THE LANCET COUNTDOWN ON CLIMATE CHANGE

THE NEED FOR CONTEXT

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The Lancet on Climate Change: The need for context
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About the author

Indur 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 an IPCC reviewer.

Executive summary

Between 1990 and 2017, the cumulative age-standardised death rate (ASDRs) from climate-sensitive diseases and events (CSDEs) dropped from 8.1% of the all-cause ASDR to 5.5%, while the age-standardised burden of disease, measured by disability-adjusted life years lost (DALYs) declined from 12.0% to 8.0% of all-cause age-standardised DALYs. Thus the burdens of death and disease from CSDEs are small, and getting smaller.

But readers of the 2019 report of the *Lancet Countdown* (hereafter 'the *Countdown*'), a partnership of 35 academic institutions and UN agencies, established by the prestigious *Lancet* group of medical journals and supported by the equally-esteemed Wellcome Trust to track progress on the health impacts of climate change, may well be left with the opposite impression, particularly if they do not delve beyond the Executive Summary, the section most likely to be read by busy policymakers or their advisors. Not once does it mention that cumulative annual rates of death and disease from CSDEs are declining, and declining faster than the corresponding all-cause rates. The *Countdown* also fails to provide adequate context for the reader to judge the burdens of mortality or disease posed by CSDEs, individually or cumulatively, relative to other public-health threats. In fact, it even suggests that the health effects of climate change are 'worsening'. But the data do not support that claim. Moreover, an analysis of the text makes it clear that the *Countdown* conflates estimates of increasing exposure, 'demographic vulnerability', and increased 'suitability' of disease transmission with actual health effects.

In addition to overlooking the diminishing overall significance of CSDEs for public health, the *Countdown* chooses to focus instead on CSDEs that have, contrary to the general trend, become more prevalent. As a case in point, dengue, a mosquito-borne tropical disease, was responsible for 40,000 deaths in 2017. This seems a lot, but it represents only 1.4% of the cumulative 2.8 million deaths from CSDEs or 0.07% of the 55.9 million people who died globally from all causes that year. Yet dengue gets more attention in the *Countdown* than malaria, another mosquito-borne tropical disease, which was responsible for fifteen times as many (620,000) deaths.

Because of its failure to provide context, the *Countdown* fails to give the reader or policymakers a balanced account of public-health threats and, therefore, risks distorting public health priorities. Without proper context, a molehill may well be mistaken for a mountain. Context is thus essential to help policymakers keep perspective and focus on larger and more important public-health problems.

Regarding context, much of this critique examines trends since 1990. This is because the data from the Institute for Health Metrics and Evaluation, on which the *Countdown* primarily relies, commences in that year. However, the declines in death and disease rates from CSDEs since 1990 are only a small proportion of longer-term declines across the globe. In the USA, one of the few places with good long-term data, death rates from dysentery, typhoid, paratyphoid, other gastrointestinal diseases, and malaria – all water-related diseases and therefore, almost by definition, climate-sensitive – declined 99–100% between 1900 and 1970.

The problems caused by the *Countdown*'s omission of context are exacerbated by its persistent use of supposed proxies and surrogates for health impacts, which they argue should increase the prevalence of various CSDEs. However, the *Countdown* used these 'proxies' without verifying whether they really are proxies; in other words, that they exhibit reproduce historical trends for mortality and morbidity. For example, the *Countdown* claims that the number of – and exposure and vulnerability to – heatwaves and other extreme weather events (EWEs) is increasing. However, long-term data show that death rates from all EWEs – extreme temperatures, droughts, floods, landslides, wildfires, storms, fog – have declined by 98.9% since the 1920s. So increased risk and/or vulnerability, even if accurately determined, do not necessarily translate into higher rates of death and disease.

The *Countdown*'s attempt to show that food security is threatened by higher temperatures is similarly problematic. Its claims are based on a construct called 'global crop growth duration', which is used as a 'proxy' for crop yield. For the five crops considered, the *Countdown* estimates that crop growth duration has been trending downwards for the past several decades. Actual data show that yields have been increasing over the same period, so crop growth duration is not a proxy for yield. Unfortunately, the *Countdown* does not yield to reality on this score.

The *Countdown* also claims that 'malaria suitability continues to increase in highland areas of Africa, with the 2012–17 average 29.9% above [a 1950s] baseline'. Nevertheless, notwithstanding any increase in the *Countdown*'s estimated 'malaria suitability', ASDR for malaria in all portions of sub-Saharan Africa (SSA) has declined between 30% and 67% over the period 1990–2017. Notably, the largest decline in ASDR for malaria (67%) was for eastern SSA (which includes the East African Highlands). This decline exceeded that for the all-cause ASDR for that area (which was 42%) over that period. Notwithstanding the *Countdown*'s estimated increase in 'malaria suitability', malaria is a diminishing problem compared to other public-health issues in that area.

The *Countdown* also suggests that we are at increasing risk from other climate-sensitive phenomena, such as wildfires and *Vibrio*, a bacteria that may cause gastrointestinal infections. However, globally, the area burnt by wildfires and the mortality burden from diarrheal diseases have both declined substantially.

Finally, the *Countdown* also claims that labour productivity has decreased due to higher temperatures, but value added per worker has actually increased, and incomes, perhaps the best measure of labour productivity, have grown virtually everywhere in real terms.

All this indicates that, contrary to the *Countdown*'s claim that the world may be 'struggling to cope with warming that is occurring faster than governments are able or willing to respond', mankind is actually reducing most CSDE risks more, and coping with them better, than with some other, larger health threats. (And as the current pandemic demonstrates, some of those health threats are considerably bigger, more certain, and much closer at hand.)

While CSDEs are major public health problems, their significance is diminishing.

Changes in global age standardised death rate (per 100,000), 1990–2017

1. Introduction

Overlooking context seems to be a hallmark of climate science. In this paper on the *Lancet Countdown's* 2019 report on the health impacts of climate change, I provide missing context regarding the burden of death from various climate-sensitive diseases and events (CSDEs), individually and cumulatively, relative to the overall burden from all causes. I also examine trends in these burdens.

This paper for the most part examines trends since 1990. This is because the data on which the *Countdown* primarily relies, and which provides readily accessible age-standardised rates of death and disease, commences in that year.[1] The improvements in public health since the 1990s are, however, just the latest chapter in a longer story that starts in the 18th century, if not earlier. As reflected in life-expectancy data, death rates began to decline slowly, but unsteadily, in the now-developed countries of Western Europe and North America in the mid- to late-18th century. By the mid- to late-19th century these declines had become steadier, and despite occasional setbacks (due to wars and, notably, the Spanish flu), long-term improvements set in. By the latter half of the 20th century, these improvements had diffused across the now-developing world.

Much of this long-term decline in death rates was due to reductions in undernutrition, and water-, vector- and food-borne diseases, most of which are infectious; generally, they are also sensitive to climate and meteorological factors. The reductions were driven by a wide variety of causes, including:[2]

- increased food supplies and better nutrition
- the spread of immunisation
- greater knowledge of the germ theory of disease
- wider adoption of practices such as sanitation, hygiene, water filtration, chlorination, pasteurisation of milk, and medical interventions (e.g. sulfa drugs and antibiotics).

The combination of these factors caused US death rates from dysentery, typhoid, paratyphoid, other gastrointestinal disease, and malaria – all water-related diseases, and which are therefore, almost by definition, climate-sensitive – to decline by 99–100% between 1900 and 1970.[3] Thus the overall reductions in the rates of death and disease since 1990 for CSDEs documented in this critique are probably a fraction of the overall improvement.

2. Climate-related death and disease: the need for context

The closest the *Countdown* comes to providing context regarding the relative magnitude of the public health problem posed by CSDEs is in its Figure 5, reproduced here as Figure 1. This figure, which occupies half a page, is buried about a quarter of the way into the paper. It consists of seven panels, which show global trends from 1990 to 2017 in mortality rates from all causes and each of six CSDEs – dengue, diarrheal diseases, forces of nature (FoN), heat and cold (H&C) exposure, malaria, and undernutrition – for six regions of the world. Altogether there are 42 data series graphed. The *y*-axis for each panel represents the global mortality rate per 100,000 population. But the *y*-axis scale is different for each of the panels. It extends from 600 to 1400 for all causes, 0 to 2 for dengue, 0 to 150 for diarrheal diseases, 0 to 10 for FoN, 0 to 10 for H&C exposure, 0 to 150 for malaria, and 0 to 40 for undernutrition. So only a dedicated and studious reader would, firstly, come across it and, secondly, recognise that dengue, for instance, is only about 0.07% of the all-causes total, or only one-fifteenth as deadly as malaria. In such circumstances, a picture may well be worth less than the proverbial thousand words; the *Countdown*'s Figure 5 may be more obfuscatory than illuminative. Also, note that it does not attempt to put cumulative mortality burden from all CSDEs into the context of overall mortality burden or in a longer temporal context. To my mode of thinking, these are extraordinary oversights.

Figure 2 is based on data from the *Global Burden of Disease 2017* study from the Institute for Health Metrics and Evaluation (IHME), the source used by the *Countdown*. It shows the trends between 1990 and 2017 in the crude global death rate from CSDEs and from other causes unrelated to climate. The cumulative crude death rate from the seven CSDEs shrank from 9.8% of the total (all-cause) burden in 1990 to 5.1% in 2017. In other words, the cumulative mortality burden of CSDEs is small relative to the all-cause burden, and getting smaller. This observation would surprise many, if not most, readers of the *Countdown*.

There are seven categories of CSDE underlying the total shown in Figure 2. These account for climate-sensitive diseases much more comprehensively than the *Countdown*'s Figure 5, as shown by a detailed analysis of each category:

- *Enteric infections.* Figure 2 accounts for more climate-sensitive diseases than the *Countdown*. The latter only considers diarrheal diseases in this category,

