Easing population to 4 billion by 2200 would help people and nature

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Abstract

The past century of increases in human population and resource consumption has produced some undesirable effects, ranging from environmental degradation to climate change to political unrest. We are accustomed to seeing these dependent variables charted with time on the x-axis. But this study presents metrics of biodiversity, consumption, and pollution and their extremely strong correlations when charted against human population size. Then we suggest that a more rapid yet non-coercive lowering of global Total Fertility Rates to 1.75 by 2050, and holding there, will produce many benefits for current and future generations of our own species and for nature. Among these benefits are reduced CO2 emissions, habitat recovery, protection of wild species, and reduced conflict over scarce resources.

Introduction

As we know, high levels of human population and consumption multiply together to produce total consumption of resources and the side effects of the consumption. This study investigates to what degree global human population levels correlate, since 1970, with 8 metrics for biodiversity, resource consumption, and pollution.

Then using the power functions from this past half century of data, we make projections toward the year 2200, premised on continued non-coercive reduction of global fertility rates to below replacement level.

This intentionally simple, global view can stimulate dialog, focus research, and motivate optimism toward the better future which is within our grasp.

We are all familiar with the curve of human population growth in the past century, with decades on the x-axis, population on the y-axis. In the past 50 years, especially, many have pointed out the undesirable effects stemming from increases in human population and resource consumption [1]. This paper looks at 8 of those effects, but in a novel way. It charts the global levels of each metric, but with population on the x-axis.

Results

Population and wildlife

There is an extremely strong correlation (Fig 1) between global human population increase and decline of wildlife populations as measured by the Living Planet Index [2]. Declines vary by species and region, but the main causes are habitat loss and then overexploitation [3]. Both arise from human population levels and then consumption. One reads of giraffe populations down 40% in 30 years. Ninety percent of blue whales lost in a century. All 3 species of orangutan critically endangered -- and the list goes on [3].

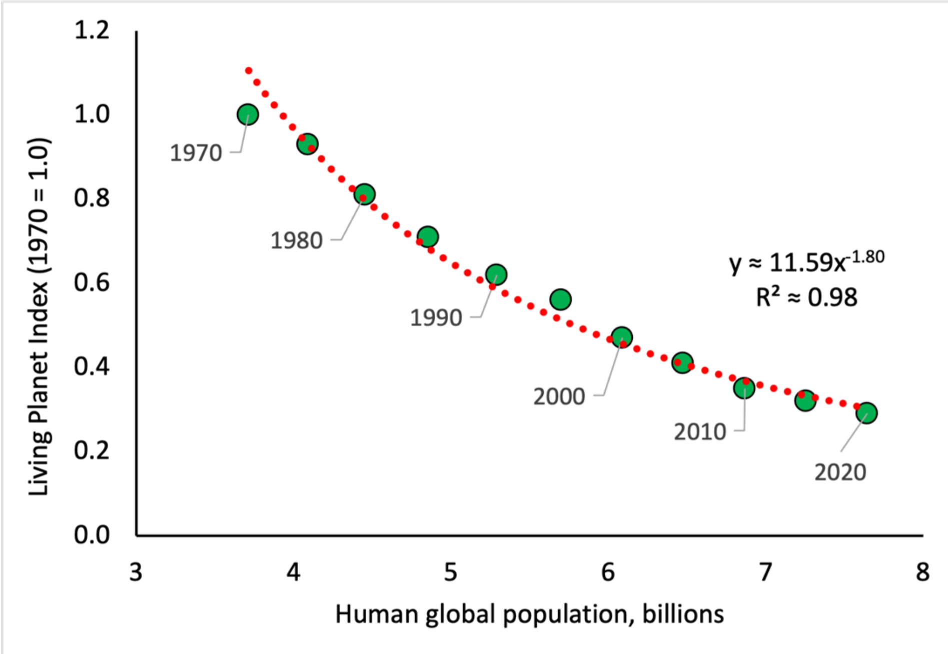


Fig. 1. Global human population and Living Planet Index 1970 to 2020. The LPI is a long-standing metric of abundance of over 5000 species of mammals, birds, fish, amphibians, reptiles [2]. 1970 abundance is indexed as 1.0. Population data is from the United Nations Population Division [4].

