Demography India
Vol. 51, No. 1 (2022), pp.1-16 ISSN 0970-454X

Global Heating and the Demographic Future

Tim Dyson[1]

Abstract: It was argued in 2005 at IUSSP Tours that avoidance and denial have characterized humanity's response to 'global warming'. Illustrative calculations showed that even if per capita CO2 emissions in each world region remained constant during 2000-50 there would still be a major rise in overall CO2 emissions—from population growth. Moreover, the actual rise would be much greater—due to rises in per capita emissions. The present paper, delivered at the virtual IUSSP conference in Hyderabad in 2021, shows that recent trends confirm these points. Thus, during 2000-19 world fossil fuel consumption rose by 45 percent. And the 2015 Paris Agreement contains no mention of negative-emission technologies. The paper explores the future through a demographic lens. It illustrates that seemingly distant dates are actually fairly close. It documents the—largely unnoticed—fact that the growth rates of atmospheric CO2 and the world's surface temperature are both accelerating. A doubling of atmospheric CO2 over preindustrial levels is likely to occur before 2100. Relatedly, the aim of restricting the global temperature rise to less than 2°C is fanciful. The paper argues that, for climate-related reasons, world population growth after 2050 is likely to be appreciably less than is currently projected.

Key words: Atmospheric CO_2, climate change, demographic transition, population decline, population growth, population projections.

'Humankind cannot bear very much reality'—T. S. Eliot, *Four Quartets*

Introduction

A paper presented at IUSSP Tours in 2005 argued that social and political responses to the problem of 'global warming' contained a huge amount of avoidance and denial—and that this would continue. Also, because of the heavy dependence of economic growth on fossil fuel use, major rises in the future consumption of coal, oil, and natural gas were seen as inevitable. Illustrative calculations showed that even if the level of per capita CO_2 emissions in each world region remained constant (as in the year 2000) by 2050 global CO_2 emissions from burning these fuels would increase by about 28 percent—i.e., from around 23.2 to about 29.6 gigatons ($GtCO_2$). This increase would come solely from projected population growth. However, the total volume of CO_2 emissions would definitely rise by *much* more than this—because in most world regions levels of per capita CO_2 emissions were likely to increase. The result would be a major rise in atmospheric CO_2 and therefore, in all likelihood, the world's temperature. Serious behavioural change to limit carbon emissions was regarded as unlikely. Therefore, the broad sway of future events was seen as set to run its course (see Dyson, 2005).[2]

[1] Professor Emeritus, Department of International Development, London School of Economics, London, WC2A AE, UK. Email: t.dyson@lse.ac.uk

[2]Dyson (2005) uses 2000 as the base year and assembles many points and arguments which, quite intentionally, are not restated here. This is partly because the experience of the last two decades has generally borne them out. But it is also because the situation humanity now confronts has moved on greatly in the space of only a few years—so much so that rather different issues must now be addressed. Note too that the present paper generally substitutes the more objective term 'global heating' for the comfier term that is 'global warming'.

Demography India
Vol. 51, No. 1 (2022), pp.1-16 ISSN 0970-454X

Against this backcloth the current paper, which was presented at the virtual IUSSP conference in Hyderabad in 2021, begins by reviewing relevant changes over the first two decades of the twenty-first century. It shows that, in *all* main respects, the situation has got very much worse. Indeed, there is disturbing evidence of an *acceleration* in *both* the rate of atmospheric CO_2 increase and the rate of global temperature rise. The paper then considers the implications of these worrying developments for demographic changes. It argues that likely consequent rises in socio-political instability will probably have major implications for future population trends—especially from around mid-century (i.e., after 2050). Of course, there is uncertainty about what will happen, particularly at lower levels of aggregation. Nevertheless, there is a need for demographers to be much less constrained in their thinking when they consider the likely effects of future global heating on future population trends.

Recent Trends

So, two decades into the twenty-first century, how have things progressed? At first sight, the situation may seem to have improved since the year 2000. For example, there is probably now greater public awareness of: the case for reducing/limiting/lowering CO_2 and other greenhouse gas (GHG) emissions; the benefits of solar/wind/geothermal/renewable energy; the advantages of ethanol/biodiesel/hydrogen fuels; ideas such as carbon budgets and carbon trading; and, progress in relation to integrated energy systems and batteries. This list could easily be extended. And the costs of many of the new technologies have plummeted. Increasingly, in many countries landscapes contain solar and wind power stations, and there are electric and hydrogen-fuelled vehicles on the road. There is also a vast amount of associated *hype*—e.g., with regard to 'sustainable' development. And the threat of global heating, and the lack of urgent political action, have been highlighted by activists like Greta Thunberg and nonviolent civil disobedience movements such as Extinction Rebellion. Also, there appears to have been some progress on the international stage. Above all, the Paris Climate Agreement of 2015 aims to restrict the global temperature rise to 'well below' 2°C above the 'pre-industrial' (i.e., 1850-1900) level; indeed, hopefully the temperature rise will be restricted to just 1.5°C.

Yet the 'hard facts' of the past two decades reveal a *very* different story. Thus, comparing world energy consumption—in exajoules (EJ)—in 2000 with the year 2019: global use of oil—still the world's leading primary energy source—grew by 25 percent (from 154 to 193 EJ); consumption of coal rose by a massive 60 percent (from 99 to 158 EJ); and natural gas usage grew by 64 percent (from 86 to 141 EJ).[3] Influenced by the 2011 disaster in Fukushima, the world's use of nuclear energy fell slightly (from 25.8 to 24.9 EJ). And there was sizeable growth of hydropower (from 26.5 to 37.6 EJ)—largely due to developments in China, including the completion of the Three Gorges Dam. Consumption of renewable energy—i.e., wind, solar, geothermal, and biomass—expanded rapidly over the period (from 2.6 to 29

[3] An exajoule is a unit of electrical energy equivalent to one quintillion joules. Using estimates for 2019 in these comparisons means that they are unaffected by the covid-19 pandemic.