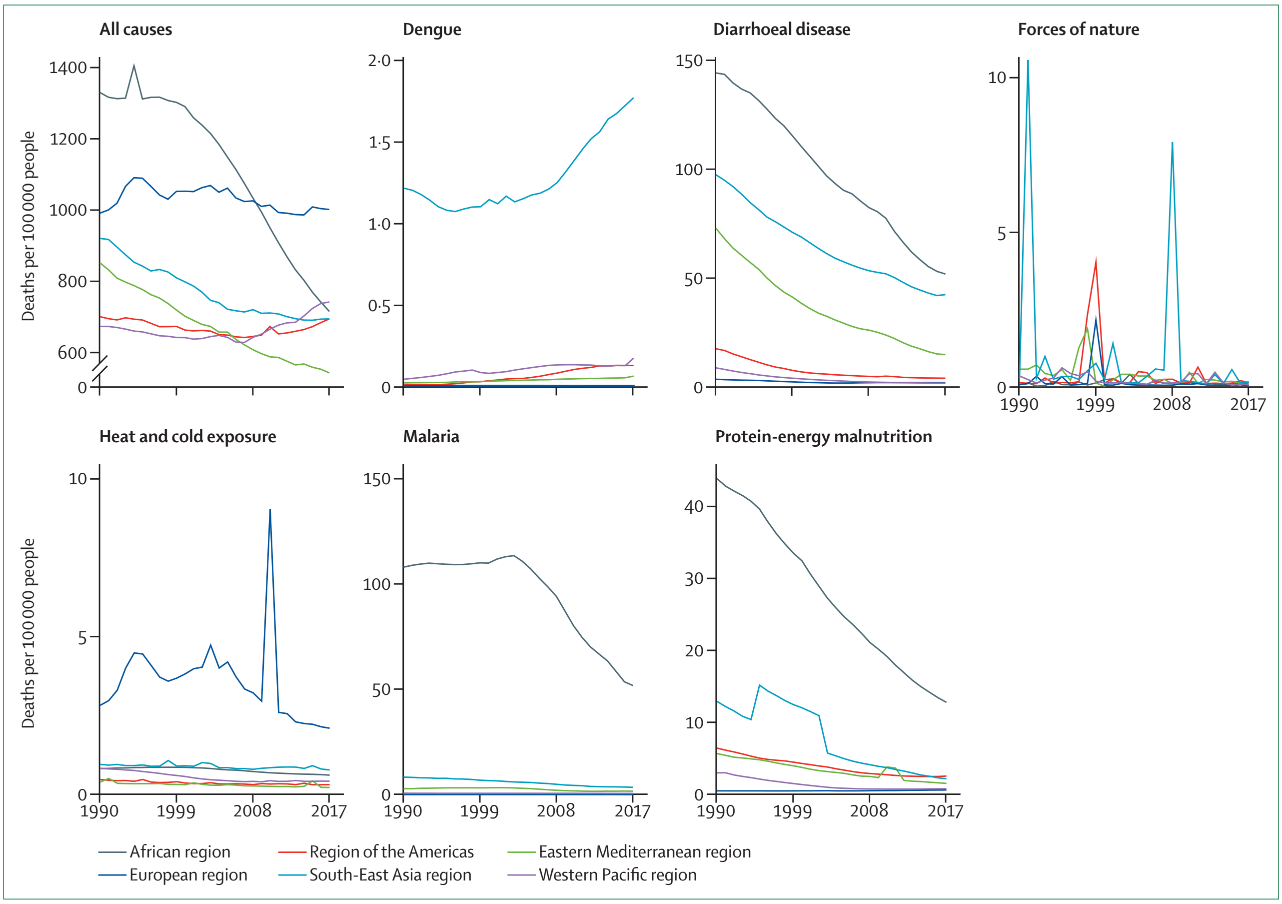


Figure 1: The *Lancet Countdown*'s Figure 5.

Original caption: Global trends in all-cause mortality and mortality from selected causes as estimated by the Global Burden of Disease 2017 study for the 1990–2017 period, by WHO region.

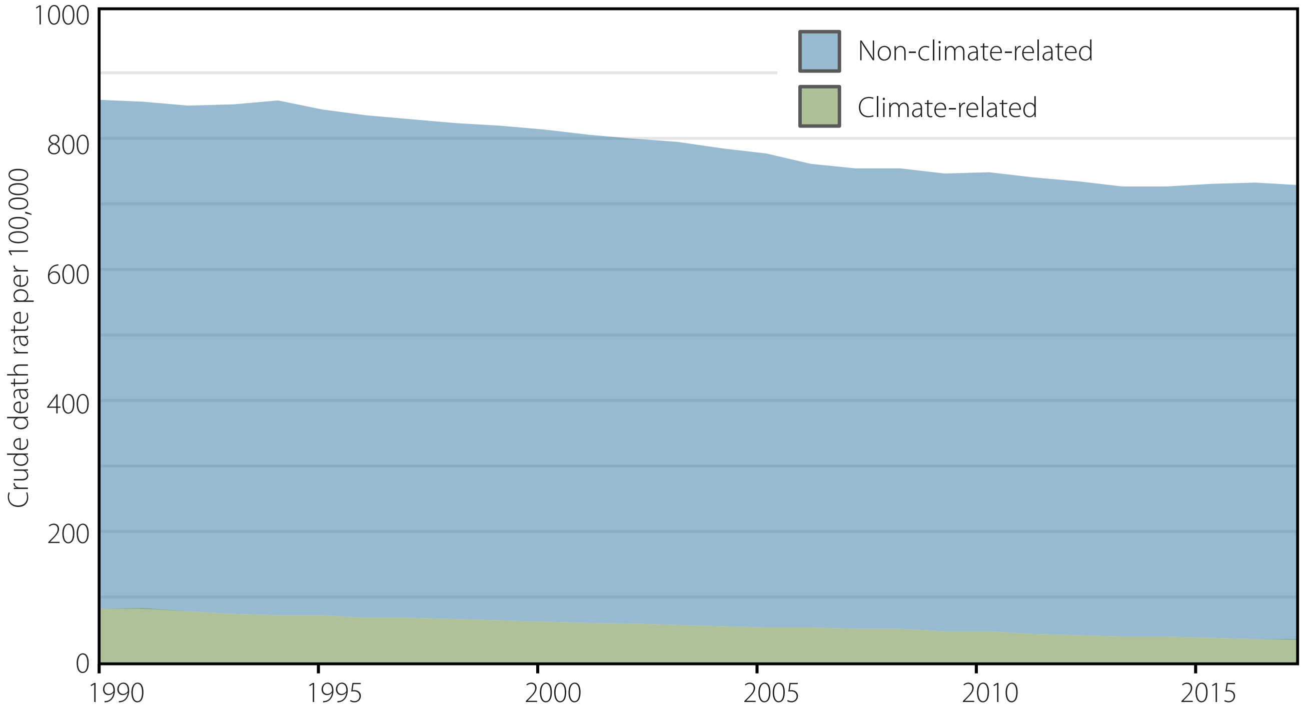


Figure 2: Climate-related deaths are a small proportion of all-cause fatalities.

Data per IHME (2019).

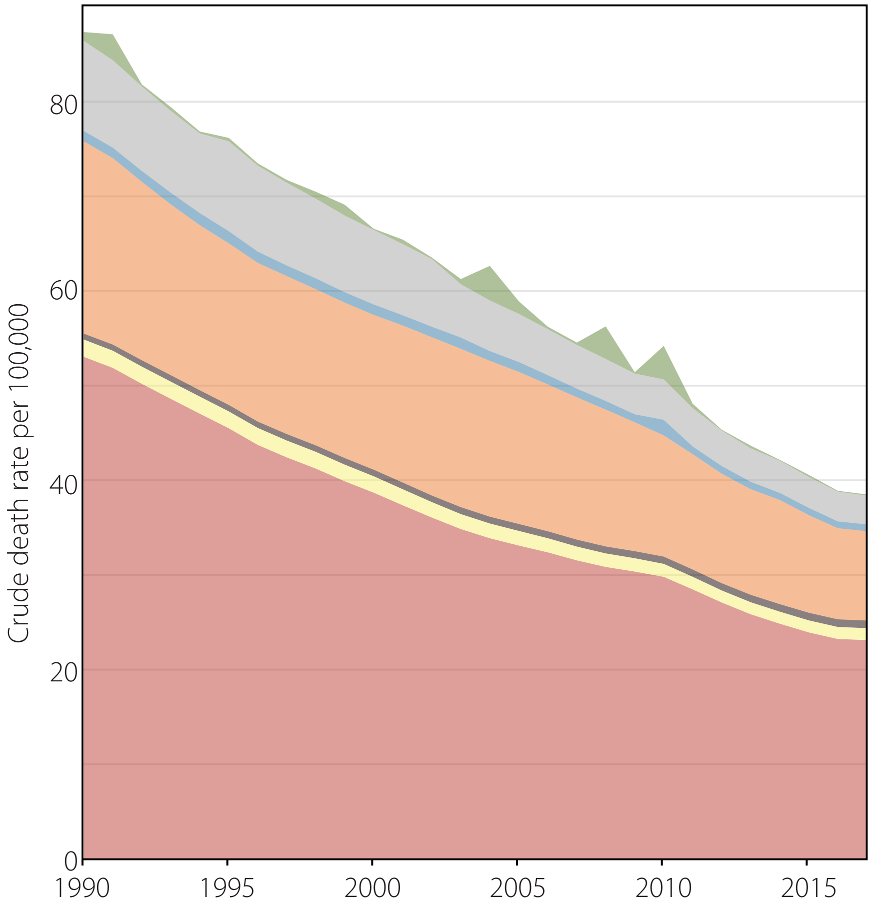
which in 2017 were responsible for 89% of deaths from enteric infections.[4] The remaining 11% are from typhoid, paratyphoid, and invasive non-typhoidal Salmonella, each of which is potentially sensitive to temperature, rainfall and the nutritional status of the population (in other words, they are sensitive to climate and weather).[5] For context, those 11% of deaths from enteric infections exceed the combined deaths from the last three categories listed below – exposure to H&C, FoN, and malignant melanoma.

- *Tropical diseases:*[6] In 2017, 86% of deaths in this category were from malaria and 5.6% from dengue. The *Countdown* examines only deaths from malaria and dengue in its Figure 5. Thus, it excludes about 8% of annual deaths from this category. The 8% includes (in decreasing order) deaths from schistosomiasis, Chagas disease, Leishmaniasis, and yellow fever.[7]
- *Protein-energy malnutrition (undernutrition):* This category is identical to that used by the *Countdown*.
- *Encephalitis*: This category is not included in the *Countdown*'s Figure 5, nor is it mentioned elsewhere in the *Countdown*.
- *Exposure to heat and cold:* This is the same as in the *Countdown*'s Figure 5.
- *Exposure to forces of nature:* This category includes weather and climate, but the *Countdown* excludes deaths from geophysical events from this category, as do Figures 2 and 3 in this paper. However, Figures 6 and 7 do not, because the age distribution used in IHME's age-standardisation was not readily available. However, any error introduced due to this simplification should be minor because of the relatively small number of deaths from geophysical events. From 1990–2017, on average there were fewer than 30,000 annual deaths from geophysical causes, or about 1% of the 2.8 million deaths from all CSDEs in 2017.[8]
- *Malignant melanoma*: This category is the same as in *Countdown*'s Figure 5.

Figure 3 is a redrawing of Figure 2, but showing only the CSDEs, so that one can better see their individual trends and relative contributions. It shows that the contribution to the crude death rate from FoN and H&C (which together include all extreme weather events) is minor, amounting to about 2.1% of all CSDE deaths in 2017. It also shows that the cumulative crude death rate for CSDEs declined by 56% between 1990 and 2017. The four largest contributors to CSDEs – enteric infections, tropical diseases, undernutrition, encephalitis – all declined. These four categories (excluding dengue) represent 94.4% of cumulative deaths from CSDEs in 2017. But because of the *Countdown*'s emphasis on den-

Figure 3: Burden of mortality from CSDEs, 1990–2017.

The FoN group excludes deaths from geophysical causes per EM-DAT (2019). Data per IHME (2019).



gue, which has apparently become more prevalent in the interim (along with certain forms of *Vibrio)*, many a reader may get the impression that mortality and morbidity from CSDEs are increasing. Dengue gets more than twice as many mentions as malaria in the full text of the *Countdown*, including two in the Executive Summary (versus none for malaria), despite accounting for only one-fifteenth as many deaths in 2017. Moreover, some mentions of malaria include claims that climate is becoming more suitable for it,[9] which may mislead a reader into thinking that malaria may be increasing (more on this below).

Figure 4, a screenshot from the *Countdown*,[10] illustrates how the lack of context may mislead a reader.

Figure 4: The Lancet *Countdown*'s Indicator 1.3.

Source: p. 1845.

Indicator 1.3: global health trends in climate-sensitive diseases

Headline finding: although mortality due to diarrhoeal diseases, malnutrition, and malaria is improving, mortality due to dengue is rising in the regions most affected by these diseases

Specifically, the *Countdown* text fails to mention that in 2017 there were 2.42 million deaths from diarrheal diseases, undernutrition and malaria, and only 40,000 from dengue. Absent such context, a reader may fail to appreciate that positive trends far outweigh negative ones. Another way it creates a false impression that CSDEs are increasing is by emphasising factors that may exacerbate diseases – increasing exposure or suitability for disease transmission, for example. However, in the real world, these do not necessarily translate into increased mortality or morbidity, assuming exposure calculations are accurate.