Population and CO2 emissions

The population-and-CO2-emission trend is also extremely strong (Fig 2). True, we are slowly shifting away from fossil fuel energies and doing better at energy conservation. But the population-and-consumption juggernaut prevails. And CO2 is only one of many forms of pollution.

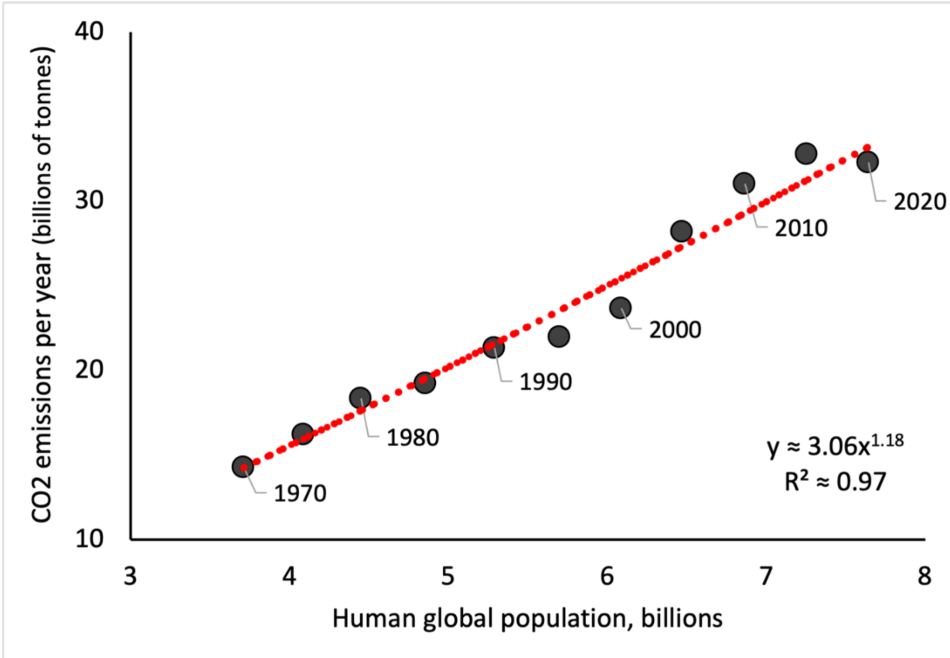


Fig. 2. Global human population [4] and CO2 emissions [5] 1970 to 2020.

For CO2 emissions, billions of tonnes are equivalent to gigatons.

Population and energy consumption

All forms of resource consumption involve energy. And so, we see a near-perfect correlation between population and energy consumption (Fig 3). In some ways we may be using energy more efficiently and moderating per capita consumption. But these measures are offset to some degree by the laudable achievement of people emerging from poverty.