EJ). But in 2019 this category of power generation still only accounted for about 5 percent of total primary energy use worldwide (British Petroleum, 2020).

A key message from these figures is that, despite all of the hype about sustainable development and renewable energy use, global consumption of fossil fuels—i.e., coal, oil, and natural gas—increased by 45 percent (from 339.5 to 492.3 EJ) in just nineteen years! The emissions from burning these fuels rose by a similar percentage—reaching 34.2 $GtCO_2$ in 2019 (the illustrative figure of 29.6 $GtCO_2$ that was mentioned above for 2050 was surpassed as early as 2007) (British Petroleum, 2020). Informing all of these developments, of course, was a 1.6 billion (i.e., 25 percent) increase in the world's population during 2000-19.

These *massive* increases in fossil fuel energy use have informed other alarming trends. In particular, between 2000 and 2019 the level of atmospheric CO_2—as gauged by the benchmark measurements made at the Mauna Loa Observatory in Hawaii—rose from 370 to 411 parts per million (ppm) (Tans and Keeling, 2021). This too is an enormous change in a very short period. The level of atmospheric CO_2 is obviously crucial in the context of the so-called 'greenhouse effect'. And perhaps the most important thing to understand about the level of atmospheric CO_2 is that it has increased *every* year since 1959—the first full year for which there is a measurement (of 316 ppm). In effect, then, the level of atmospheric CO_2 is continually being ratcheted upwards. The measurements for 2020 and 2021 are respectively 414.2 and 416.4 ppm. Even more disturbingly, as column (ii) of Table 1 clearly shows, the size of the average annual increment in atmospheric CO_2 has risen—i.e., there is an *acceleration*. Thus, during 2000-09 the average annual increment was +1.91 ppm per year; and for 2010-19 it was +2.40 ppm. The acceleration dates from the 1960s.[4]

Table 1: Global atmospheric CO_2 concentrations and surface temperature anomaly estimates, 1990-2019

	CO_2 at Mauna Loa		Temperature HadCRUT4		Temperature GISTEMPv4	
Decade	Average annual level (ppm)	Average annual increment per decade	Average annual temp anomaly (°C)	Average annual change per decade (°C)	Average annual temp anomaly (°C)	Average annual change per decade (°C)
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
1990-99	360.46	+1.53	0.275	+0.019	0.383	+0.011
2000-09	378.58	+1.91	0.463	+0.020	0.591	+0.028
2010-19	400.21	+2.40	0.612	+0.023	0.807	+0.032

Notes: The CO_2 data are National Oceanic and Atmospheric Administration/Earth System Research Laboratories measurements from Mauna Loa taken from Tans and Keeling (2021). HadCRUT4 temperature anomalies are relative to 1961-1990 and are taken from Morice et al. (2020). GISTEMPv4 temperature anomalies are relative to 1951-1980 and are from GISTEMP Team (2021).

[4] The annual mean growth rate of atmospheric CO_2 has increased since the 1960s. However, in the 1990s there was a slight fall in the growth rate compared to the 1980s (Tans and Keeling, 2021). This reflected very low growth rates in 1992 and 1993 and was probably related to the eruption in 1991 of Mount Pinatubo in the Philippines.

For completeness, it should be noted that the period 2000-19 also saw major rises in the levels of methane (CH_4) and nitrous oxide (N_2O) in the atmosphere (see Dlugokencky, 2021a, 2001b). These are both important, if secondary, GHGs. In their cases too, the annual increments show little sign of slowing, and they are both being influenced upwards by, among other things, increased human activities (e.g., in agricultural production) linked to population growth.

Turning to the world's surface temperature (land and marine), as recently as 2014 deniers of global heating could point to 1998—an abnormally warm year—to prop up their claim that there was no increase in temperature.[5] However, estimates for years after 2014 mean that this subterfuge is no longer possible. In fact, the rise in temperature from around 1980 looks almost inexorable. Thus, and as expected, and as both the respected HadCRUT4 and GISTEMPv4 temperature anomaly series summarized in columns (iii) and (v) of Table 1 show, 2000-09 supplanted the 1990s as the warmest decade since direct measurements began; and 2010-19 then supplanted 2000-09. The year 2020 was the third hottest on record according to HadCRUT4, and joint equal hottest (with 2016) according to GISTEMPv4. Importantly, notice that both of these standard global time series suggest that the average annual temperature rise is *accelerating* (see columns (iv) and (vi)).[6] This may partly reflect a reduction of particulate matter in the atmosphere—leading to a decrease in negative atmospheric aerosol forcing (Hansen and Sato, 2020). But it may also reflect—and contribute to—the acceleration in the level of atmospheric CO_2. Whatever the explanation, it is an extremely disturbing development which for some reason has been poorly articulated beyond the specialist scientific community.