For example, consider the remarks in Figure 5, another excerpt from the *Countdown* report.[11]

Figure 5: The Lancet *Countdown*'s Indicator 1.4.

Source: p. 1845.

> **Indicator 1.4: climate-sensitive infectious diseases**
> *Indicator 1.4.1: climate suitability for infectious disease transmission—headline finding: suitability for disease transmission has increased for dengue, malaria,* V cholerae *and other pathogenic* Vibrio *species. The number of suitable days per year in the Baltic for pathogenic* Vibrio *transmission reached 107 in 2018, the highest since records began, and two times higher than the early 1980s baseline*

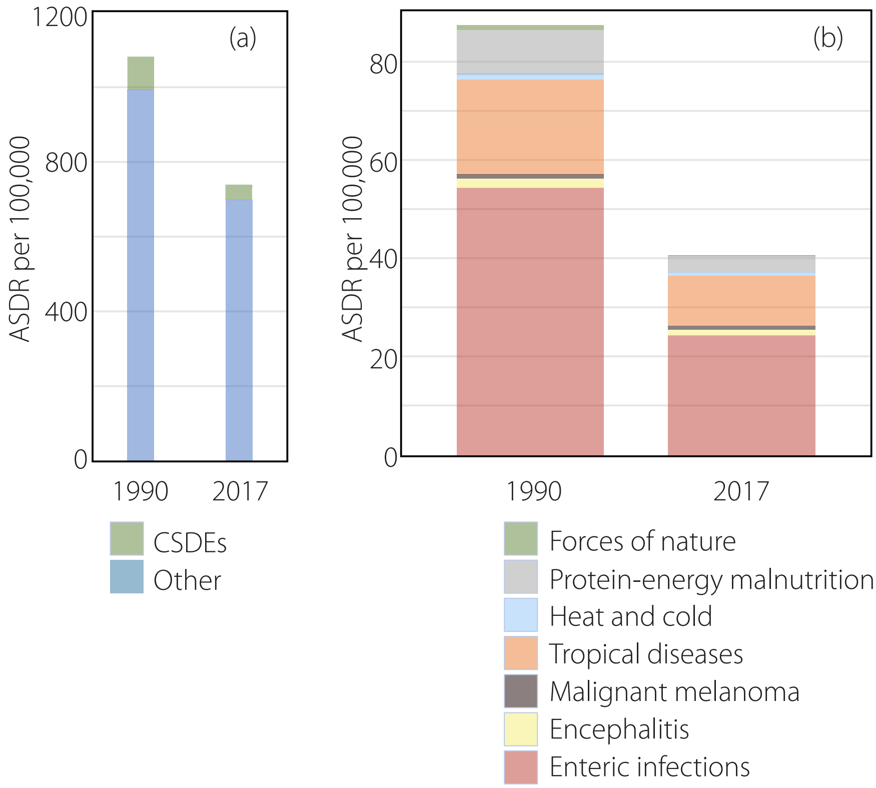
Yet, as shown in Figure 3, crude death rates for enteric infections (which include diarrheal diseases such as cholera and other *Vibrio*-caused diseases), and tropical diseases (which include malaria) have declined *substantially*. And as we will see below, age-standardised death rates (ASDRs) from diarrheal diseases and malaria have also declined.

The trends in crude death rates in Figures 2 and 3 do not account for the changing age distribution over time, so they may underestimate the improvement in health status. Figure 6 therefore shows the equivalent ASDRs.

Figure 6a reaffirms the finding that death rates from CSDEs are small relative to the total rate from all causes, and are becom-

Figure 6: Age-standardised death rates, 1990 and 2017.

(a) CSDEs versus other causes (b) CSDEs by type. The ASDRs for the FoN category includes deaths from geophysical causes. Hence, for that category, they are overestimates but, as noted above, the contribution of geophysical events to deaths in 1990 and 2017 is relatively minor. Source: IHME (2019).



ing smaller. Between 1990 and 2017 the ASDR from all CSDEs declined by 54%, while the all-cause ASDR reduced by 32%. As shown in Figure 6b, the ASDRs for enteric infections and tropical disease have declined by 55% and 48%, respectively.[12] Notably, the ASDR for malaria (not shown in the figure) declined by 24% over this period. Therefore, despite the *Countdown*'s claim that 'climate suitability for disease transmission' for malaria has increased (see Figure 5), actual ASDR from malaria has declined.

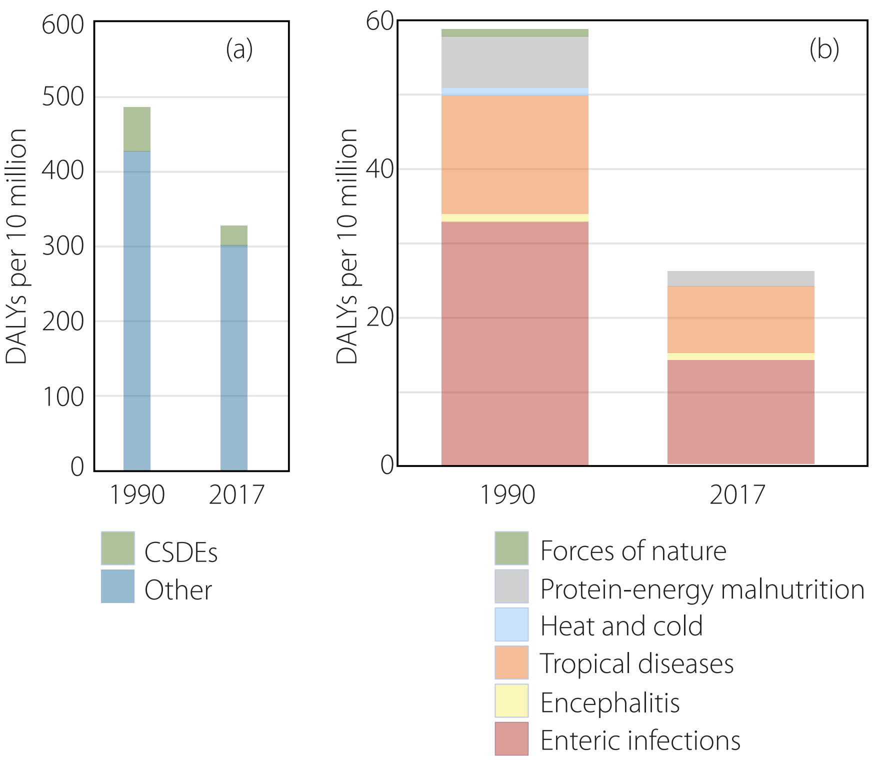
Figure 7 provides a similar breakdown of the age-standardised rate for the burden of disease. It shows that:

- Climate-sensitive diseases now contribute a smaller portion of the all-cause disease burden than they used to. This remarkable decline is neither noted in the text of the *Countdown*'s Executive Summary nor discussed under 'Indicator 1.5: Global health trends in climate-sensitive diseases' or 'Indicator 1.6: Climate-sensitive infectious diseases.' However, those portions of the *Countdown* noted that mortality from dengue and malignant melanoma – minor contributors to the cumulative disease burden from CSDEs – increased.
- Contrary to claims in the *Countdown*'s Executive Summary that the world may be 'struggling to cope with warming that is occurring faster than governments are able, or willing to respond',[13] the world is not only coping with most of the increasing risks of CSDEs, it is actually reducing most such risks, and is coping with CSDEs better than it is with other, larger health threats.

Figure 7 also shows that the most consequential climate-sensitive diseases and events in terms of public health are enteric

Figure 7: Age-standardised burden of disease, 1990 and 2017.

Disability adjusted life years lost, (DALYs) per 10 million. (a) CSDEs versus other causes (b) CSDEs by type. Several of the CSDE types have DALYs close to zero, particularly for 2017, and are not shown. Source: IHME (2019).



infections, tropical diseases, and undernutrition, in that order. The burdens of death and disease from encephalitis, exposure to heat and cold, forces of nature, and malignant melanoma are essentially within the noise level of deaths from all causes or cumulative CSDEs. This is remarkable given the coverage hot and cold extremes and deaths from forces of nature get in the media and the *Countdown*. Together, these two factors contributed just 2% of CSDE deaths in 2017, themselves only 6% of all-cause deaths.

Note that, given the very similar declining patterns for the burdens of death and disease, in the rest of this report only the burden of death is shown in the figures.

3. Claims regarding health impacts in the Executive Summary

According to the *Countdown*'s Executive Summary:

> A child born today will experience a world that is more than four degrees warmer than the pre-industrial average, with climate change impacting human health from infancy and adolescence to adulthood and old age. Across the world, children are among the worst affected by climate change. Downward trends in global yield potential for all major crops tracked since 1960 threaten food production and food security, with infants often the worst affected by the potentially permanent effects of undernutrition (indicator 1.5.1). Children are among the most susceptible to diarrhoeal disease and experience the most severe effects of dengue fever. Trends in climate suitability for disease transmission are particularly concerning, with nine of the ten most suitable years for the transmission of dengue fever on record occurring since 2000 (indicator 1.4.1). Similarly, since an early 1980s baseline, the number of days suitable for *Vibrio* (a pathogen responsible for part of the burden of diarrhoeal disease) has doubled, and global suitability for coastal *Vibrio cholerae* has increased by 9.9%.[14]

An analysis of statements in the above passage is revealing.

Children are the worst affected

The *Countdown* paper makes two strong claims about the effects of climate change on children:

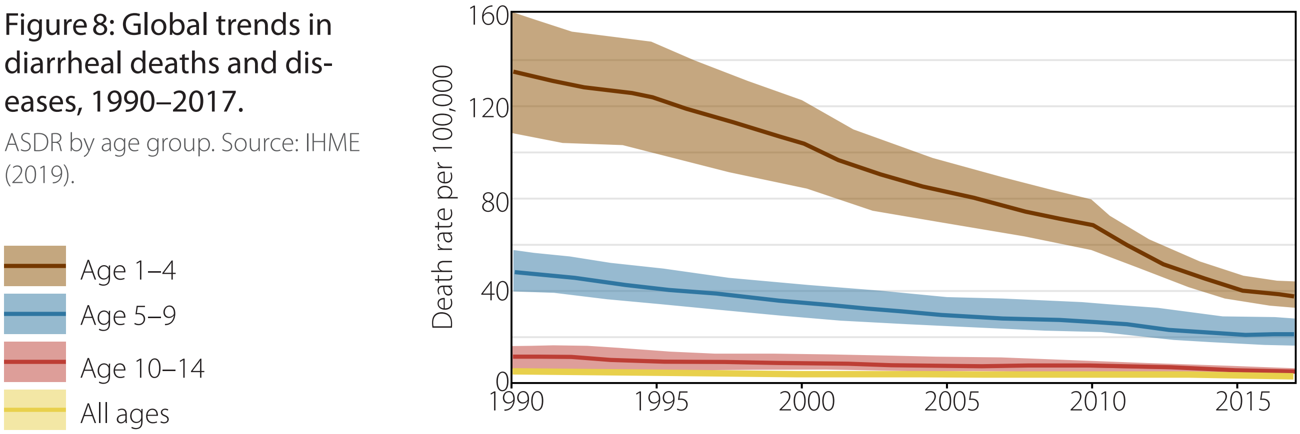
> *Sentence 2:* 'Across the world, children are among the worst affected by climate change.'
>
> *Sentences 4 and 5:* 'Children are among the most susceptible to diarrhoeal disease and experience the most severe effects of dengue fever. Trends in climate suitability for disease transmission are particularly concerning, with nine of the ten most suitable years for the transmission of dengue fever on record occurring since 2000 (indicator 1.4.1).'