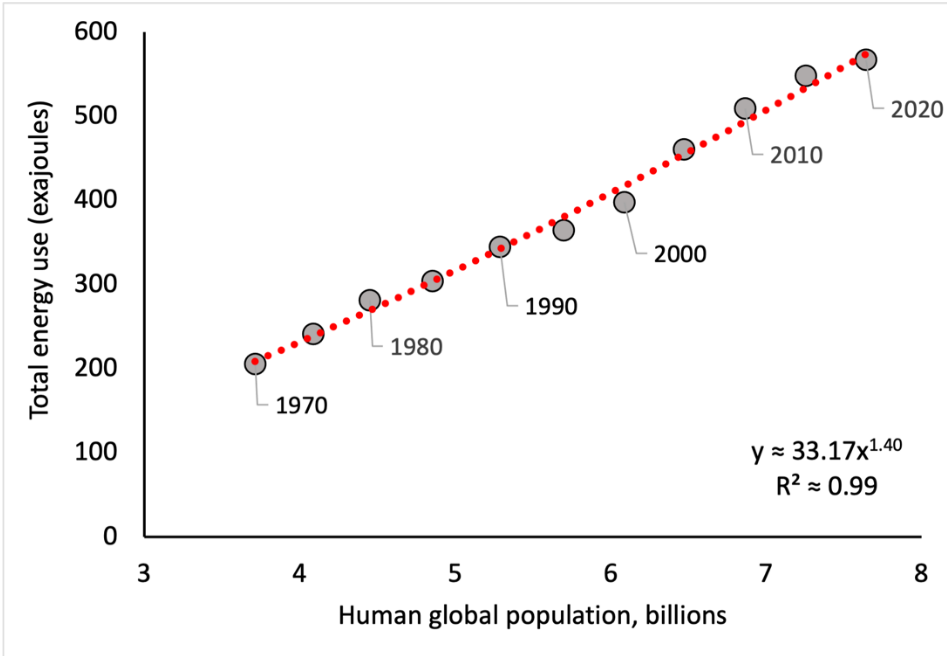


Fig. 3. Global human population and total energy consumption 1970 to 2020. [4,5]

Population and ecological footprint

The Ecological Footprint [6] incorporates resource use both land and sea, and it has increased with increasing population (Fig 4). Ecological footprint counts cropland, forest use, area for absorbing anthropogenic CO2 emissions, grazing land, marine and inland waters for providing human food, and built-up land of human infrastructure. Even without the metric, comparing photographs of a half-century ago and the present, one sees the trend.

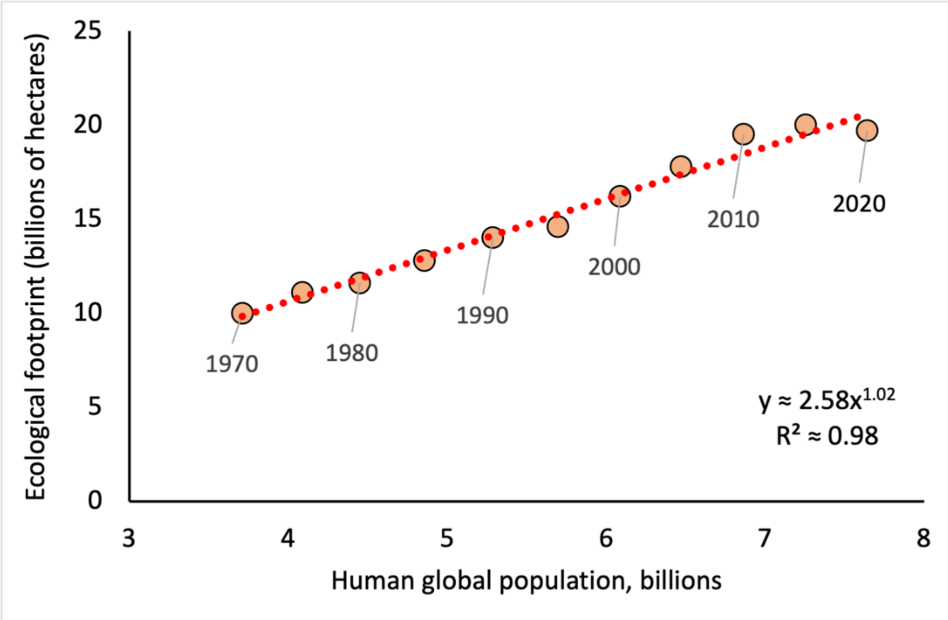


Fig. 4. Global human population [4] and ecological footprint [6] 1970 to 2020.

Population and freshwater

As with other resources, river flows and groundwater from rainfall are finite. So, freshwater per capita has declined as population has increased (Fig 5).