In this context, the Paris Agreement's aim of limiting the global temperature rise to less than 2°C is surely unrealistic—especially given that a rise of around 1.1°C in temperature (over the pre-industrial level) is thought to have *already* taken place, and because during 2000-19 heating is estimated to have been occurring at average annual rates of +0.022°C (HadCRUT4) and +0.030°C (GISTEMPv4). Moreover, the Paris Agreement itself contains something of a deception. This is because it makes no specific mention of the negative-emission technologies (NETs) which are required to achieve its own stated aims. NETs include approaches to reduce the level of atmospheric CO_2. However, the aim of restricting the global temperature rise to less than 2°C is actually based on the—unstated—assumption that NETs will be introduced on a huge scale later during the present century (Anderson, 2015).[7] That

[5] The occurrence of a major El Niño/Southern Oscillation—which involves considerable ocean surface warming—contributed to the (then) record temperature recorded for 1998. Of course, unlike the level of atmospheric CO_2, global temperatures do go up and down from year to year, although on a distinctly rising trend.
[6] The HadCRUT4 anomaly series are produced by the UK Meteorological Office in association with the Climate Research Unit at the University of East Anglia; the GISTEMPv4 series are produced by the Goddard Institute for Space Studies which is affiliated with the Earth Institute at Columbia University. The National Climatic Data Center in the United States also produces global temperature estimates and related anomalies. They too suggest an acceleration, but because they employ a very long reference period (1901-2000) they are not shown here.
[7] Biomass energy carbon capture and storage (BECCS) is one prominent NET (Anderson, 2015). For other potential approaches to GHG removal from the atmosphere, see Harthan and Lindley (2021).

this is indeed the case is now generally agreed (e.g., see IPCC, 2018). Terms like 'magical thinking' and 'techno-utopia', have been used to describe the current state of NETs.

To conclude this section, the sixth assessment report—AR6—of the Intergovernmental Panel on Climate Change (IPCC) states that '[c]limate change is already affecting every inhabited region across the globe with human influences contributing to many observed changes in weather and climate extremes' (IPCC, 2021: 41). Moreover, and despite difficulties in measuring changes at the global level, AR6 finds clear evidence of a relatively recent acceleration in factors such as: overall levels of precipitation, the incidence of heavy rainfall events, the occurrence of heatwaves, the frequency of tropical cyclones, and the rate of world sea level rise (IPCC, 2021: 7-12).

With this as background, and adopting a specifically *demographic* lens, the paper now considers the implications of global heating for the future.

The Future

Perhaps the first thing to say regarding climate change and future population trends is that by various demographic criteria seemingly distant dates—such as the end of the twenty-first century—are actually fairly close in time. By way of illustration: given current world mortality conditions, more than 90 percent of children born in the year 2021 will be alive in 2050, and over 40 percent will survive to 2100.[8] Indeed, even the year 2200 lies well within the compass of two overlapping, if long, lifetimes.

Until now, population growth has been the second most important factor contributing to the rise in world CO_2 (and other GHG) emissions—second only to economic growth with its hitherto heavy reliance on the burning of fossil fuels (e.g., see Bongaarts, 1992; Cohen, 2010). Between 2020 and 2050 population growth will have a significant—although diminishing—influence on global CO_2 emissions, which at some point within that time period are expected to peak and then start to fall.

In this context, the United Nations projects with reasonable confidence that between 2020 and 2050 the world's population will grow by roughly 2 billion. However, two major emitting regions—most crucially East Asia (including China, which by itself accounted for 28 percent of world CO_2 emissions in 2019), but also Europe (responsible for about 9 percent of world CO_2 emissions)—are projected to experience slight population declines (of 4-5 percent).[9] This signals a coming era in which regional population *declines* will contribute—albeit only modestly—to regional reductions in CO_2 emissions. In Europe, a fall in total CO_2 emissions has been occurring since about 2007 (although this

[8] United Nations (2019) is the source of the population estimates and projections used in this paper.
[9] In this and the next two paragraphs, the broad statements regarding future levels of CO_2 emissions are informed by statistics on past trends from Our World in Data (2021) and illustrative projections to 2030 provided by Climate Action Tracker (2021). The CO_2 emissions data exclude emissions from land use changes and cement production. The regions discussed in these paragraphs cover about 96 percent of the world's population. The statements on current regional contributions to overall carbon emissions and per capita emission levels relate to 2019. In relation to the population figures, see footnote 8.

partly reflects the 'export' of industrial production to other countries).[10] In East Asia, however, a fall in overall CO_2 emissions appears to be at least a decade away; what actually happens will depend greatly upon what happens in China—about which there is considerable uncertainty.

The UN projects fairly limited population growth over 2020-50 for Latin America (an increase of 17 percent), Southeast Asia (19 percent), and South-central Asia (24 percent). There is evidence that a fall in CO_2 emissions has been occurring in Latin America since around 2014; therefore, the effect of future population growth in this region may only be to slow the rate of an already established fall. For both Southeast Asia and South-central Asia, it seems likely that future demographic growth will initially contribute to a further rise in CO_2 emissions before then—slightly—slowing a fall. That said, especially in South-central Asia any peak in emissions is likely to occur rather late during the period 2020-50. This is because in India (responsible for about 7 percent of world CO_2 emissions in 2019) the level of per capita emissions—at only about 1.8 tons per person—is still exceptionally low and it will almost certainly rise significantly in the next few decades.

North America ranks second only to East Asia in terms of total CO_2 emissions. By itself, the United States accounts for about 14 percent of global CO_2 emissions and it also has a very high level gauged on a per capita basis—of around 15.3 tons per person. North America is likely to be the region where population growth—projected at 56 million (i.e., 15 percent) for the period 2020-50—will have the biggest effect on global emissions (reflecting the very high per capita level). However, this effect will work through slowing an already established fall in emissions rather than in contributing to a rise (overall CO_2 emissions in the US have been falling since around 2007). Finally, slightly more than half of the UN's projected world population growth of 2 billion for 2020-50 relates to Africa, a region which only accounts for about 4 percent of global CO_2 emissions. Africa's average level of per capita emissions—about 1.1 tons per person—is, and will doubtless remain, very low. Consequently, the impact of future population growth on CO_2 emissions in this region—while sizeable in percentage terms—will probably be fairly small in the global context.