These statements may be true, but the *Countdown* Executive Summary fails to note that the effect of climate-sensitive diseases on children's health is diminishing rapidly. It also informs the reader that the number of days suitable for *Vibrio* – one of the many pathogens contributing to diarrheal diseases – has doubled and that the suitability of *Vibrio cholerae*, in particular, has increased by 10%.[15] So, is the burden of death and disease from diarrheal diseases increasing for children?

Figure 8 shows that between 1990 and 2017 the burdens of death and disease from diarrheal diseases declined substantially for all ages, and also for children aged 1–4, 5–9 and 10–14, despite any increase in temperature. ASDR from diarrheal diseases for all ages declined by 57%, substantially more than the 15% decline from all causes. Corresponding declines for children aged 1–4 years, in particular, were even larger (63% and 72% from all causes and diarrheal diseases, respectively); for children between 5–9 years, the declines were almost the same (57.1% and 57.3%, respectively); and for children between 10–14 years, they declined more from diarrheal diseases than from all-causes (57.1% and 52.0%, respectively). This shows that while diarrheal diseases may theoretically be exacerbated by climate change, their ASDR has overall declined more than the all-cause ASDR anyway. This suggests that there are other, more controllable factors to which their extent and severity is more sensitive. It also shows that if current trends continue, unless economic progress is inhibited, perhaps through an unintended consequence of controlling energy usage,

Figure 8: Global trends in diarrheal deaths and diseases, 1990–2017.

ASDR by age group. Source: IHME (2019).



by the time the next century rolls in, the public health toll of diarrheal diseases may well be minimal. Diarrheal diseases are, after all, one of the original diseases of poverty and under plausible scenarios the world will be substantially wealthier by 2100.

But remarkably, unless a reader is willing to wade through the weeds of the *Countdown* report, they will not learn of the reduction in death and disease from diarrheal diseases, undernutrition and malaria. A reader of Sentence 4 may well be lulled into thinking that the ASDRs for diarrheal diseases and dengue are of the same order of magnitude; the relative magnitudes can only be discerned well into the main report.[16] Specifically, on p. 1845, the discussion of Indicator 1.3 suggests that malaria has declined, but even then, it says almost in the same breath that dengue has increased, and it fails to discuss the differences in the magnitudes of the burdens.

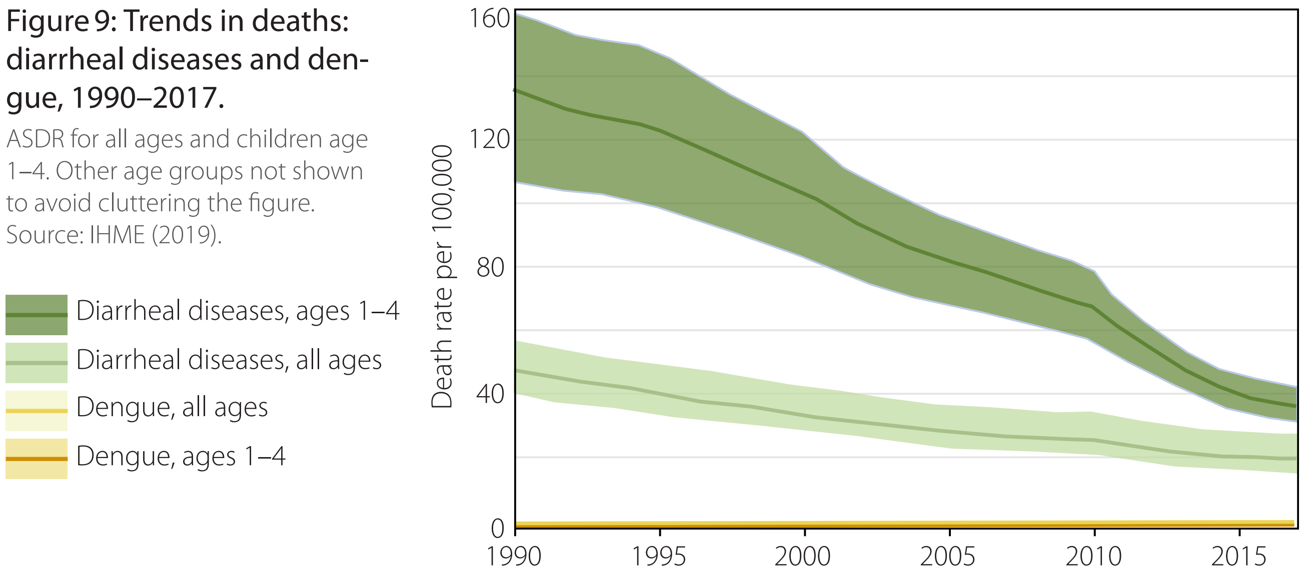


Figure 9: Trends in deaths: diarrheal diseases and dengue, 1990–2017.

ASDR for all ages and children age 1–4. Other age groups not shown to avoid cluttering the figure. Source: IHME (2019).

Figure 9 illustrates trends in deaths from diarrheal diseases and dengue, in total and for children aged 1–4 years; deaths from dengue are at least an order of magnitude smaller. By comparison with diarrheal diseases, any increase in the burdens of death and disease for dengue are essentially lost in the noise.

Threats to food security

> *Sentence 3:* 'Downward trends in global yield potential for all major crops tracked since 1960 threaten food production and food security, with infants often the worst affected by the potentially permanent effects of undernutrition (indicator 1.5.1)'

The claim that food production and food security is threatened is based on a theoretical construct, 'global yield potential', rather than trends in actual global yield or food supplies. In fact, yields for virtually all crops have increased. Figure 10a illustrates this for cereal yields, which have increased steadily. This is true for the world as a whole, and for India, China, the least-developed coun-

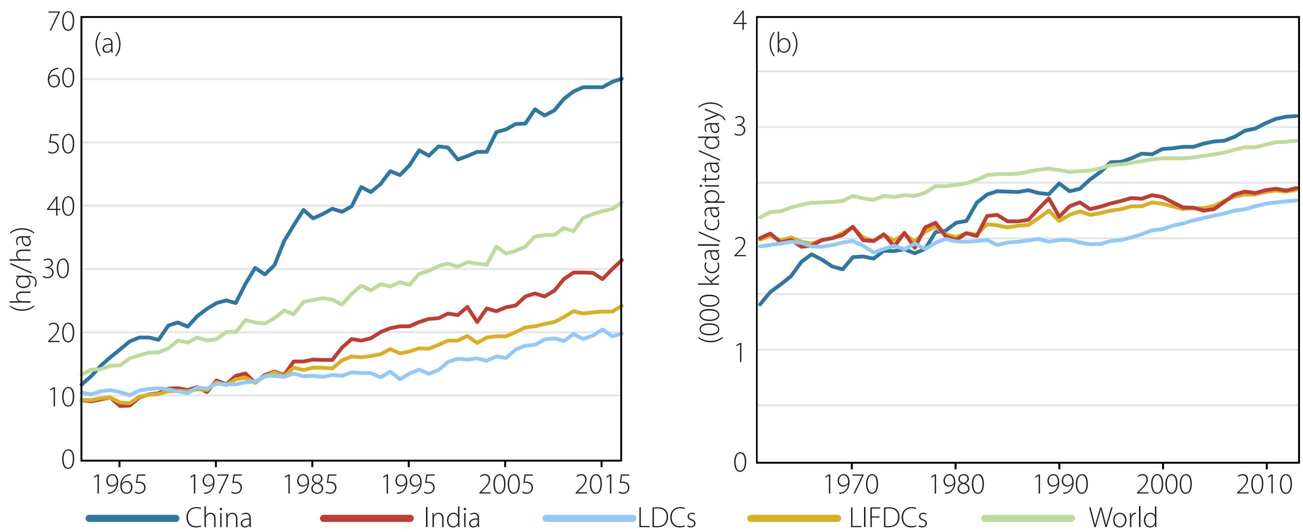


Figure 10: Cereal yields and food supplies.

(a) Cereal yields; (b) food supplies per capita. LDCs, Least-developed countries; LIFDCs, low-income food-deficit countries. Source: FAOSTAT (2019).

tries (LDCs) and the low-income food-deficit countries (LIFDCs). The increases in yields have helped boost food supplies per capita (Figure 10b) and reduced chronic hunger and undernutrition over the long term.[17] In turn, death and disease from protein-energy malnutrition (or undernutrition) have declined substantially (see Figures 3 and 6).

Away from the Executive Summary, in its subsection discussing Indicator 1.5.1, the *Countdown* report acknowledges that food production has increased, but its headline finding is that 'global crop yield potential' has declined (see Figure 11, which is a screenshot from the *Countdown*).

Figure 11: The Lancet *Countdown*'s Indicator 1.5.
Source: p. 1847.

> **Indicator 1.5: food security and undernutrition**
> *Indicator 1.5.1: terrestrial food security and undernutrition—headline finding: data from all major crops tracked—maize, wheat, rice, and soybean—showed that increases in temperature have reduced global crop yield potential*

It goes on to note that the number of undernourished 'appears to have been increasing since 2014, driven by challenges

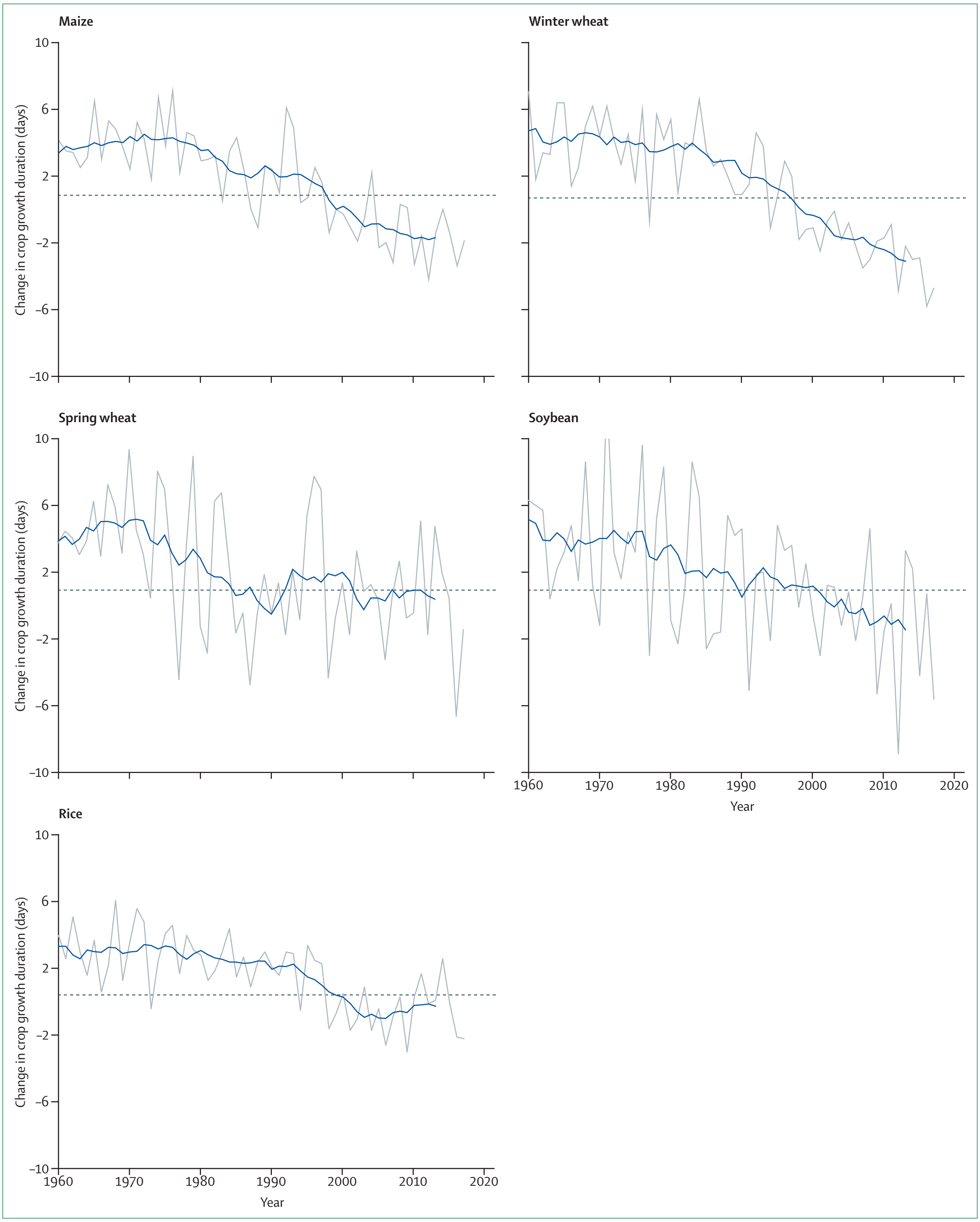


Figure 12: The *Countdown*'s Figure 9.

