbeing, these show that HDI

Table 4: Trends in HDI, 1990–2017

	HDI 1990	HDI 2017	% increase
LDCs	0.35	0.52	51
SSA	0.40	0.54	35
India	0.43	0.64	50
South Asia	0.44	0.64	45
China	0.50	0.75	50
East Asia and Pacific	0.52	0.73	42
Arab states	0.56	0.70	25
Latin America and Caribbean	0.63	0.76	21
Europe and Central Asia	0.65	0.77	18
USA	0.86	0.92	7
World	0.60	0.73	22

Source: UNDP, at http://hdr.undp.org/sites/default/files/2018_human_development_statistical_update.pdf, visited May 12, 2019.

has improved virtually everywhere. In fact, of the 186 countries for which the UN provides data for 1990–2017, only three – Syrian Arab Republic, Libya and Yemen, all in the throes of civil wars – failed to improve their HDI.[91]

Table 4 also indicates that, for the most part, but not invariably, human wellbeing, as measured by the HDI, advanced more rapidly in the lesser developed areas than in the more developed worlds. In other words, by this measure as well, inequality has been shrinking for the most part.

7.5 Other quality of life indicators

Access to electricity, the Internet and mobile phones are the hallmarks of modernity and advance individual wellbeing and quality of life.

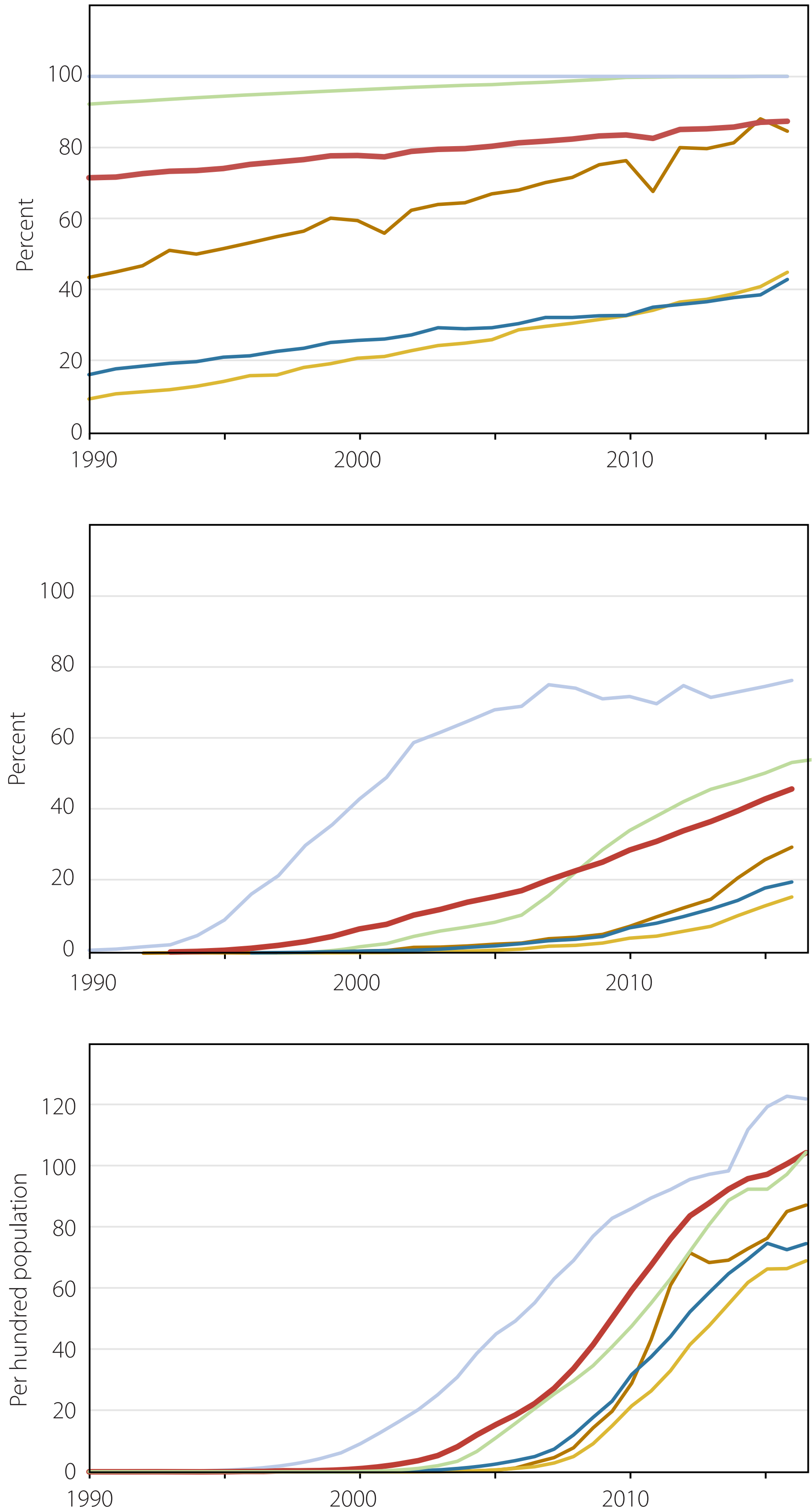
Electricity allows individuals to use energy in their personal environment without polluting it (although it can result in substantial pollution at or near the point of generation). It provides round-the-clock lighting, air conditioning, and refrigeration. It can also be used for heating, cooking, and running appliances, computers, other electronic devices, and machinery. Because of its centrality to modern existence, its loss is often rightly considered to be an emergency. Following natural disasters, restoration or maintenance of electricity is usually a priority.