Turning to the level of atmospheric CO_2 and the Earth's surface temperature, it is almost certain that there will be significant increases in both of these measures. The effect of an increase in the former on the latter is usually assessed in terms of a doubling of atmospheric CO_2 over the pre-industrial level. This equates to an increase from around 280 ppm to 560 ppm. The standard view has long been that such a doubling would, with a lag, lead to a temperature rise of 1.5-4.5°C (central figure 3°C, National Research Council, 1979). But given the estimated 1.1°C of heating that has already taken place, and the future heating that is currently committed in the climate system (perhaps as much as +0.3°C) the lower end of the 1.5-4.5°C range is now regarded as unlikely. Research generally results in central estimates

---

[10] The statement about the fall in Europe excludes Russia where overall CO_2 emissions have been roughly constant since about 2000.

of between 3°C and 4°C. An influential recent study concludes that there is a two-thirds chance of the figure lying between 2.6°C and 3.9°C (Sherwood et al., 2020).

Against this background, it appears likely that the level of atmospheric CO_2 will reach 560 ppm before or around the year 2100. Thus, assuming the continuation of annual rises of +1.91 and +2.40 ppm (as per the decades 2000-09 and 2010-19 in Table 1) would lead to 560 ppm being reached in the years 2098 and 2082 respectively. However, assuming a rise of +2.90 ppm (to make a modest allowance for a future acceleration in the rise) would mean that the level is attained as soon as 2071.[11] It is worth noting that having reached 416 ppm in 2021 we are already almost half-way to a doubling of atmospheric CO_2. In relation to the world's surface temperature, a continuation of the average annual rises for 2000-19 of +0.022°C (HadCRUT4) and +0.030°C (GISTEMPv4) would lead to 2°C being reached around 2060 and 2050 respectively. And if these average annual rises continued then by 2100 the corresponding figures would be 3°C and 3.5°C. Of course, these illustrative calculations make no allowance for any acceleration of the temperature increase.

These sorts of temperature rise for this century—let alone the next century—suggest strongly that the future will become increasingly dire. A multitude of warnings illustrate this. For instance, Petteri Taalas, Secretary General of the World Meteorological Organization, recently remarked that '[o]n the current path of carbon dioxide emissions, we are heading towards a temperature increase of 3 to 5 degrees Celsius by the end of the century' (World Meteorological Organization, 2020). The latest report of the Intergovernmental Panel on Climate Change (AR6) refers to climate change as being widespread, rapid, and intensifying, and states that many of the attendant changes that are now underway are likely to be irreversible (IPCC, 2021). Further, ahead of the international climate conferences in Scotland in 2021 and Egypt in 2022 the UN Secretary General Antonio Guterres has repeatedly warned that humanity is on course for a 'climate catastrophe' with terrible wildfires, floods, cyclones and hurricanes becoming the 'new normal' (e.g., see United Nations, 2021, 2022a). This is what is meant by the term 'dangerous' climate change. To avoid such a bleak scenario would have required taking *much* greater action *much* earlier. It is unsurprising, then, that there are more and more ominous forecasts about what lies ahead (e.g., see Anderson and Bows, 2011; Wallace-Wells, 2019; Gilding, 2019).

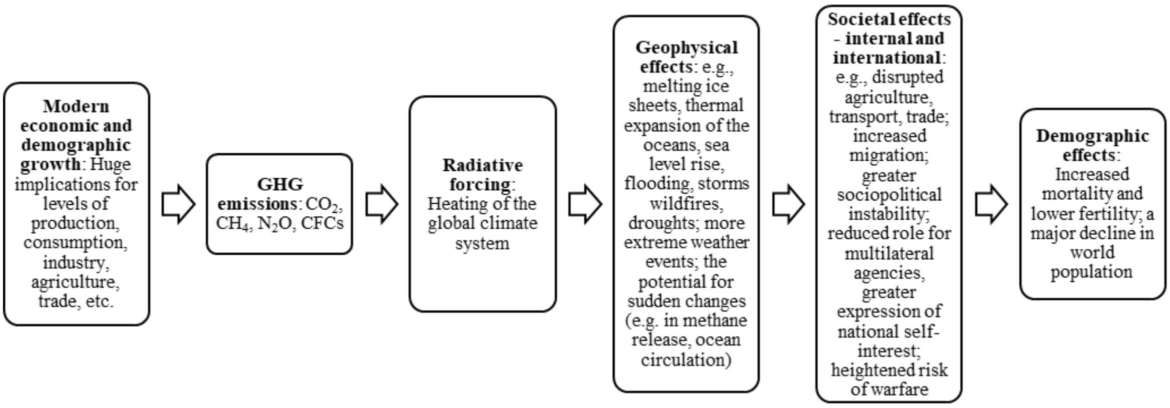
Even on the—highly unlikely—basis that there are reductions in CO_2 emissions in line with the Paris Agreement, it is still quite possible that the Earth's system has already been sufficiently destabilized to lead to a temperature rise of 4°C with huge, if lagged, increases in sea-level. What appear to be underway are various geophysical 'cascades'—in which particular processes (e.g., the retreat of mountain glaciers, summer sea-ice loss) trigger other processes (e.g., forest dieback, raised oceanic

[11] In the context of this acceleration, there are increasing signs that the capacity of the world's oceans, soils, and terrestrial vegetation to absorb CO_2 is declining. See, for example, Gatti et al. (2021).

bacterial respiration) and, in turn, still more processes (e.g., permafrost thaw, release of CH_4 from ocean floors, etc.) (see Steffen et al., 2018).