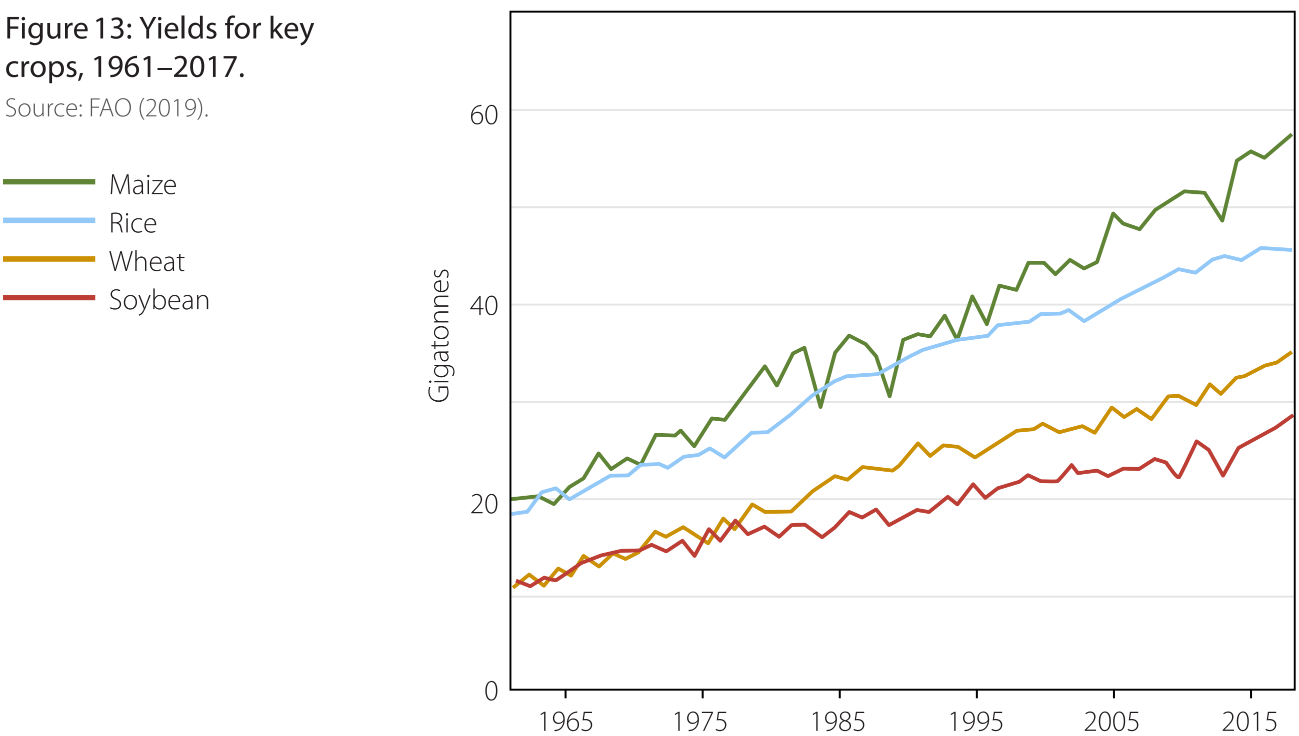
Original caption: Change in global crop growth duration as a proxy for crop yield. Dashed line = the average change in crop duration of the 1981–2010 baseline. Grey line = annual global area-weighted change. Blue line=running mean over 11 years (5 years forward, 5 years backward).

to access, availability, and affordability of food.' But what do challenges to access, availability and affordability have to do with climate change? And to the extent these challenges are due to meteorological conditions, how does the *Countdown* divine it is due to a change in climate rather than weather? Unfortunately, the *Countdown* is not forthcoming on these questions.

The *Countdown*'s notion that food production is dropping, or will drop, is based on estimates of crop growth duration, which it explains is 'a proxy for yield potential for maize, wheat, rice and soybean, and is based on the time taken in a year to accumulate a reference period (1981–2010) accumulated thermal time. A reduction in crop growth duration means the crop matures too quickly with lower seed yield'.[18] This text is accompanied by a five-panel figure showing that growth durations for these crops have been declining since the 1970s, if not earlier. The figure is reproduced above as Figure 12. The original caption in the *Countdown* reads, 'Change in global crop growth duration as a proxy for crop yield'. But why use a proxy when actual yield data are readily available on the web from the UN Food and Agriculture Organization (FAO)?

Figure 13 plots actual yield data from 1961 through 2017 for the same crops as were used in Figure 12: maize, wheat, soybean and rice. This show that yields for each have actually increased, and more or less steadily.

Figure 13: Yields for key crops, 1961–2017.
Source: FAO (2019).



It is also pertinent to ask why, if the *Countdown* wanted to use the change in global crop growth duration as a proxy for yields or yield potential, it did not verify whether it was a valid proxy, by assessing how well the two measures tracked each other. This would be normal practice if the scientific method were followed. Any comparison between Figures 12 and 13 would have shown that crop growth duration, while interesting, is not a good proxy for crop yield. Perhaps it was more important to advance a narrative than subject an assumed proxy to a rigorous test, and confirmation bias may indeed have played a role: as the *Countdown* text accompanying the five-panel figure notes, an estimated downturn in crop yield potential 'resonates' with the notion that higher temperatures reduce yields. (Or perhaps it was an effort to convince the reader that the *Countdown* was familiar with 'sound' science.) Specifically, the *Countdown* text notes (emphasis added):[19]

> Globally, crop yield potential for maize, winter wheat, and soybean has reduced in concert with increases in temperature (Figure 8), challenging efforts to achieve [Sustainable Development Goal] 2 to end hunger by 2030. *This data resonates with a meta-analysis of the literature by Zhao and colleagues, which suggests that global yields of these four key crops are reduced respectively by 6%, 3.2%, 7.4%, and 3.1%, globally for each 1°C increase in global mean temperatures*.

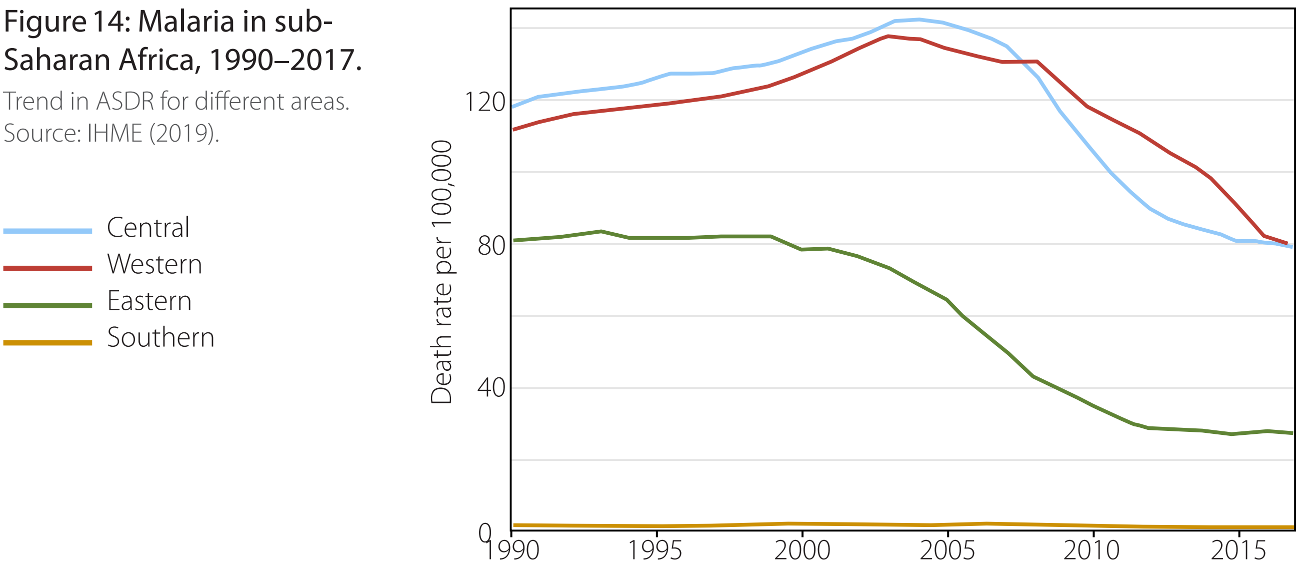
The burden of diarrheal disease

> *Sentence 6:* 'Similarly, since an early 1980s baseline, the number of days suitable for *Vibrio* (a pathogen responsible for part of the burden of diarrhoeal disease) has doubled, and global suitability for coastal *Vibrio cholerae* has increased by 9.9%'

The number of 'days suitable for Vibrio' may have increased, but in the wider context, deaths from, and the burden of, diarrheal diseases have declined (see Figure 7). So once again there is, coupled with omitted context, the divergence in trends between a plausible proxy and reality.

Figure 14: Malaria in sub-Saharan Africa, 1990–2017.

Trend in ASDR for different areas.
Source: IHME (2019).



According to the *Countdown*, 'Malaria suitability continues to increase in highland areas of Africa, with the 2012–17 average 29.9% above [a 1950s] baseline'. However, ASDR for malaria in all portions of sub-Saharan Africa (SSA), the region most afflicted by this disease, has declined between 30% and 67% from 1990 to 2017 notwithstanding any increase in a theoretical construct such as 'malaria suitability' (see Figure 14).

The largest decline was for the eastern SSA (which includes the East African Highlands). The 67% decline seen in that part of the world is larger than the 42% decline in the all-cause ASDR, indicating that despite the estimated increase in 'malaria suitability', malaria in eastern SSA is of diminishing importance relative to all the other public health problems facing the population.