Mobile phones and the Internet not only connect us to friends, relatives, and associates, they provide us with almost instant access to information. They can also increase resilience and help reduce the impacts of natural disasters by allowing warnings to be broadcast widely and rapidly and responses to be organised.[92] They can increase public safety, and mobile phones are often given to children as a precautionary measure.[93] They save users innumerable hours that would otherwise have been spent researching, shopping, or wrestling with problems and identifying solutions. In other words, like lighting, they have allowed human beings to 'expand' the time they have (to use or misuse, as desired).[94]

Figure 21 shows trends in access to electricity, and Internet and mobile phone usage from 1990 onward for China, India, the US, the Less Developed countries, sub-Saharan Africa and the world. They indicate that the proportions of people with access to these amenities are increasing rapidly, and converging to the levels seen in the US. This is therefore yet another example of shrinking inequality around the world.

Figure 21: Access to modern amenites

(a) Electricity, 1990–2016 (b) Internet 1990–2016 (c) mobile telephones 1990–2017. Source: WDI (2019).



8. Terrestrial biological productivity

Greening of the Earth

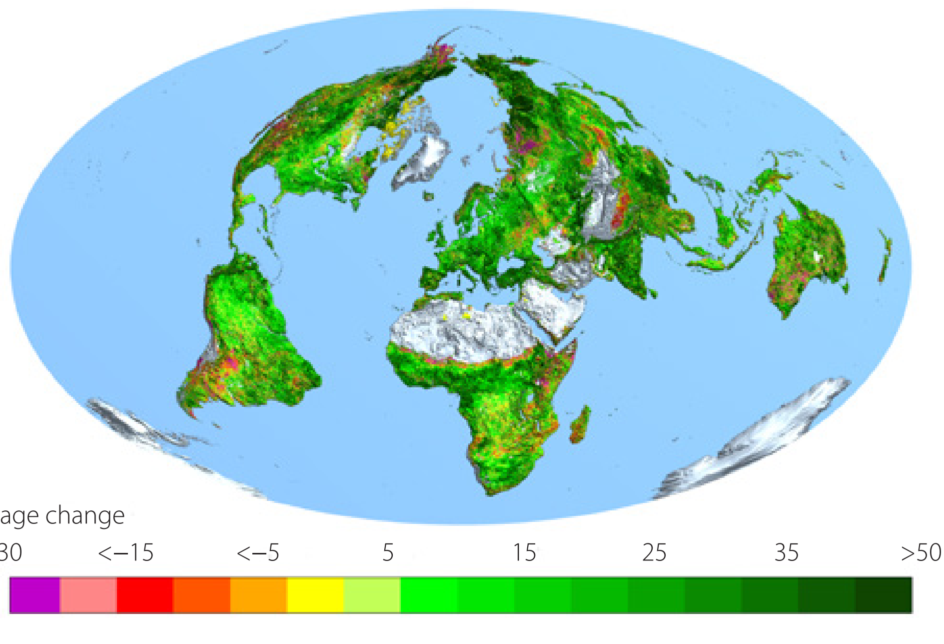
In the popular narrative, climate change will exacerbate droughts and desiccate vegetation, the Earth will turn brown and wildfires will consume the landscape.[95] However, satellite data directly contradicts this story. It shows the world has become greener and more productive as atmospheric carbon dioxide concentration has increased (see Figure 22). But for the narrative, this would be unremarkable, since it has been known since de Saussure's 1804 publication, *Recherches Chimiques sur la Végétation,* that plants grow by absorbing carbon dioxide from the atmosphere. Moreover, as shown in Sections 2 and 3 respectively, droughts and wildfires are no more frequent or extensive than in the past. In fact, this greening confirms Arrhenius' prediction that higher carbon dioxide levels would 'raise the intensity of vegetable life'.[96]