Against this backcloth, Figure 1 presents a simple general illustrative model which highlights selected key linkages. Thus, beginning in the decades around 1800, a combination of modern economic growth *and* population growth (resulting from the global demographic transition) has underpinned massive rises in CO_2 and other GHG emissions and, therefore, changes in the composition of the Earth's atmosphere—leading to radiative forcing and global heating. In turn, the heating is having geophysical effects—e.g., flooding, heatwaves, extreme weather events, etc.—some of which—e.g., the loss of ice sheets and glaciers, and increased release of CO_2 from forest fires—contribute to yet further heating in a self-reinforcing cycle. In turn, geophysical processes have societal effects which operate both internally and internationally. The societal effects include, for example, disruption of food supplies, food price rises, reduced living standards, migration, conflict, and increased socio-political instability. Finally, there are demographic effects which, at the global level, work through mortality and fertility.

Figure 1: Selected linkages between modern economic and demographic expansion, environmental and societal consequences, and population decline



The initial causal processes in Figure 1—i.e., modern economic growth and demographic transition—first emerged in Europe roughly two hundred years ago. However, in terms of their global occurrence, and their effects, they have mostly been *much* more recent. In particular, both processes have escalated hugely in the world in the period since World War II.

To illustrate this fundamental point, in the space of just the seventy-years from 1950 to 2020: the human population grew from around 2.5 to 8 billion, an increase of about 220 percent (United Nations, 2019); the average level of GDP per capita for the world—taken as a crude measure of material consumption—rose from about \$3,300 to \$15,200, an increase of around 360 percent (Bolt and van Zanden, 2020); and annual global CO_2 emissions grew from 6 to about 36.4 $GtCO_2$, a rise of approximately 500 percent (Our World in Data, 2021). Moreover, it is basically in this same short time period that the level of atmospheric CO_2 has been destabilized. In 1950 the level was still only around

309 ppm i.e., not much above the preindustrial figure of *c*. 280 ppm. Today however, as noted, it exceeds 416 ppm and is rising relentlessly.[12]

It is in this context that all of the previously-mentioned signs of *acceleration* (e.g., in atmospheric CO_2 and resulting geophysical processes) become even more disturbing. In brief, a huge amount has happened in a very short historical period. One implication of this may be that we have lost any capacity to significantly influence trends, let alone 'control' them.[13] And, of course, this comes *on top of* the facts that: the changes needed to decarbonise any society are incredibly difficult; avoidance and denial of global heating continue to be widespread; and, everywhere, political institutions are simply not up to the task of transforming societies at anywhere near the required rate.[14] Furthermore, there is of course appreciable *momentum* in demographic, economic, social, political, and climate processes—all of which would need to be overcome.[15]

These things said, at present there is no clear evidence that global heating is having significant demographic effects at the global level. For instance, mortality in most countries has been declining for decades. And there are many ways in which further declines can be achieved. Also, statistics from the International Disaster Database suggest that there has been a long-term reduction in 'climate-related' deaths—i.e., those specifically caused by floods, droughts, storms, wildfires, and heatwaves; moreover, in some places the temperature rises experienced so far have probably had beneficial effects, for example in reducing deaths because of the occurrence of milder winters (e.g., see Lomborg, 2020). Nevertheless, the lack of evidence that heating is having adverse mortality effects may partly be because, as in other respects, there is substantial momentum to the process of mortality decline; and it may also reflect the fact that most of the global temperature rise—and the acceleration—has been quite recent (i.e., since the 1980s). Moreover, there is mounting evidence that changes in the world's climate are having increasingly negative effects on human health—e.g., in terms of the spread of infectious and parasitic diseases, heat-related illnesses, and levels of food insecurity (e.g., see Romanello et al., 2022).

Furthermore, the main ways in which it is thought that global heating will slow the pace of mortality decline, and indeed begin to generate rises, do *not* pertain to individual events like floods, storms, and heatwaves. Rather, as is implied in Figure 1, they relate to larger processes which over

[12] Dollars are in 2011 prices. The global CO_2 emission figures cited in this paragraph differ slightly from those used elsewhere in the paper because they include emissions from the manufacture of cement. The figure for atmospheric CO_2 of 309 ppm for 1950 results from back-projecting from the measurement for 1959 (of 316 ppm) on the basis of the average annual increment for the period 1959-68 (of 0.8 ppm). For the baseline measurements, see Tans and Keeling (2021).

[13] See, for example, the considerations mentioned in footnote 11.

[14] A recent study by Anderson, Broderick and Stoddard (2020) shows that Sweden and the UK, countries which like to see themselves as 'climate progressive', in fact fall very far short of what is required for the Paris Agreement. Relatedly, everywhere, the politicians in power change, which can lead to major turnarounds in government policies.

[15] Such issues are not discussed any further here, although they are touched on in Dyson (2005).

various timescales contribute to, and result from, wider societal disruption (e.g., loss of cultivatable land, flooding of cities, food shortages, increased socio-political instability, etc.). In short, due to such factors, *cascades* of adverse events can—and do—occur in the socio-political realm. And they can be unexpected and sudden. In this respect, most initial accounts of the civil war in Syria, which began in 2011, were framed in terms of *pre-existing* social and political conditions. There was scant mention of the preceding lengthy and severe drought—which may have partly resulted from climate change. Subsequently, however, there has been discussion of whether factors related to global heating played a role in the genesis of the Syrian conflict—something which certainly cannot be discounted (e.g., see Kelley, 2015; Selby et al., 2017).