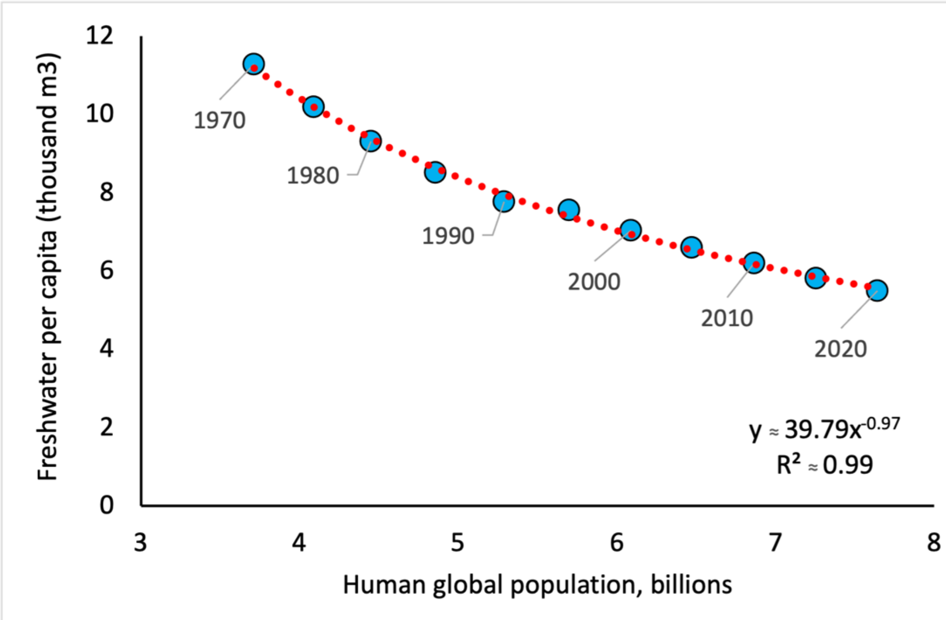
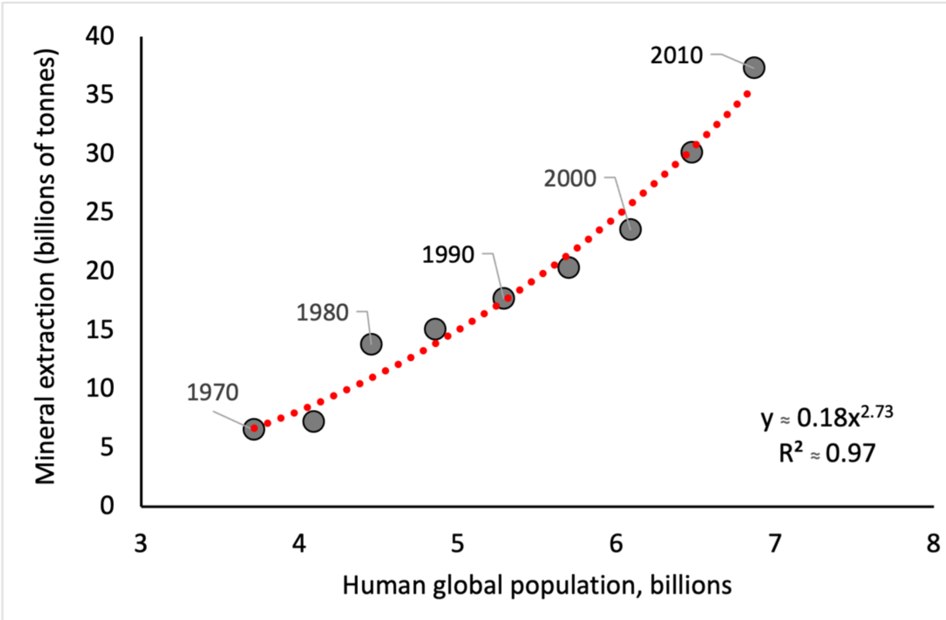


Fig. 5. Global human population [4] and internal freshwater resources per capita [7] 1970 to 2020.

Population and mineral extraction

The correlation between population growth and mineral extraction is strong despite the ups-and-downs of world mineral prices and production incentives. (In Fig 6, note the 'boom' of the 1980 data point, and the 'slump' of 2000). As population increases, demand for minerals increases for construction of material infrastructure and durable goods.

92 

93 **Fig. 6. Global human population [4] and mineral extraction [8] 1970 to 2010.**
94 Mineral extraction data combines tonnage of metal ores and non-metallic
95 minerals.

96 **Population and plastics production**

97 Large-scale production and use of plastics began around 1950 [9]. But
98 plastics production, and the waste much of it becomes, have risen apace with
99 population (Fig 7).