Satellite data shows that from 1982 to 2009, 25–50% of global vegetated area had become greener while only 4% had become browner.[97] This is mostly due to carbon dioxide fertilisation, which increases the rate of photosynthesis and water-use efficiency of most plants, but also to nitrogen deposition, climate change, and to land use change.

In addition, global leaf area has increased at a rate of 2% or more per decade from 2000 to 2017.[98] The greening occurred disproportionately in China and India, which accounted for 25% and 7% of the global net increase in leaf area respectively, despite only having 7% and 3% of global vegetated area respectively. Greening came mainly from forests (42%) and croplands (32%) in China, and croplands (82%) in India, suggesting that the greening is from reforestation and agricultural practices (e.g. fertilisers and multi-

Figure 22: Change in leaf area across the globe, 1982–2015.

Source: R Myneni.



cropping). If so, then it is consistent with the increased agricultural yields shown in Figure 15.

Contrary to prevailing wisdom, tree cover globally has increased by over 2 million km^2 between 1982 and 2016, an increase of 7%.[99] Global bare ground cover decreased by more than 1 million km^2, a reduction of 3%, most notably in agricultural regions in Asia. 60% of all land use/cover changes were associated with direct human activities and 40% with indirect drivers such as climate change. These results indicate that there has been net reforestation and net de-desertification, partly due to climate change.

Productivity has been shown to have increased significantly from 1982 to 2011 in nearly half of global grasslands, while declining significantly in only a tiny proportion (1.5%).[100] Global gross primary productivity (i.e. carbon uptake) increased along with greenness over the same period, at a rate of 0.6 ± 0.2% per year. This change was driven mainly by an increase in plants' water use efficiency, an expected but underemphasised consequence of higher atmospheric carbon dioxide concentrations.[101] More than half of the world's vegetated land showed significant positive trends.

The increased productivity from higher rates of photosynthesis and water use efficiency due to higher carbon dioxide concentrations means that the biosphere is producing more plant matter per unit of land and per unit of water. In other words, there is more food for all organisms, even under water-stressed conditions. In other words, the Earth should be able to sustain larger amounts of biomass: more representatives of every species of plant and animal and, possibly, more species. It should also become more resilient to drought, a chronic problem that is detrimental to virtually all life forms.

This suggestion seems to find support in a study by Steinbauer et al. (2018), who reviewed 145 years of plant surveys on European mountain-tops and found

> …a continent-wide acceleration in the rate of increase in plant species richness, with five times as much species enrichment between 2007 and 2016 as fifty years ago…This acceleration is strikingly synchronised with accelerated global warming and is not linked to alternative global change drivers. The accelerating increases in species richness on mountain summits across this broad spatial extent demonstrate that acceleration in climate-induced biotic change is occurring even in remote places on Earth, with potentially far-ranging consequences not only for biodiversity, but also for ecosystem functioning and services.[102]

Similarly, various analyses of species diversity in mountain regions – from the Andes,[103] the Austrian Tyrol,[104] and the Eastern Himalayas[105] have found increased species diversity, directly contradicting claims that greenhouse gas-induced warming would be detrimental to biodiversity.