Several further considerations are worth noting here. Most obviously, perhaps, the crisis in Syria illustrates the capacity for increases in migration (both internal and international). Such migration can itself have destabilizing effects. On a wider canvas, it is clear that pre-existing circumstances (political, religious, socio-economic, etc) mean that there are *potential* conflicts in many places around the world, and that it may only need a small change to set them off. In such locations, global heating may act as a *remote* (i.e., underlying) causal force behind increased socio-political destabilization. As such, it may often remain unnoticed—compared to more proximate considerations which tend to receive greater attention. Moreover, especially in the interconnected modern world, the links between climate change and societal disruption are likely to be extremely complex.[16] For instance, it has been argued that socio-political disruption in the Middle East around the year 2011 was influenced by unusual climate events in places as far distant as Australia and China (Sternberg, 2013).

Finally, while mortality and migration receive most attention in relation to future demographic developments, history strongly suggests that the fertility response to global heating will probably be *at least* as significant. In this context, there is already evidence that 'climate anxiety' is influencing attitudes towards childbearing among potential parents in low fertility populations. This anxiety reflects people's concern about the state of the world in which any child will grow up and have to live. But it also reflects people's concern about the environmental damage that a child is likely to contribute during the course of his or her lifetime (e.g., see Schneider-Mayerson and Ling, 2020; Arnocky et al., 2012). Beyond these issues, lower fertility—compared to what would otherwise prevail—is likely to result from intensified levels of socio-economic and other forms of stress. And it can also be expected to result from conditions of upheaval and conflict.

Discussion

It is difficult to look at the geophysical trends and see anything but troubled times ahead for humankind. There is considerable uncertainty, of course. And many politicians, in particular, will

[16] Interconnectedness and specialization, so often portrayed as strengths, can also be sources of weakness. Relatedly, 'just in time' supply procedures and low stock levels are also potential sources of vulnerability.

continue to claim that their governments are 'on track' to reduce CO_2 and other GHG emissions at the required speed. However, the view taken here is that stated succinctly by Clive Ponting (2007: 408), namely that 'the underlying economic and social forces that have dominated the world in the last two hundred years are simply too strong to be altered in the decisive way that would be needed to make the sort of reductions in carbon dioxide output that climate scientists regard as essential if catastrophe is to be avoided'. Accordingly, the likely general implications of the current reality must be faced, including in the field of demography.

In this context, it must be admitted that history provides no direct portents for contemplating the demographic future—other than that changes in climate have undoubtedly had profound implications for population trends in the past. For example, the warming that ended the last glacial period laid the basis for the rise of agriculture and the occurrence of what is often termed the 'first demographic transition' (e.g., see Coale, 1974; Bocqet-Appel, 2011). Also, there are reasons to think that global temperature fluctuations do much to explain the striking synchronicity of population trends which has prevailed at either end of the Eurasian land mass for most of recorded history (e.g., see McEvedy and Jones, 1978; Galloway, 1986). Again, the occurrence of an extremely cold period in the mid-seventeenth century, linked to low sunspot activity, appears to have led to the demise of a substantial fraction of humankind (Parker, 2013: xxvii). Other illustrations can be provided.[17] But in most cases they relate to fairly small changes in temperature in which colder periods were more difficult and warmer periods were more benign. In short, when thinking about the effects of, say, a 3-4°C temperature *rise* by the end of the present century, we are entering largely uncharted terrain.

Hitherto demographers have chiefly been concerned with assessing the contribution of various forms of population change to increases in CO_2 emissions. As noted, population growth has emerged as the principal factor here, with compositional changes, like ageing and urbanization, being very much secondary. Inevitably, consideration of the role that global heating may play in the demographic future has been limited and somewhat speculative. However, one area of relevant research has involved identifying groups who might be forced to migrate—such as 'climate change refugees' from small low-lying island states (e.g., see Wyett, 2014; Thomas and Benjamin, 2018). On a wider canvas, the Stern Review (2007) suggested that by 2050 at least 200 million people might be permanently displaced by a mixture of rising sea levels, increased flooding, and greater desertification. Similarly, the World Health Organization (2018) considers that between 2030 and 2050 there may be an extra 250,000 excess deaths each year due to climate-related increases in malnutrition, malaria, diarrhoea, and heat stress. That said, if the world's temperature gets hotter along the lines that have been discussed in this paper, then such notional numbers are likely to be very much on the low side for the period beyond 2050. It is notable

[17] Of course, cases of demographic decline are often the outcome of other kinds of environmental over-extension (e.g., see, Ponting, 1991; Diamond, 2006).

too that research which tries to relate impending temperature increases to prospective numbers of deaths is almost always based on the assumption of a smooth temperature trajectory into the future. However, there are many ways in which global heating may entail major *discontinuities*—societal as well as geophysical.[18] Indeed, 'climate chaos' rather than the bland term 'climate change' may well turn out to be a more objective phrase for future events.[19]

Turning to population projections, the subject of global heating and climate change has received surprisingly little attention. For example, a series of essays written by demographers to accompany publication of the UN's long-range population projections out to the year 2300 makes almost no mention of the subject (United Nations, 2004). The same applies for the regular UN biennial population projections out to the year 2100 which, besides including occasional general references to climate change, make no mention of global warming (e.g., see United Nations, 2019, 2020, 2022b). Using a probabilistic approach, recent UN population projections mostly incorporate a 'normal' mortality variant trajectory which, among other things, reflects the '*historical* variability of changes' (United Nations, 2019 (emphasis added)). However, a major difficulty with this approach is that, almost certainly, historical trends are going to constitute an increasingly weak basis for the formulation of assumptions about future mortality (and fertility). Any incorporation of the effects of global heating on future population trends can probably only be illustrative, but at the very least such effects deserve more discussion. That said, one suggestion might be to combine a (new) high mortality variant with a low fertility variant within the UN's regular population projections.[20] A welcome move here is provided by the illustrative projections of KC and Lutz (2014). In the most extreme case, their projections incorporate a massive disaster (during 2025-30) in which 10 percent of the entire human population dies. But because it is a one-off calamity, afterwards an essentially normal population growth trajectory is resumed. On the present view, however, a case can be made for illustrative aggregate projections which incorporate *recurrent* adverse events.[21]