Additional health impacts from climate change

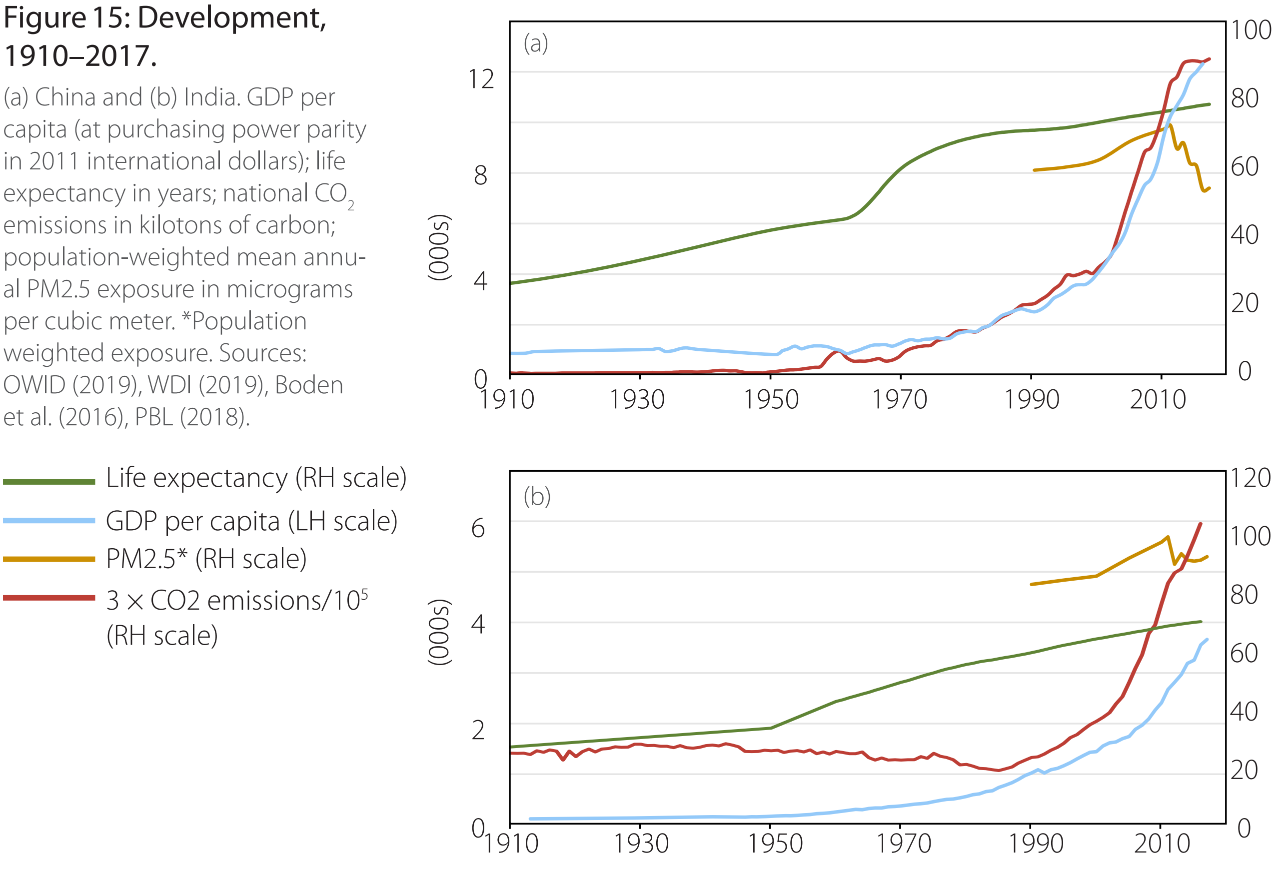
Deaths from air pollution

According to the *Countdown*,[20] emissions – principally driven by fossil fuels and exacerbated by climate change – may have been responsible for 7 million deaths from global air pollution in 2016, including 2.9 million deaths from PM2.5 particulates.[21] Seven million deaths in 2016 is equivalent to 12.6% of all deaths that year.[22] According to the World Health Organization, the source cited by the *Countdown*, in 2012 there were 1.03 million deaths due to ambient air pollution in China, and 0.62 million in India.[23]

If these estimates – based on statistical associations rather than hard cause-of-death data from death certificates – are accurate, then for 2012, 11.1% of all deaths in China and 6.6% in India were due to outdoor air pollution.[24] However, there is no hint of any decline in life expectancy during the period when carbon dioxide increased dramatically, which should have coincided with increases in outdoor air pollution. Figure 15 shows that life expectancies

Figure 15: Development, 1910–2017.

(a) China and (b) India. GDP per capita (at purchasing power parity in 2011 international dollars); life expectancy in years; national CO_2 emissions in kilotons of carbon; population-weighted mean annual PM2.5 exposure in micrograms per cubic meter. *Population weighted exposure. Sources: OWID (2019), WDI (2019), Boden et al. (2016), PBL (2018).



in China and India increased alongside the population-weighted PM2.5 exposure increase in the 1990s and early-2000s, and continued to increase after that. This indicates that deaths from outdoor air pollution do not substantially decrease life expectancies (if at all), are overestimated, or they are more than overwhelmed by all the factors associated with economic development and energy use that improve life expectancy (e.g. increased ability to switch from solid fuels to cleaner gas or liquid fuels, especially in the household), or some combination of these factors.

Further support for this observation comes from a comparison of a ranking of Chinese cities by air quality versus one by life expectancy (both for 2018). It 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 air quality.[25] Notably, Beijing is 10th by life expectancy but 28th by air quality. 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 air quality. Moreover, 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.

Notably, these are among the most industrialised (and urbanised) areas, not just in China, but in the world. Similarly, in India, Delhi normally ranks among the top three in terms of life expectancy but is among the worst in terms of air quality.

Finally, note that both (unadjusted) life expectancies and health-adjusted life expectancies in India and China continued to improve through the ramp up of fossil-fuel usage in the 1990s to the 2010s, notwithstanding the increase or subsequent decrease in emissions and ambient concentrations of PM2.5 and other pollutants.[26]

Extreme weather events

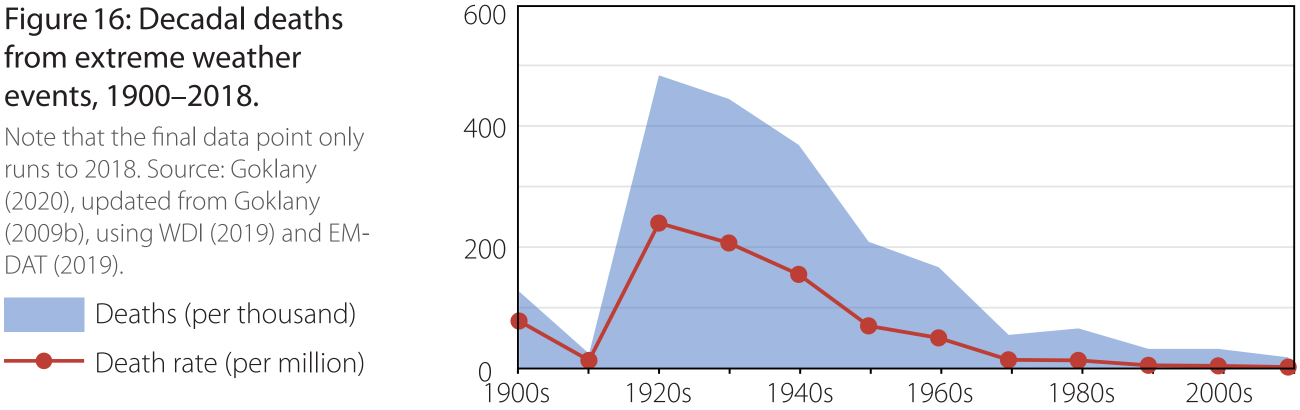
The *Countdown* claims that 'families and livelihoods are put at risk from increases in the frequency and severity of extreme weather conditions…'[27] Further on, it states:

> Populations aged 65 years and older are particularly vulnerable to the health effects of climate change, and especially to extremes of heat. From 1990 to 2018, populations in every region have become more vulnerable to heat and heatwaves…In 2018, these vulnerable populations experienced 220 million heatwave exposures globally, breaking the previous record of 209 million set in 2015 (indicator 1.1.3). Already faced with the challenge of an ageing population, Japan had 32 million heatwave exposures affecting people aged 65 years and older in 2018, the equivalent of almost every person in this age group experiencing a heatwave.[28]

Figure 16 shows, however, that since the 1920s, global death rates from all EWEs (extreme temperatures, droughts, floods, landslides, wildfires, storms, fog) have declined by 98.9%. Annual

Figure 16: Decadal deaths from extreme weather events, 1900–2018.

Note that the final data point only runs to 2018. Source: Goklany (2020), updated from Goklany (2009b), using WDI (2019) and EM-DAT (2019).



deaths from EWEs have decreased by 96.1% over this period, despite a more-than-tripling of the population. The vast majority of these reductions occurred before human-induced global warming became a concern for the public and policymakers (arguably no earlier than the signing of the 1992 Rio Declaration, and probably later). This reinforces the fact 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 impacts over multiple decades.[29] This suggestion is confirmed by another paper, which showed that the global mortality rate from EWEs dropped by a factor of 6.5 between 1980–1989 and 2007–2016.[30]

For context, the average global annual death toll from all EWEs in 2010–2018 was 19,021.[31] This is only 0.035% of the current global all-cause annual death toll of about 56 million;[32] clearly, the toll from extreme weather events receives a disproportionate share of publicity.

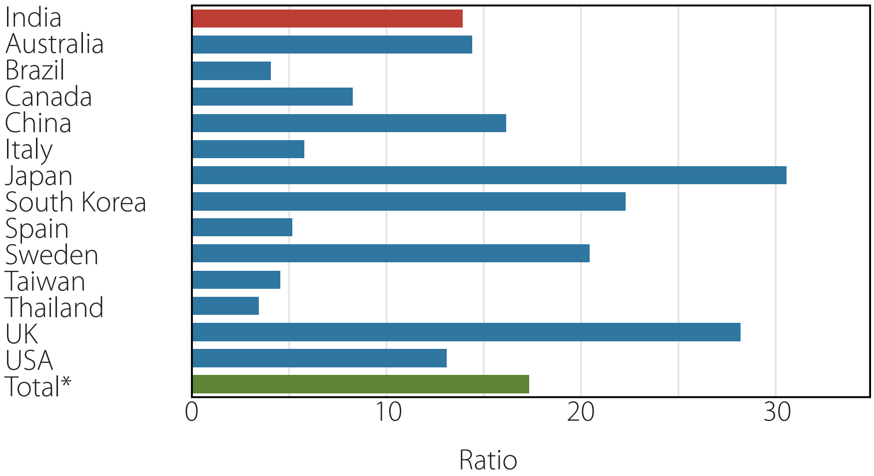
The above estimate (0.035%) also accounts for a small fraction of deaths attributable to temperature deviations from a locality- or region-specific optimum temperature at which mortality seems to be at a minimum.[33] It has long been known that more people die in colder (winter) months than in summer months in most temperate areas and, possibly, in some tropical settings as well.[34] The *Countdown*, however, ignores deaths from cold temperatures, which might be reduced due to climate change.

Recent systematic studies of all-cause mortality, some published in *The Lancet* itself, indicate that there is an optimum average daily temperature at which mortality is minimised. This occurs somewhere between the 60th percentile of the average daily temperature for some tropical countries to more than the 90th percentile for some temperate countries.[35] Most of these optimum temperatures are clustered in the 78th to the 93rd percentile range.[36] These studies also indicate that there are about fifteen times as many deaths attributable to colder-than-optimum than to warmer-than-optimum days (see Figure 17).

There is substantial evidence of a decline in mortality from heat in several countries in recent years, suggesting adaptation and/or acclimation. Gasparrini et al. found that relative risks associated with high temperatures declined significantly in 2006

Figure 17: Ratio of deaths attributable to colder-than-optimum versus those attributable to warmer-than-optimum temperatures.

The blue and black ('Total') bars are from Gasparrini et al. (2015); the red from Fu et al. (2018). *The Total bar is based on the aggregate deaths for countries in blue.



compared to 1993 in the US, Japan, and Spain; for Canada they found a decrease, but it was not significant.[37] The authors were unable to make any determination for Australia and South Korea due to low statistical power, and found 'little evidence' of change for the UK. Interestingly, they found that risk to the US population 'seems to be completely abated in 2006 for summer temperatures below their 99th percentile'. A study of the US found that, notwithstanding any urban heat island effect, there was a 80% decline in mortality rates on hot days during the 20th century.[38] Also, some evidence suggests that societies may adapt better to heat rather than cold. A study of communities in Japan and Korea found that relative risk of mortality from heat waves declined over time, but for cold waves it apparently *increased*.[39] Another analysis, this time of ten countries, found that cold-related mortality substantially exceeded heat-related mortality.[40] The authors also found that:

> Despite a warming trend, heat-related deaths decreased over the study period in most of the countries studied.
>
> The trends in cold-related mortality were less consistent. Five countries showed a decrease, and one an increase.