Terrestrial habitat and biodiversity loss

Habitat saved through increase in agricultural productivity

Since the start of the Industrial Revolution in around 1750, global population has increased approximately tenfold, from about 800 million to almost 8 billion. The need to feed and clothe these billions has led to a massive conversion of natural habitat to agricultural lands (including lands for crops and pastures). The resulting habitat loss is generally acknowledged to be the primary threat to terrestrial species conservation.[106]

Fortunately, agriculture has become more productive in the last few decades, a development which has contained habitat loss.[107] Figure 23 indicates that, despite continued growth in global population and food supplies per capita, agricultural land area peaked around 2000.[108] Between 1961 and 2013, global population increased from 3.1 billion to 7.2 billion (a 133% increase) and per-capita food supplies increased by 31%. Yet agricultural land only increased by 8%, from 4.5 to 4.8 billon hectares (Bha). This implies that, on average, one hectare of agricultural land produced 2.8 times as much dietary energy in 2013 as it did in 1961.[109] Had agricultural productivity remained at its 1961 level and *all else remained the same*, then agricultural land would have had to increase to 13.7 Bha to meet the current demand for dietary energy.[110] But that is more than the global area of potentially productive land that exists today: land that is neither barren, nor covered by permanent snow and glaciers, namely, 11.3 Bha.[111] These calculations also imply that increased productivity since 1961 has saved 8.9 Bha from conversion to agricultural uses.[112]

Note that the assumption *that all else remains the same* implies that agricultural technology is frozen at its 1961 level; in other words, that no new technologies are adopted and nor is there an increase in the penetration of existing technologies. The calculation also assumes that new agricultural land would be just as productive as existing agricultural land. This is unlikely, since the most productive lands are most likely already in use. This means that the figure of 8.9 Bha saved is an underestimate.

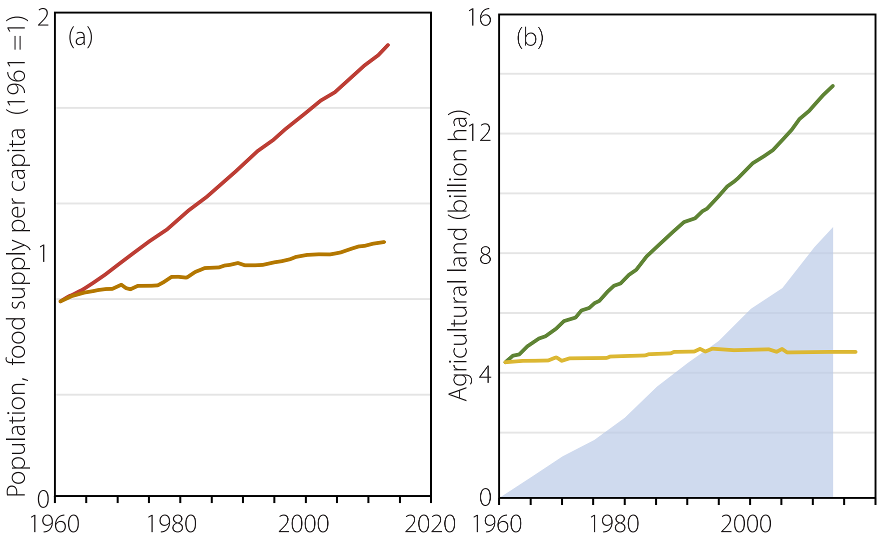


Figure 23: Habitat saved from conversion to agriculture because of increased productivity since 1961.

(a) Growth in population and food supply per capita. (b) Land required to deliver food supply in (a) with/without technological advances. Source: Calculated from FAOSTAT (2020).