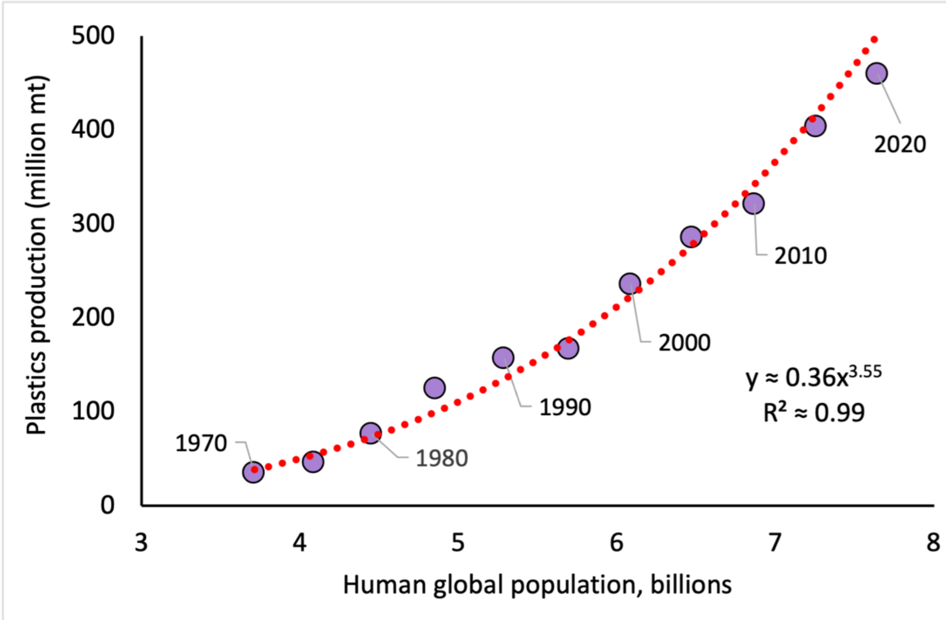


Fig. 7. Global human population [4] and plastics production [9,10] 1970 to 2020.

Population and pesticide use

Here too, efforts to reduce consumption are mostly offset by increased consumption elsewhere, and so pesticide use rises with population increase (Fig 8).

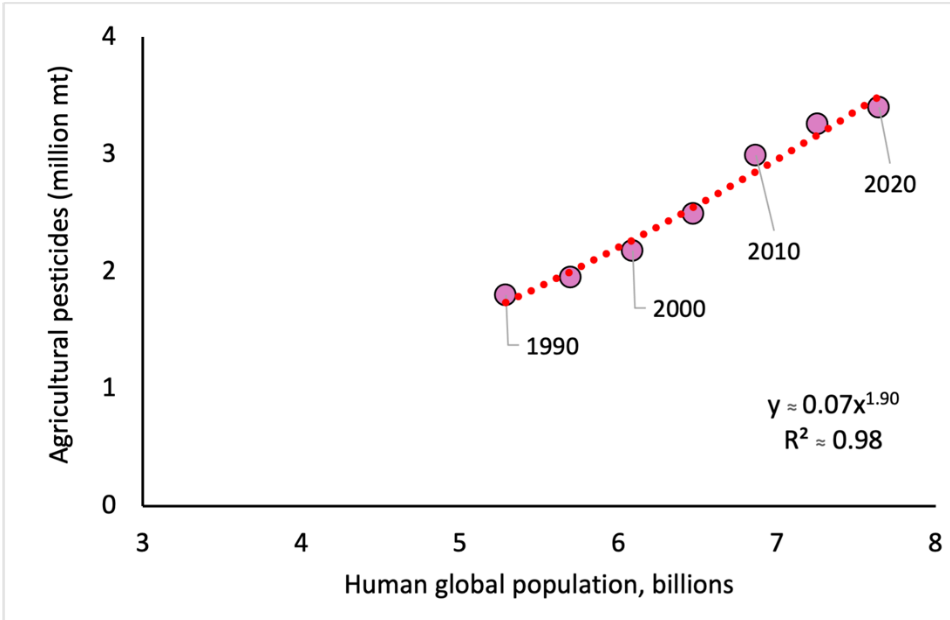


Fig. 8. Global human population [4] and pesticides use [11] 1990 to 2020.
Reliable pre-1990 pesticide data was not available.

Discussion

The greater the population, the more total energy consumption, CO2 emissions, loss of natural habitat and biodiversity, diminished fresh water per capita, increased mineral extraction, increased production and pollution by plastics and pesticides. This is not an anti-human statement, but a plain fact.