The UN's current medium variant projection is that between 2020 and 2050 the world's population will grow by nearly two billion people—with the addition of several hundred million more people projected for 2050-2100. However, in 2050 the world's population will only be growing at around 0.5 percent per year. Indeed, apart from sub-Saharan Africa, all world regions are projected to be experiencing growth that is either negative or near-zero in 2050. Accordingly, for most of humanity,

---

[18] Geophysical possibilities here include accelerated ice sheet melting, large-scale methane release, and a collapse of the thermohaline circulation system in the world's oceans.
[19] Use of the term 'climate change' may itself be considered a form of avoidance in that arguably the word 'change' is overly neutral.
[20] Whereas for fertility there are high and low variants, for mortality there are usually only the normal and constant variants.
[21] For a simple example of such a projection, albeit unrelated to global heating and in circumstances of relatively high potential population growth, see Cassen and Dyson (1976: 126-28). The criticisms of the UN projections made in this paragraph also largely apply to alternative population projections for the world and its countries (e.g., see Vollset et al., 2020; Lutz et al., 2018).

relative to the projection, it will only take a small additional fall in the birth rate, and/or rise in the death rate, to bring about—or in some regions amplify—circumstances of population decline. Indeed, by 2050 even sub-Saharan Africa's population may be significantly smaller than is currently projected.

In sum, if global heating continues at its current accelerating pace, the world's population may start to decline significantly earlier—and faster—than is currently envisaged. In this context, the heightened uncertainty brought about by the fact of global heating deserves *much* more discussion by those who make population projections. Otherwise, they run the risk of, to borrow the palaeontologist Richard Fortey's words, exemplifying the 'kind of optimism built into our species that seems to prefer to live in the comfortable present rather than confront the possibility of destruction' (see Parker, 2013: xv).

In conclusion, the global demographic transition occurred over a period of roughly 250 years—from the late eighteenth century to (it seems likely) the second half of the twenty-first century. During this time the world's population will have grown by roughly a factor of ten. This growth in human numbers has contributed significantly, if remotely, to global heating; and the fact of *past* population growth continues to have a lasting influence through the unprecedented size of the *current* world population. Looking ahead, population growth in itself is set to have a fast-diminishing influence on global heating. But given recent accelerating geophysical trends, a reverse influence—i.e., from heating to human numbers—now looks highly likely.

Acknowledgement

This paper has benefitted from discussions with Kevin Anderson, Stan Becker, and Chris Rapley. The usual disclaimer applies.

References

Anderson, K., 2015, 'Talks in the city of light generate more heat'. Nature 528 (437).

Anderson, K. and A. Bows, 2011, 'Beyond 'dangerous' climate change: Emission scenarios for a new world'. Philosophical Transactions of the Royal Society, A 369(1934): 20-44.

Anderson, K., Broderick, J. F. and J. Stoddard, 2020, 'A factor of two: How the mitigation plans of 'climate progressive' nations fall far short of Paris-compliant pathways'. Climate Policy 20(10): 1290-1304.

Arnocky, S., Dupuis, D., and M. L. Stoink, 2012, 'Environmental concern and fertility intentions among Canadian university students'. Population and Environment 34(2): 279-92.

Bhargava, A., 2021, 'Econometric modelling of carbon dioxide emissions and concentrations, ambient temperatures and ocean deoxygenation'. Journal of the Royal Statistical Society, Series A DOI: 10.1111/rssa.12732.

Bocquet-Appel, J-P., 2011, 'When the world's population took off: The springboard of the neolithic demographic transition'. Science 333(6042): 560-61.

Bolt, J. and J. L. van Zanden, 2020, 'Maddison style estimates of the evolution of the world economy. A new 2020 update'. https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2020.

Bongaarts, J., 1992, 'Population growth and global warming'. Population and Development Review 18(2): 299-319.

British Petroleum, 2020, Statistical Review of World Energy 2020. London: British Petroleum.

Cassen, R. and T. Dyson, 1976, 'New population projections for India'. Population and Development Review 2(1): 101-36.

Climate Action Tracker (2021). https://climateactiontracker.org/.

Coale, A. J., 1974, 'The history of the human population'. Scientific American 231(3): 40-51.

Cohen, J., 2010, 'Population and climate change'. Proceedings of the American Philosophical Society 154(2): 158-82.

Diamond, J., 2006, Collapse. London: Penguin Books.

Dlugokencky, E., 2021a, 'Trends in atmospheric methane'. National Oceanic and Atmospheric Administration/Earth System Research Laboratories (www.esrl.noaa.gov/ccgg/trends_ch4/).

Dlugokencky, E., 2021b, 'Trends in atmospheric nitrous oxide'. National Oceanic and Atmospheric Administration/Earth System Research Laboratories (www.esrl.noaa.gov/gmd/ccgg/trends_n2o/).

Dyson, T., 2005, 'On development, demography and climate change'. Population and Environment 27(2): 117-49. For the IUSSP conference version, see https://iussp2005.princeton.edu/sessions/6.

Galloway, P., 1986, 'Long-term fluctuations in climate and population in the preindustrial era'. Population and Development Review 12(1): 1-24.

Gatti, L.V., Basso, L.S., Miller, J.B. et al., 2021, 'Amazonia as a carbon source linked to deforestation and climate change'. Nature 595: 388-93. https://doi.org/10.1038/s41586-021-03629-6.

Gilding, P., 2019, Climate Emergency Defined. Melbourne: National Centre for Climate Restoration.