Population
Food supply per head

Land requirement:
No new technology
Actual
Habitat saved

Habitat saved by fossil fuels

Most of the increase in agricultural productivity over the last century was enabled through technologies that rely on fossil fuels: nitrogen fertilisers, synthetic pesticides and irrigation. Fertiliser and pesticide production rely almost entirely on fossil fuels, which are used both as feedstocks and to provide energy for the manufacturing processes.[113] Irrigation, except where it relies on gravity alone, needs energy for transporting and distributing water. In addition, two indirect effects of the use of fossil fuels, namely carbon dioxide fertilisation and nitrogen deposition, have also increased yields.[114]

Here I will estimate a *lower bound* for the global increase in habitat loss that would occur assuming current food production were maintained in the absence of nitrogen fertilisers and carbon dioxide fertilisation. The analysis ignores the increased productivity from the use of synthetic pesticides and irrigation powered directly. In addition, it focuses only on wild habitat saved from conversion to cropland. In other words, it ignores any habitat saved from conversion to pasture.

Currently, agricultural land occupies 37.4% of the global terrestrial area, excluding Antarctica.[115] A total of 12.2% is devoted to cropland, and the remainder to pasture.

> *Nitrogen fertilisers:* It has been estimated that the Haber-Bosch process is responsible for 48% of global food production; that is, they have increased food production by 92%.[116]
>
> *Carbon dioxide fertilisation:* The IPCC estimates that doubling pre-industrial atmospheric carbon dioxide levels (277 ppm) would increase productivity by 20–25%. As of 2019, we are about half-way there (409 ppm).[117] Assuming linearity between increases in yield and carbon dioxide, carbon dioxide fertilisation has increased yields by 10–12% to date. Note, however, that the assumption of linearity underestimates the increase in yield.[118] In the following, I will assume carbon dioxide fertilisation increased global agricultural yield by 10%.

Thus, nitrogen fertilisers and carbon dioxide fertilisation have together increased global food production by 111%.[119] In other words, fossil fuels are responsible for more than half of global food production. Without them, food would be scarcer, and prices higher (assuming all else, including food demand, stays constant). To maintain the food supply, croplands would have to more than double, to *at least* 26% of the world's land area (ex-Antarctica). Adding in pastureland, the human footprint on the planet would increase to 51.2% of the world. In other words, fossil fuels have saved 13.8% of the non-frozen parts of the world from being converted to agriculture.

Note also that these calculations assume that the new cropland would be as productive as existing cropland, something

which, as already noted, is unlikely. Moreover, it ignores the contributions of synthetic pesticides and irrigation. Thus, if habitat loss is already the major threat to ecosystems and biodiversity, getting rid of fossil fuels would only make a bad situation catastrophically worse.

9. Discussion

I have examined empirical trends in:

- a wide variety of climate- and weather-related phenomena;
- commonly accepted indicators of human and environmental wellbeing;

to verify whether, consistent with received wisdom, they are getting worse over time due to higher atmospheric carbon dioxide concentrations (and resulting climate change). The results are summarised in Tables 5 and 6, respectively. They indicate that, except for the fact that hot days have increased while cold days have decreased, none of the trends are consistent with the received narrative. Regarding weather and climate phenomena (Table 5):

- cyclones, tornadoes, floods and droughts are not getting any worse;
- wildfires are less extensive than they used to be;
- cereal yields and food supplies have increased;
- coastal margins and beaches have not been shrinking.

Table 5: Climate and weather: the standard narrative versus reality

Claim per standard narrative	Supported by current trends?	Section
More hot days and fewer cold days	Yes	2
Cyclones/hurricanes more intense or frequent	No	2
Tornadoes increase and become more intense	No	2
Floods more frequent and more intense	No	2
Droughts more frequent and intense	No	2
Area burned by wildfire increasing	No. Area peaked in mid-19th century	3
Cereal yields decrease	No. They have tripled since 1961	5
Food supplies per capita decrease	No. Increased 31% since 1961	5
Land area and beaches shrinking, coral islands submerged	No. Marginal expansion	6

Regarding human wellbeing (Table 9.2):

- mortality and economic losses to extreme weather events have declined;
- access to clean water has increased;
- death rates from climate- and weather-sensitive vector-borne and parasitic diseases have declined.