Technological, social, cultural, and economic factors have nudged each of these trends slightly upwards or downwards, year by year, region by region. We see hopeful signs, even, with recent downward deflections of CO2 emissions and of ecological footprint (see the 2020 dots in Figs 2 and 4). Families and nations who have lowered their fertility rates generally find increased prosperity [4,12].

Still, the power of population and overall resource consumption shapes the trends seen here, and other trends not charted for space reasons. For example, there has been a recent huge increase in lithium extraction to supply the non-fossil fuel energy industry [5]. Water pollution has been curtailed in many areas but is on the rise, globally [13]. The numbers of armed conflicts also correlate somewhat strongly with population growth [14], and nearly half of these conflicts are linked to resource scarcities [15].

A better path for the next two centuries

We hear talk of intergenerational equity. What kind of world do we want for the children of the future? Most people would opt for a world free of resource conflicts and poverty, a world of thriving nature and pleasant climate. We mean well, for the most part. But as seen by the trends here our efforts are not urgent enough. Consider where the arcs of these metrics will go if we faintly hope for population to settle at over 11 billion after the year 2100.

Suppose instead we were to achieve a zero then negative population change rate much sooner. Suppose starting with the projected 9.7 billion by 2050 [4], we moderated to a minus 0.6% annual rate. The UN low projection does not reach -0.6% until 2130. But achieving the minus 0.6% in 2050 and maintaining it would ease the global human population back to where it once was, just under 4 billion, by the year 2200. Is there evidence we could achieve this?

Recent history suggests the answer is Yes. The global population growth rate was 1.25% in 2012 and 0.82% in 2021 [4]. That's a 0.43% decrease in 9 years. At that rate, it would take 30 years to go from positive 0.82% to minus 0.60%. The later part of the transition might (or might not) be more difficult than the earlier part. But with more attention to the benefits of smaller family sizes and continued progress on meeting unmet contraceptive needs the projection might be achieved. We are already slowly progressing toward a sub-replacement rate by the sum of billions of individuals' choices, but we would do well to hasten the progress.

Then, with global population gently returning to its 1970 level, we should see the other metrics changing accordingly, by a reversal of the power functions they each displayed 1970 to 2020. Fig 9 suggests the recovery we might see with the Living Planet Index, and the moderation of energy consumption and CO2 emissions. We could chart the other metrics, and they would progress similarly toward a more moderate ecological footprint, water consumption, mineral extraction, and so on.