Finally, an analysis of temperature data from 7,000 stations around the world from 1901–2010, found 'significant warming in all seasons but more so in the colder months', that nighttime temperatures warmed more than daytime, and 'warming is generally stronger for the coldest than for the warmest value.'[41] In other words, cold extremes, which seem to be more dangerous, are reducing faster than the less dangerous hot extremes are increasing. These changes are consistent with expectations from global warming. The authors suggest that, *ceteris paribus*, there should be a net reduction in mortality due to any global warming.

Labour productivity

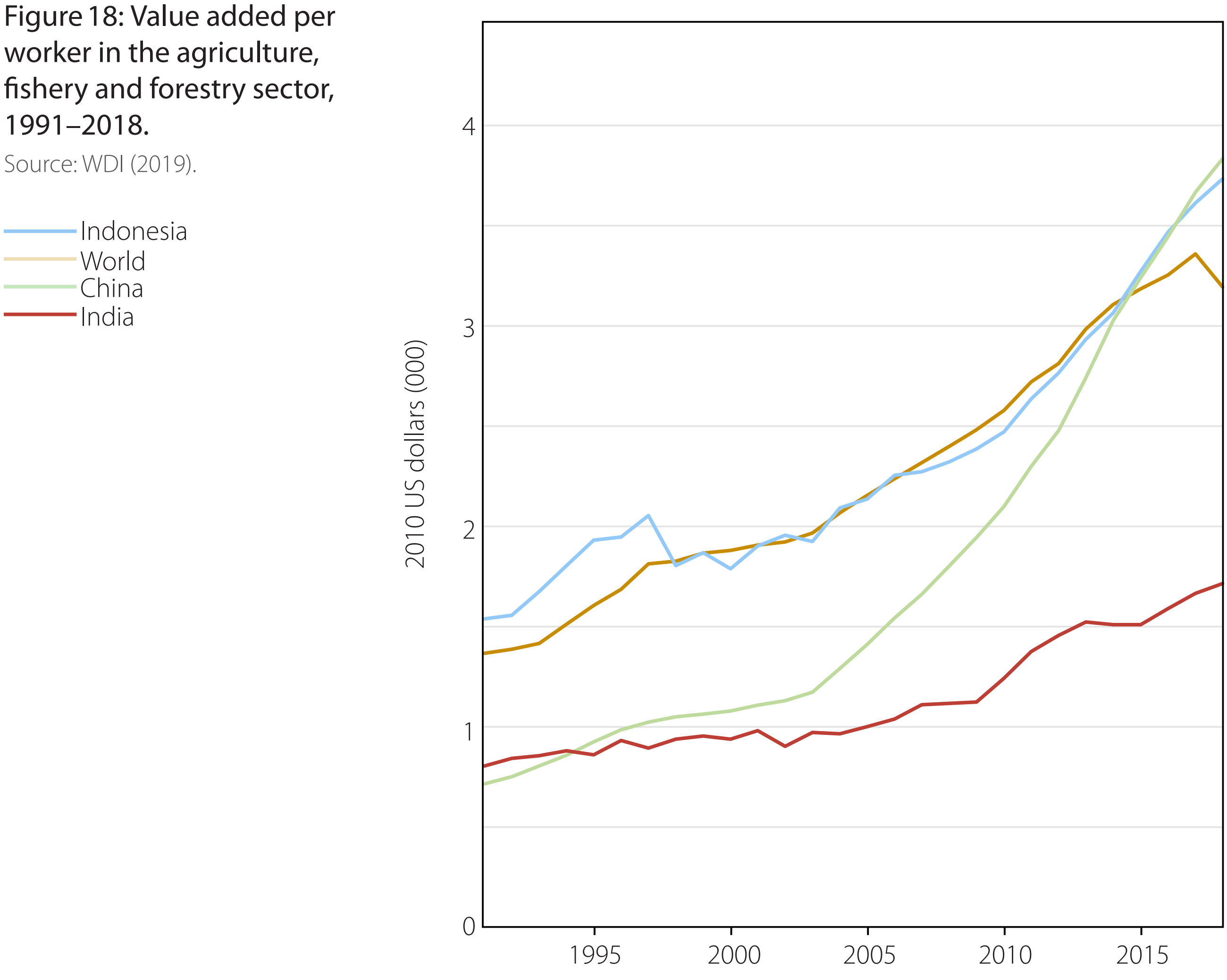
According to the *Countdown*,[42] increases in temperatures and heatwaves have decreased global labour productivity in all sectors of the economy. The majority of the decrease is in the agricultural sector, because agriculture is primarily an outdoor activity and therefore more subject to the elements than other sectors. There are apparently smaller productivity decreases in the manufacturing and service sectors, in that order. The *Countdown*'s Figure 3 indicates that India, China and Indonesia are the countries most affected by the decline in labour productivity. Note, however, that there is no indication in the *Countdown* or its Appendix whether the models used to estimate these changes have been validated using data that were not employed in developing the model itself; in other words, against out-of-sample data.

The *Countdown*'s analysis is based on an examination of various weather-related factors to estimate 'heat strain', which is postulated, not unreasonably, to affect labour productivity. However, if their calculations are correct, then value added per worker affected should be falling. Figure 18 shows the revevant data (in constant 2010 US dollars) for the agriculture, forestry and fishing sectors, in total, and for China, India and Indonesia. They all show a more-or-less continuous increase from 1991 through to 2018. For China, value added per worker in 2018 was 5.4 times its 1991 level. For the world as a whole, and for India and Indonesia in particular, value added per worker more than doubled over the same period. An exception seems to be the decline in world value added from 2017 to 2018, although there was concurrently a decline in the work hours lost for the world. Clearly, there is a lot more to productivity than outdoor weather conditions.

The increase in labour productivity is likely due, firstly, to increased and/or more efficient use of fossil-fuel-dependent tech-

Figure 18: Value added per worker in the agriculture, fishery and forestry sector, 1991–2018.

Source: WDI (2019).



nologies such as fertilisers, pesticides, irrigation and diesel-powered machinery, which collectively boost agricultural yields, for instance, and allow more work to be done in a shorter period of time.[43] Secondly, outdoor weather conditions are increasingly less relevant to maintaining labour productivity – we use energy to cool our microenvironment if it's too warm, or heat it if it's too cold. Thirdly, it should be noted that economic activity in many areas is as high as it is in part because of the ability to control workers' microenvironments. In wealthier countries, agricultural workers frequently work from air-conditioned cabs in their trucks, tractors and combine harvesters. If economic growth continues, these efficiency-enhancing practices should spread to their counterparts in developing countries. Thus limiting fossil fuel use to mitigate climate change (or its impacts), as the *Countdown* seems to favour, could be counterproductive in terms of maintaining or advancing labour productivity, as well as general habitability. This is because without cheap fossil fuels the land would be less productive and, therefore, more land and labour would be required to maintain any given level of food production.

Wildfires

The *Countdown*'s discussions of wildfire rely heavily on information that has been cherrypicked, both temporally and geographically. Specifically, its discussions focus on a limited time period and limited geography. In essence, it relies on anecdotes without providing context. In the Executive Summary, it states,

> 77% of countries experienced an increase in daily population exposure to wildfires from 2001–14 to 2015–18 (indicator 1.2.1). India and China sustained the largest increases, with an increase of over 21 million exposures in India and 17 million exposures in China over this time period.[44]

Later, it states that in 2018, '152 countries [experienced] a marked increase in the daily population exposures to wildfires compared with baseline (indicator 1.2.1).' Note that 'one exposure' is 'one person-day'.[45]

But the Earth predates 2001, and the *Countdown* neglects to inform the reader that ice-core records, charcoal measured in lake and marine sediments, and scars on tree-rings show that global burned area has been declining since around 1850.[46] Satellite data confirm the trend indicating that the burned area declined by 24.3 ± 8.8% from 1998 to 2015.[47] Also, the American Meteorological Society's annual *State of the Climate* report found that globally, fire activity during 2018 was 'the lowest since the start of the record in 1997...This reinforced the long-term downward trend in fire emissions driven by changes in land use in frequently burning savannas'.[48]

Moreover, the *Countdown*'s statistics regarding millions of additional person-days of exposures are misleading for a variety of reasons:

- Increase in exposure does not necessarily translate into greater health impacts, as we have already seen.

- India's average population for 2015–2018 is about 1,200 million. Therefore, there are potentially 438,000 million person-days of exposure each year. The 21 million person-days of exposure translates to the average person being exposed 0.005% of the time. The *Countdown* masks this by omitting any context, which, based on the foregoing, seems to be part of its *modus operandi*. Moreover, a 'measured' increase over four years is not necessarily an indicator of climate change rather a fluctuation due to weather.
- Most countries have seen their populations increase. This begs the question: how are *Countdown*'s reported increases in exposure partitioned between population growth and increasing numbers and/or extent of wildfires? The *Countdown* is silent on this.

Finally, how does the *Countdown* differentiate between changes due to weather and those due to long-term climate change? The report is silent on this as well.

4. Conclusion

The contribution of climate-sensitive diseases and events to the all-cause burden of death and disease is small, and getting smaller. Between 1990 and 2017, the cumulative ASDR for CSDEs declined by 54%, while the all-cause ASDR declined by 32%. Consequently, the ASDR from CSDEs dropped from 8.1% of all-cause ASDR to 5.5%. Over the same period, the age-standardised burden of disease declined from 12.0% to 8.0% of all-cause age-standardised DALYs.

The *Lancet Countdown* overlooks the diminishing significance of CSDEs for public health and chooses instead to emphasise those

diseases that have become more prevalent today, although their contributions to death and disease are still relatively minor. Thus, despite the fact that dengue was responsible for 40,000 deaths in 2017 (only 1.4% of cumulative mortality from CSDEs, or 0.07% of all-cause mortality), it gets more attention in the text than malaria, which was responsible for 620,000 – fifteen times as many – deaths. Needless to say, such disproportionate focus is inappropriate for providing the reader with a balanced account of threats and risks in order to help develop public health priorities.

The *Countdown* also dwells in several instances on factors that arguably might have led to an increase in CSDEs but fails to verify whether their burdens of death or disease in fact increased. For example, the *Countdown* claims that heatwaves and other extreme weather events are increasing, and that exposure and vulnerability to heat is increasing too. However, long-term data indicate that global death rates from all EWEs have declined by 99% since the 1920s.

Also, with respect to the purported impact of climate change on food security, the *Countdown* uses a construct called 'global crop growth duration' as a proxy for crop yield in order to show that food security is threatened by higher temperatures from climate change. However, the trend for crop growth duration for the five crops considered is downward, whereas actual data shows the opposite: yields have been increasing for most of the last 50 or 60 years. The *Countdown* should have verified whether and to what extent crop growth duration is a proxy for yield before relying on it in its report.

Similarly, the *Countdown* also implies that we are at increasing risk from other climate-sensitive diseases and events but does not present any data that mortality and disease burdens have actually increased from them. It claims that exposures are increasing or conditions are becoming more conducive to their spread (for example, wildfire, malaria and *Vibrio*), but global area burnt by wildfires and ASDRs from malaria and diarrheal diseases have declined substantially.

The *Countdown* also claims that labour productivity has decreased due to higher temperatures and heatwaves, but value added per worker has actually increased significantly, and incomes have grown virtually everywhere.

All this shows that business-as-usual is quite successful in mitigating the risks associated with CSDEs, whether they are due to climate change or merely weather, and that the world is coping with them better than with other major public health problems.