Most importantly, as carbon dioxide emissions have increased since the start of the Industrial Revolution, virtually every measurable and significant objective indicator of human wellbeing has advanced:

- life expectancy and income levels have improved;
- poverty levels have declined;
- people are living longer and healthier lives;
- the human development index has advanced virtually everywhere.

Nor is there any sign of a recent sustained turnaround in these indicators, although there are minor fluctuations from year to year. These results reaffirm the findings of several previous studies that have found, contrary to prevailing dystopian narratives, that the state of humanity has improved since the start of the Industrial Revolution, and continues to improve into the present,[120] poverty is declining and global inequality is improving in terms of incomes and critical indicators of human wellbeing: life expectancy, human development index, and access to cleaner water.[121]

Regarding the rest of nature, the Earth is greener and more productive. Increased land productivity – a result of the use of fossil fuels – means that the area of land converted to human uses peaked in around 2000. Without fossil fuels, cropland would have to increase significantly to maintain current food production. Thus fossil fuels have reduced habitat loss by at least 14% of the global terrestrial area, saving numerous species and ecosystems. This fact refutes claims that fossil fuels are detrimental to biodiversity and ecosystems.

10. Conclusion

While climate may have changed for the warmer:

- Most extreme weather phenomena have not become more extreme, more deadly, or more destructive.
- Empirical evidence directly contradicts claims that increased carbon dioxide has reduced human wellbeing. In fact, human wellbeing has never been higher.
- Whatever detrimental effects warming and higher carbon dioxide may have had on terrestrial species and ecosystems, they have been swamped by the contribution of fossil fuels to increased biological productivity. This has halted, and turned around, reductions in habitat loss.

Table 6: Human welfare: the standard narrative versus reality

Claimed or implied impact	Reality to date	Section
Access to water will decline	While pressure has gone up with population, access to cleaner water is up	2
Mortality from EWEs will increase	False. Mortality rate from EWEs has declined by 99% since the 1920s	2
More people will die from heat	Fewer people are dying from heat. Globally, about 15 times as many people die from cold than heat, so warming should, if anything, have reduced mortality	2
Economic losses from EWEs will increase	False	2
Death rates from climate-sensitive diseases (e.g. malaria and diarrhea) will increase	False. Global crude death rates have declined 96% since 1900 for malaria. Age-standardised death rates for diarrheal diseases have declined 56% since 1990	4
Hunger will become more prevalent	False. Hunger rates have declined in the long term despite a 250% population increase since 1961	5
GDP per capita will decline	False. GDP per capita has quadrupled since 1950 even as CO_2 have sextupled	7
Poverty will increase	False. Global poverty rates have declined significantly since 1820 because GDP per capita have increased 14-fold	7
Life expectancy will decline	False. Global life expectancy has more than doubled since the start of industrialisation	7
Public health will suffer	False. Health-adjusted life expectancy has increased with economic development, and energy use	7
Human development index (HDI) will decline, and quality of life will decline	False. HDI has increased, and more people have access to, and use, modern amenities such as electricity, the Internet and mobile phones	7
Inequality will expand	Globally inequality has decreased in terms of incomes, life expectancies, HDI, as well as access to modern-day amenities	7
Biological productivity is under threat	The earth is greener and more productive. Habitat lost to agriculture has peaked due to fossil fuel dependent technologies	8

- To the extent that inequality is deplorable, global inequality in terms of income, life expectancy, human development and access to modern amenities have declined and continue to decline.
- The detrimental effects of carbon dioxide and fossil fuels are overwhelmed by other concurrent changes that are beneficial.
- Fossil fuels have allowed the population to increase even as the wellbeing of the average person has improved and the Earth has become greener and more productive. As a result, habitat lost to human uses has been halted, despite population increases. These are the very definitions of success for a species.

In the future, books on agnotology will devote chapters to how the standard narrative on climate change impacts took hold among the religious and secular leaders of the 21st century despite copious evidence to the contrary.

Note

The UK Met Office declined GWPF's offer to publish a counterview as an appendix to this paper.

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