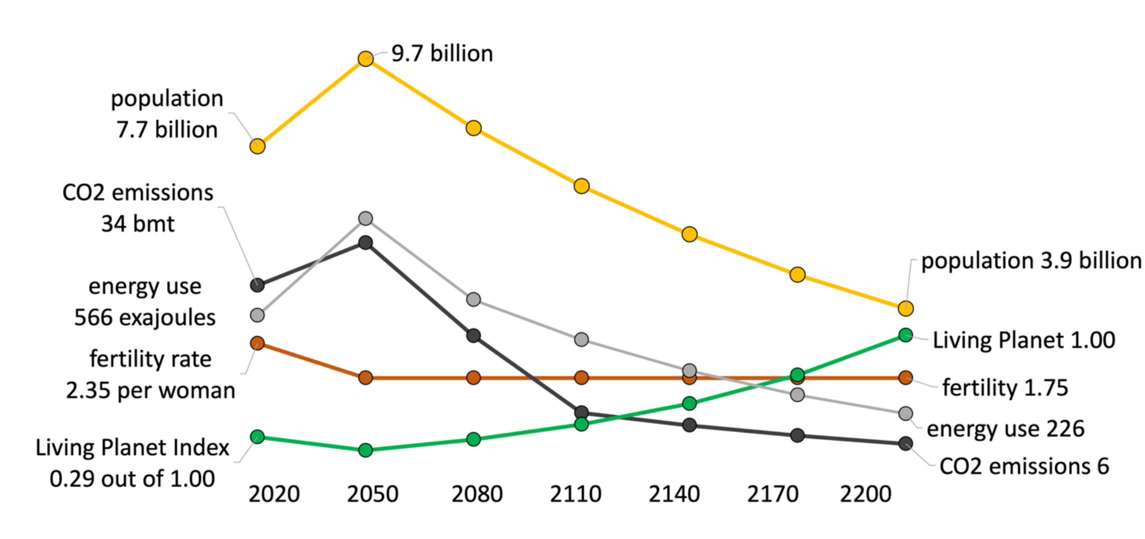


Fig. 9. Projections 2020 to 2200 if global fertility rate of 1.75 is achieved by 2050. The UN population projection for 2050 is charted (9.7 billion). Then for 2050 to 2200 population is projected at a -0.6% change per year, achievable by a global TFR of 1.75 [16]. Units are children per woman. For CO2, units are billion metric tonnes.

Answering four questions

For types of questions have been raised about this hopeful projection.

"But haven't we have long known these metrics have increased, and also known population has increased?" Yes. But though all this data is publicly available, it appears in a new light when population is cast as the independent variable.

"But isn't it impossible to predict global fertility rates exactly?" Yes, and the longer the time horizon, the more uncertainty. But this paper does not say what the fertility rates will be, but rather, what might be the benefits be if TFR were to drop below replacement level and stay there.

"But might it be that population decline fails to reverse these trends?" If one were to argue that a gentle easing to more moderate population levels would not reverse these trends, one must also propose mechanisms thwarting the reversal. But such mechanisms defy logic and experience. For example, 'As population gradually shrinks, everyone begins consuming more energy per capita' or 'polluting more per capita'. To the contrary, the metrics might reverse even faster than predicted here. For example, working in favor of biodiversity is improved knowledge, effort, and protection of habitat and wildlife, compared to 1970. Far more effort is being devoted to energy conservation and reduction of CO_2 emissions. More attention is being given to reducing plastic pollution and pesticides, and so on.

"But how to maintain sub-replacement fertility rates? By legislation? Policy? Education?" As we have seen since the mid-1960s [4], fertility rates have declined and, in general, the decline has not depended on legislation nor even policy. Instead, it has been increased educational and economic opportunities for women, decreased social pressure to bear children early and often, and increased contraceptive availability and use.

How to get on the better path

When women are free to decide whether or not to have children, or when, or how many, fertility rates tend to fall toward replacement level or below. (See for example a 2022 meta-analysis of 508 studies worldwide [17].) Europe achieved a TFR below 1.75 in 1990 and has settled to below 1.50 since then. In 2020, North America reduced its TFR to 1.63. Latin America and the Caribbean was 1.89, on track for a TFR of 1.75 by 2030. Asia reduced to 1.98 in 2020 and its TFR continues to decline slowly.

Fertility rates can decline by half and without coercion, and to below replacement level. Iran needed only 9 years to accomplish it (4.08 in 1992 to 1.94 in 2001). South Korea, 12 years (4.07 in 1972, 1.93 in 1984). Tunisia, 15 years (4.10 in 1987, 1.97 in 2002). Others took longer: Bangladesh, 28 years (3.85 in 1993, 1.98 in 2021), and Costa Rica, 37 years. (4.16 in 1972, 1.98 in 2009). But some dropped below TFR 1.75 years ago. To list just a few of dozens [4], we see the USA in 1976, Canada in 1980. Hungary 1983, Norway 1987; Barbados 1990. Thailand 1999. Australia 2001. Brazil in 2013. We see also that once fertility declines to these levels, it tends to stay there with only minor oscillations.

But Africa averaged 4.2 children per woman as of 2022. Its population growth of 2.37% per year forecasts a doubling in 30 years. Though progress has been made (TFR was 5.2 in 2000), more and quicker progress would be welcomed. More and better health infrastructure and education are essential to achieve this, and self-interest can motivate families as well as nations. As other world regions have proven, moderate fertility is essential to poverty reduction [18]. Families have more income per child, and infrastructure can catch up to demand.

Besides population levels, the other driver of the trends shown here is per capita consumption. As we've remarked, this will tend to increase for those emerging from poverty. But offsetting this, perhaps, are the many in the affluent countries realizing they are happier with moderate rather than extravagant levels of consumption [19].

Conclusion

This report hopes to increase our attention to population levels, the future, and to stimulate discussion of the opportunity available but to which we are only slowly progressing.