Notes

1 IHME, 2019.

2 See, for example, Omran, 1971; McKeown et al., 1972; Fogel, 1986; Armstrong et al., 1999; CDC 1999; Goklany, 2007a.

3 Goklany 2009a, 2020.

4 IHME, 2019.

5 See e.g. Akil et al., 2014; MacLennan et al., 2014; Saad et al., 2018.

6 I use this as shorthand for IHME's 'neglected tropical diseases and malaria' category.

7 See e.g. Tamayo et al., 2018; Yang and Bergquist, 2018; WHO, 2019.

8 EM-DAT, 2019; IHME, 2019.

9 *Countdown*, pp. 1845–46.

10 *Countdown*, p. 1845.

11 *Countdown*, p. 1845.

12 IHME, 2019.

13 *Countdown* Executive Summary, pp. 1837–38.

14 *Countdown*, Executive Summary, pp. 1836–37.

15 *Countdown*, Executive Summary, p. 1836.

16 *Countdown*, p. 1845.

17 Goklany, 2020.

18 *Countdown*, p. 1847.

19 *Countdown*, p. 1847, emphasis added and citations omitted.

20 The following subsections on air pollution, extreme weather, and wildfires draw liberally from Goklany, 2020.

21 *Countdown*, Executive Summary, p. 1837.

22 Calculated from IHME, 2019.

23 WHO, 2016.

24 WHO, 2018; IHME 2019.

25 Travel China Guide, 2019, based on Government of China, 2019, in Chinese; Wikipedia, 2019.

26 Goklany, 2020.

27 *Countdown*, Executive Summary, p. 1836.

28 *Countdown*, Executive Summary, p. 1837.

29 Goklany, 2007a, 2012b, 2020.

30 Formetta and Feyen, 2019.

31 EM-DAT, 2019.

32 IHME, 2019.

33 Gasparrini et al., 2015; Fu et al., 2018.

34 Goklany, 2009b, 2015.

35 Gasparrini et al., 2015a; Fu et al., 2018.

36 Goklany, 2020.

37 Gasparrini et al., 2015b.

38 Barreca et al., 2016.

39 Lee et al., 2018.

40 Vicedo-Cabrera et al., 2018.

41 Donat et al., 2013.

42 *Countdown*, pp. 1837, 1842.

43 Goklany, 2012.

44 *Countdown*, Executive Summary, p. 1837.
45 *Countdown*, p. 1844.
46 Hamilton et al., 2018.
47 Andela et al., 2017.
48 Blunden and Arndt, 2019.

Bibliography

Akil, Luma, H. Anwar Ahmad and Remata S. Reddy, 2014. 'Effects of climate change on Salmonella infections.' *Foodborne Pathogens and Disease* 11, no. 12: 974–980.

Andela, N., Morton, D. C., Giglio, L., Chen, Y., Van Der Werf, G. R., Kasibhatla, P. S. et al., 2017. 'A human-driven decline in global burned area'. *Science*, 356(6345), 1356–1362.

AP, 2018. Weather. Even the eyelashes freeze: Yakutia, Russia sees minus 88.6 degrees F. Available at https://abc13.com/2960957/.

Armstrong, Gregory L., Laura A. Conn, and Robert W. Pinner, 1999. 'Trends in infectious disease mortality in the United States during the 20th century.' *JAMA* 281, no. 1: 61–66.

Arora, V. K., and J. R. Melton, 2018. 'Reduction in global area burned and wildfire emissions since 1930s enhances carbon uptake by land'. *Nature Communications*, 9: 1326.

Barreca, Alan, Karen Clay, Olivier Deschenes, Michael Greenstone, and Joseph S. Shapiro, 2016. 'Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century'. *Journal of Political Economy*, 124(1): 105–59.

Blunden, J. and D. S. Arndt, (eds) 2019. State of the Climate in 2018. *Bulletin of the American Meteorological Society*, 100 (9), Si–S305.

Boden T, Marland G, Andres B, 2016. Global CO_2 emissions from fossil-fuel burning, cement manufacture, and gas flaring. Oak Ridge National Laboratory, Oak Ridge. CDC. 1999. [Centers for Disease Control and Prevention]. '*Achievements in Public Health, 1900–1999*' MMWR 48 (1999).

China Travel Guide, 2016. Available at https://www.travelchinaguide.com/climate/air-pollution.htm. Visited October 13, 2019. Based on *Technical Regulation on Ambient Air Quality Index (on trial)*. Ministry of Environmental Protection of the People's Republic of China (in Chinese).

Donat, M. G., L. V. Alexander, H. Yang, I. Durre, R. Vose, R. J. H. Dunn, K. M. Willett et al., 2013. 'Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset'. *Journal of Geophysical Research: Atmospheres*, 118(5): 2098–2118.

EM-DAT. 2019. EM-DAT: The CRED/OFDA International Disaster Database. Online Database. https://www.emdat.be/.

FAOSTAT, 2019. On-line database, UN Food and Agricultural Organization, downloaded February 14, 2019.

Fogel, Robert W., 1986. 'Nutrition and the decline in mortality since 1700: some preliminary findings.' In: Stanley L. Engerman and Robert E. Gallman, eds., *Long-term Factors in American Economic Growth*, pp. 439–556. University of Chicago Press, 1986.

Formetta, Giuseppe, and Luc Feyen, 2019. 'Empirical evidence of declining global vulnerability to climate-related hazards.' *Global Environmental Change,* 57: 101920.

Fu, Sze Hang, Antonio Gasparrini, Peter S. Rodriguez, and Prabhat Jha, 2018. 'Mortality attributable to hot and cold ambient temperatures in India: a nationally representative case-crossover study'. *PLoS Medicine*, 15(7): e1002619.

Gasparrini, Antonio, Yuming Guo, Masahiro Hashizume, Eric Lavigne, Antonella Zanobetti, Joel Schwartz, Aurelio Tobias et al. 2015a. Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet*, 386(9991): 369–75.

Gasparrini, Antonio, Yuming Guo, Masahiro Hashizume, Patrick L. Kinney, Elisaveta P. Petkova, Eric Lavigne, Antonella Zanobetti et al 2015b. 'Temporal variation in heat-mortality associations: a multi-country study'. *Environmental Health Perspectives*, 123(11): 1200–1207.

Ge, Quansheng, Jingyun Zheng, Zhixin Hao, Yang Liu, and Mingqi Li, 2016. 'Recent advances on reconstruction of climate and extreme events in China for the past 2000 years'. *Journal of Geographical Sciences*, 26(7): 827–54.

Goklany, Indur M. 2007. The improving state of the world: why we're living longer, healthier, more comfortable lives on a cleaner planet. Cato Institute, Washington, DC.

Goklany, Indur M. 2009a. 'Have increases in population, affluence and technology worsened human and environmental well-being?' *The Electronic Journal of Sustainable Development* 1, no. 3 (2009): 15.

Goklany, Indur M. 2009b. Deaths and death rates from extreme weather events: 1900–2008. *Journal of American Physicians and Surgeons*, 14(4): 102–109.

Goklany, Indur M. 2012b. Is climate change the number one threat to humanity? *Wiley Interdisciplinary Reviews: Climate Change* 3(6): 489–508.

Goklany Indur M. 2020. Fact checking influential narratives of current impacts of climate change (working title). Report, Global Warming Policy Foundation, forthcoming.

Hamilton, Douglas Stephen, S. Hantson, C. E. Scott, J. O. Kaplan, K. J. Pringle, L. P. Nieradzik, A. Rap, G. A. Folberth, D. V. Spracklen, and K. S. Carslaw, 2018. 'Reassessment of pre-industrial fire emissions strongly affects anthropogenic aerosol forcing'. *Nature Communications*, 9(1): 3182.

Institute for Health Metrics and Evaluation (IHME), 2019. Global Burden of Disease 2017 Results Tool, at http://ghdx.healthdata.org/gbd-results-tool.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Kuddus, Md Abdul, Emma S. McBryde, and Oyelola A. Adegboye, 2019. 'Delay effect and burden of weather-related tuberculosis cases in Rajshahi province, Bangladesh, 2007–2012.' *Scientific Reports* 9, no. 1: 1–13.

Lancet Countdown 2019. Watts N et al. 2019. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *The Lancet* 394(10211): 1836–78.

Lee, W., Choi, H.M., Lee, J.Y., Kim, D.H., Honda, Y. and Kim, H., 2018. Temporal changes in mortality impacts of heat wave and cold spell in Korea and Japan. *Environment International*, 116: 136-146.

Lewis, Nicholas, and Judith Curry, 2018. 'The impact of recent forcing and ocean heat uptake data on estimates of climate sensitivity'. *Journal of Climate*, 31(15): 6051–71.

Lewis, Nicholas and Peter Grünwald, 2018. 'Objectively combining AR5 instrumental period and paleoclimate climate sensitivity evidence'. *Climate Dynamics*, 50(5–6): 2199–216.

Lindsey, Rebecca and LuAnn Dahlman. 2020. Climate change: global temperature. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature.

McKeown, Thomas, R. G. Brown, and R. G. Record, 1972. 'An interpretation of the modern rise of population in Europe.' *Population Studies* 26, no. 3: 345–382.

MacLennan, Calman A., Chisomo L. Msefula, Esther N. Gondwe, James J. Gilchrist, Paul Pensulo, Wilson L. Mandala, Grace Mwimaniwa et al., 2017. 'Presentation of life-threatening invasive nontyphoidal Salmonella disease in Malawian children: A prospective observational study.' *PLoS Neglected Tropical Diseases* 11, no. 12: e0006027.

Omran, Abdel R., 2005. 'The epidemiologic transition: a theory of the epidemiology of population change.' *The Milbank Quarterly,* 83, no. 4: 731–757.

OWID. [Our World in Data]. 2019. On-line database at https://ourworldindata.org/.

PBL, 2018. Trends in global CO_2 and total greenhouse gas emissions; 2018 report. PBL report 3125.

Saad, Neil J., Victoria D. Lynch, Marina Antillón, Chongguang Yang, John A. Crump, and Virginia E. Pitzer, 2018. 'Seasonal dynamics of typhoid and paratyphoid fever.' *Scientific Reports* 8, no. 1: 1–9.

Tamayo, Laura D., Felipe Guhl, Gustavo A. Vallejo, and Juan David Ramírez, 2018. 'The effect of temperature increase on the development of Rhodnius prolixus and the course of Trypanosoma cruzi metacyclogenesis.' *PLoS Neglected Tropical Diseases* 12, no. 8: e0006735.

Vicedo-Cabrera, Ana M., Francesco Sera, Yuming Guo, Yeonseung Chung, Katherine Arbuthnott, Shilu Tong, Aurelio Tobias et al. 2018. 'A multi-country analysis on potential adaptive mechanisms to cold and heat in a changing climate'. *Environment international*, 111: 239–46.

WDI. [World Development Indicators]. 2019. World Bank Databank. https://databank.worldbank.org/reports.aspx?source=world-development-indicators#.

WHO. 2016. Ambient air pollution: a global assessment of exposure and burden of disease. Geneva, Switzerland: World Health Organization, 2016.

WHO. 2019. Leishmaniasis. Available at https://www.who.int/news-room/fact-sheets/detail/leishmaniasis.

Wikipedia. 2019. List of cities in China by life expectancy. Available https://en.wikipedia.org/wiki/List_of_cities_in_China_by_life_expectancy. Visited October 13, 2019. Based on Chinese governmental sources (in Chinese).

Yang, Guo-Jing, and Robert Bergquist, 2018. 'Potential impact of climate change on schistosomiasis: a global assessment attempt.' *Tropical Medicine and Infectious Disease* 3, no. 4: 117.

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Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

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