GISTEMP Team, 2021, GISS Surface Temperature Analysis (GISTEMP), v4. NASA Goddard Institute for Space Studies. https://data.giss.nasa.gov/gistemp/.

Hansen, J. and M. Sato, 2020, 'Accelerated global warming'. http://www.columbia.edu/~jeh1/mailings/2020/20201214_GlobalWarmingAcceleration.pdf.

Harthan, H. and A. Lindley, 2021, Greenhouse Gas Removal Briefing Paper 1. Cambridge: Centre for Climate Repair at Cambridge University.

IPCC, 2018, Special Report: Global Warming of 1.5°C. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/sr15/.

IPCC, 2021, Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution to the Sixth Assessment Report. Intergovernmental Panel on Climate Change. Version subject to final copy-editing available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

KC, S. and W. Lutz, 2014, 'Alternative scenarios in the context of sustainable development', in W. Lutz, W. P. Butz and S. KC (eds.) World Population and Human Capital in the Twenty-first Century. Oxford: Oxford University Press.

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R. and Y. Kushnir, 2015, 'Climate change in the fertile crescent and implications of the recent Syrian drought'. Proceedings of the National Academy of Sciences 112(11): 3241-46.

Lomborg, B., 2020, False Alarm. New York: Basic Books.

Lutz, W., Goujon, A., KC, S., Stonawski, M., and N. Stilianakis (eds.), 2018, Demographic and Human Capital Scenarios for the 21st Century: 2018 Assessment for 201 Countries. Luxembourg: Publications Office of the European Union.

McEvedy, C. and R. Jones,1978, Atlas of World Population History. Harmondsworth: Penguin Books.

Morice, C., Kennedy, J., Rayner, N., and P. D. Jones, 2020, 'Temperature data, HadCRUT4'. https://crudata.uea.ac.uk/cru/data/temperature/.

National Research Council, 1979, Carbon Dioxide and Climate. Washington, DC: National Academies Press.

Our World in Data, 2021, 'CO2 and greenhouse gas emissions'. https://ourworldindata.org/.

Parker, G., 2013, Global Crisis—War, Climate Change and Catastrophe in the Seventeenth Century. London: Yale University Press.

Ponting C., 1991, A Green History of the World. London: Sinclair-Stevenson.

Ponting C., 2007, A New Green History of the World. London: Vintage Books.

Romanello, M., Di Napoli, C., Drummond, P., Green, C., Kennard, H., P. Lampard, et. al., 2022, 'The 2022 report of the Lancet Countdown on health and climate change: Health at the mercy of fossil fuels'. Lancet. https://doi.org/10.1016/S0140-6736(22)01540-9

Schneider-Mayerson M. and L. K. Ling, 2020, 'Eco-reproductive concerns in the age of climate change'. Climatic Change 163(2): 1007-23.

Selby, J., Dahi, O. S., Fröhlich C. and M. Hulme, 2017, 'Climate change and the Syrian civil war revisited', Political Geography 60(September): 232-44.

Sherwood, S., Webb, M. J., et al., 2020, 'An assessment of Earth's climate sensitivity using multiple lines of evidence'. Review of Geophysics. (https://doi.org/10.1029/2019RG000678).

Steffen, W., Rockström, J., Richardson K., et al., 2018, 'Trajectories of the Earth System in the Anthropocene'. Proceedings of the National Academy of Sciences 115(33): 8252-59.

Stern, N., 2007, The Economics of Climate Change, The Stern Review. Cambridge: Cambridge University Press.

Sternberg, T., 2013, 'Chinese drought, wheat and the Egyptian uprising: How a localized hazard became globalized', in C. E. Werrell and F. Femia (eds.) The Arab Spring and Climate Change: A Climate and Security Correlations Series. Washington D.C.: Center for American Progress.

Tans, P. and R. Keeling, 2021, 'Trends in atmospheric carbon dioxide'. https://www.esrl.noaa.gov/gmd/ccgg/trends/global.html.

Thomas, A. and L. Benjamin, 2018, 'Policies and mechanisms to address climate-induced migration and displacement in Pacific and Caribbean small island developing states'. International Journal of Climate Change Strategies and Management 10(1): 86-104.

United Nations, 2004, World Population to 2300. New York: United Nations Population Division.

United Nations, 2019, World Population Prospects 2019. New York: United Nations Population Division, custom data acquired via website. https://population.un.org/wpp.

United Nations, 2020, Report of the United Nations expert group meeting on methods for World Population Prospects 2021 and beyond. New York: United Nations Population Division.

United Nations, 2021, 'Call for 'decisive action now' to avoid climate catastrophe'. https://news.un.org/en/story/2021/09/1100382.

United Nations, 2022a, 'World headed for climate catastrophe without urgent action'. https://www.unep.org/news-and-stories/story/world-headed-climate-catastrophe-without-urgent-action-un-secretary-general

United Nations, 2022b, World Population Prospects 2022: Summary of Results. New York: United Nations Population Division.

Vollset, S. E., Goren, E., Yuan, C., Cao, J., Smith, A. E., Hsiao, T., et al., 2020, 'Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: A forecasting analysis for the Global Burden of Disease Study'. Lancet 396 (10258): 1285-1306.

Wallace-Wells, D., 2019, The Uninhabitable Earth: A Story of the Future. London: Allen Lane.

World Health Organization, 2018, Climate Change and Health. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

World Meteorological Organization, 2020, 'WMO confirms 2019 as second hottest year on record'. https://public.wmo.int/en/media/press-release/wmo-confirms-2019-second-hottest-year-record.

Wyett, K., 2014, 'Escaping a rising tide: Sea level rise and migration in Kiribati'. Asia and the Pacific Policy Studies 1(1): 171-85.