Population and per capita consumption multiply together to produce their impacts. Some may feel the effort should be mostly or entirely on reducing per capita consumption. Some progress can be made, but a significant share of resource consumption is to fulfill needs for food, clothing, shelter, transportation, education, health care, and other infrastructure. By contrast, though procreation is sometimes spoken of as a need, choosing to limit oneself to one or two children per woman does not infringe on that need.

Ending and gently reversing human population growth will ease pressure on natural resources, help lessen poverty, reduce pollution, possibly reduce resource and immigration conflicts, improve quality of life in densely populated areas. A more modest population will better protect earth's natural heritage, including its wild habitats, wild species, and its climate. This is at once a most pro-nature and pro-human strategy. It is within our grasp if we only realize it.

Materials and Methods

The Eight Metrics, 1970 to 2020

These were easily plotted using data from the references cited, with the x-axis as global population.

Population Projection to 2200

To project population, we need a formula for its slow but exponential change. The Australian Mathematical Sciences Institute [20] provides a nice explanation of a calculus-derived formula using the natural logarithm (thus the "2.7128" below). The population equation can be expressed as:

$$\text{population after t years} = \text{initial population} * 2.7128^{(\text{growth rate}*\text{t})}$$

Our projection assumes we can keep child mortality low and life expectancy high, as they are at present.

To determine the growth rate exponent which would ease population down to 4 billion by 2200, we consult a fertility-rate-and-population calculator [16]. We set starting population, child mortality, and life expectancy as projected for 2050. We set a flat demographic pyramid because by 2050 a declining TFR will have been near replacement level for some years. Then, testing various TFR, we find 1.75 children per woman would achieve the minus 0.6% annual rate of change.

Living Planet Index Projection to 2200

As population plateaus and then declines, habitat recovery should exceed habitat loss. Overexploitation of species and inanimate resources should decrease. To project this scenario, we can apply the formula derived from the population-and-Living-Planet-Index power function in Fig 1. We need caution, though. This time, when population is at 7 or 6 or 5 billion, the average per capita consumption rate might be higher than it was a half-century ago. A greater proportion of humanity should have emerged from poverty. But offsetting this might be a moderation of consumption by the more affluent, combined with more attention to habitat conservation. So, with an 'approximately equals' sign:

$$\text{Living Planet Index projection} \approx 11.59 * \text{population}^{-1.80}$$

CO2 Emissions Projection to 2200

The future of CO2 emissions depends on the degree of economic growth and the transition to non-fossil fuel energies. So, we first make a base projection using the power function formula from Fig 2:

$$\text{global } CO_2 \text{ emissions, billions of tonnes} \approx 3.06 * \text{population}^{1.18}$$

Then, beginning with a CO_2 emissions projection for 2050, we decrease the projected emissions by 1% per year [21] from 2050 to 2110, letting fossil fuels settle at 40% of the energy mix. This is a conservative projection, not forecasting a stronger phase out or a "global net zero emissions economy". It is in line with the least idealistic of the three projections to 2100 made by the Shell oil company [22].

Total Energy Use Projection to 2200

For global total energy use in 2050, we use a projection of 902 exajoules [21]. Beyond 2050 we then apply the population-and-energy-consumption power function shown by the Fig 3 data:

$$\text{global total energy consumption, exajoules} \approx 33.17 * \text{population}^{1.40}$$

Again, the total could decline faster than population declines if, among the affluent, energy is used more efficiently or if per capita consumption declines. Then again perhaps not, depending on what level of affluence is attained by people still emerging from poverty.

Running these formulas and charting the results, we produce Fig 9. For the other metrics charted in this study (Figs 4 through 8), similar methods could be used, employing the particular power functions each metric exhibited 1970 to 2020.

Acknowledgments

The author would like to thank 4 colleagues who reviewed the manuscript.

- Dee Boersma, Professor and Director of the Center for Ecosystem Sentinels at the University of Washington
- Ana M. Fonseca, Associate Professor in the Energy, Environment, and Health Research Unit, Universidade Fernando Pessoa, Portugal
- Natin Guzmán Arce, Profesor II B de la Universidad Nacional de Costa Rica
- Peter Matanle, Professor of East Asian Studies, University of Sheffield, U.K.

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