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How Many People Can the Earth Support?[1]

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Two thousand years ago, the Earth probably had 100-300 million people. The human population reached one billion in 1800-1830, and seven and a half billion in 2017. Adding the latest billion took 12-13 years. Another billion people are expected in the next 12 years.

Though the number of people more than doubled from about 3.7 billion in 1970 to 7.5 billion in 2017, experts dispute whether the number of people will ever double again to 15 billion. Nevertheless, the population of Africa, the continent with by far the lowest income per person and by far the fastest rate of population growth, will nearly quadruple between 2015 and 2100, according to the United Nations' 2015 projections.

At current birth rates, a woman has 2.5 children during her lifetime on average worldwide, still above the 2.1 children per woman that would stabilize population size in the long term. The population would double in 59 years if it continued to grow at its present rate of increase of nearly 1.2 percent per year, but a constant growth rate seems very unlikely. It is much more likely that the average number of children per woman and the population growth rate will continue to fall as they have over the past half century.

1. This paper was first published in French translation as "La capacité humaine de la Terre", Revue Projet n°359, été 2017.

Despite rapid population growth, average human well-being has improved. For the world, life expectancy at birth (or average life length) rose from 46 years in 1950–1955 to 70 years in 2010–2015, by UN estimates. In 2015, Africa's average life length was 60 years and rising, but remained far below Northern America's life expectancy of 79 years.

While the global number and the global fraction of chronically undernourished people fell over recent decades, a global pattern of local hunger persists in parts of Africa, south Asia, and Latin America. The estimated number of chronically undernourished people dropped from 940 million around 1970 to fewer than 800 million in 2017. Among the world's roughly 675 million children under 5 years old, an estimated 156 million (nearly one-quarter) are stunted (short height for age), which is an irreversible, disabling result of chronic malnutrition, and another 50 million are wasted (too thin for height), a result of acute malnutrition or malabsorption.

Widespread chronic and episodic hunger persists despite current annual production of about 2.5 billion tonnes of cereal grains, according to the Food and Agricultural Organisation. These cereals could provide adequate nutritional energy to 10-12 billion people, if everyone had enough income to buy food in world grain markets. However, in 2015–16, only 43% of cereals fed humans; another 36% fed animals to provide meat for people wealthy enough to buy meat; and 21% went to other, mainly industrial uses. Earth could nourish all people well if people chose to end hunger.

Future changes in numbers of children, duration of life, family structure, migration, and urbanization; nutrition, health, and education; economic growth and trade; war and peace; global and regional climates, oceans, and life forms, are uncertain. One source of uncertainty that most demographers overlook is this: Can the Earth support the nearly 4 billion additional people that the UN projects for 2100 (with a 95% range of uncertainty from 2 billion to 6 billion additional)? Can the Earth continue to support the 7.5 billion people it has in 2017, at present or better levels of well-being? How many people can the Earth support?

In 1679 Antoni van Leeuwenhoek estimated not more than 13.4 billion. Since 1679 at least ninety additional estimates were published. These estimates of the Earth's

"human carrying capacity" ranged widely, from less than one billion to more than a billion billion billion. There is neither an increasing nor a decreasing trend in these estimates. The scatter has increased with time, contrary to what one might expect from estimates of a constant of nature. One conclusion is immediate: many of the published answers cannot be nearly right – or there is no single right answer.

That there is no single right answer becomes clear when the methods used to obtain these estimates are examined. One commonly used method assumes that a single factor, usually food, constrains population size. (This assumption is wrong. Population often grows fastest in poor countries with the least food and slowest in wealthy countries with abundant food. This fact does not seem to deter those who assume that food limits population growth.) In this method, an estimate of the maximum possible annual global food production is divided by an estimate of the minimum possible annual food requirement per person to find the maximum possible number of minimal shares that the food supply could be divided into, and this number is taken as the maximum number of people the Earth can support.

The maximum possible food production depends not only on environmental constraints like soil, rainfall, terrain, and the length of the growing season, but also on human choices, individual and collective: which plant and animal species are chosen for cultivation; the technology of cultivation; credit available to farmers; farmer education; infrastructure to produce and transport farm inputs (including irrigation capacity and hybrid seed development); infrastructure to transport, store, and process farm outputs; economic demand for food from other sectors of the economy; and international politics and markets that affect trade inputs and outputs. Culture defines what is food: where a Hindu may see a sacred cow, a non-Hindu American may see a hamburger on hooves. If edibility alone determined what is food, cockroaches would be in great demand.

The minimum food requirement depends not only on physiological requirements (2,000-2,500 kilocalories per person per day, on average for most national populations) but also on cultural and economic standards of what is acceptable and desirable. Not everyone who has a choice will accept a vegetarian diet with no more than the minimum calories and nutrients required for normal growth.

The notion of human carrying capacity is a specious metaphor from wildlife management and animal husbandry, as if humans were a herd of deer, antelopes or cattle – as if humans had no choices of what and how much to consume, of what and how much to produce, by what means and with what consequences.

Earth's capacity to support people is determined both by natural constraints, which some will emphasize, and by human choices, which others will emphasize. Many of these choices are decisions made by billions of people in their daily lives (turn off the light when you leave the room, or leave it on; wash hands before eating, or don't bother; pick up litter in the schoolyard, or add to it). The cumulative results of what may be unconscious individual actions amount to major collective human choices: consume more or less fossil fuel; spread or prevent infectious diseases; degrade or beautify the environment.

Personal and collective choices affect the average level and the distribution of material well-being; technology; political institutions governing individual liberty, change, and conflicts within and between nations; economic arrangements regarding markets, trade, employment, regulation, and non-market consequences of market activities; family size and structure, migration, care of the young and elderly, and other demographic arrangements; physical, chemical, and biological environments (do we want a world of humans and cereals only?); variability or stability; risk or robustness; the time horizon (five years ahead, or fifty, or five hundred); and values, tastes, and fashions.

I emphasize the importance of values. Values determine how parents trade off the number of their children against their children's quality of life; how they balance parents' freedom to reproduce and children's freedom to eat. Many choices that appear to be economic depend heavily on individual and cultural values. Slavery was, but is no longer, an option for economic activity. Should massive chronic and episodic hunger continue to be a permitted outcome of economic systems? Should industrial economies develop renewable energy sources, or should they keep burning fossil fuels and leave the transition to future generations? Should women (and, by symmetry, should men) work outside their homes, leaving the care of children and elderly in the hands of others? How many people the Earth can support depends in part on how many will wear cotton and how many polyester; on how many will eat beef and how many bean sprouts; on how many will want

parks and how many will want parking lots; on how many will want Jaguars (luxury sports cars) with a capital *J* and how many will want jaguars (endangered felines) with a small *j*. These choices change with time and circumstance, and so will how many people the Earth can support.

In the coming century, we, our children, and their children are less likely to face absolute limits than difficult trade-offs among aspects of population (not limited to population size, but including aging, migration, urbanization and family structure) and economic well-being and environmental quality and dearly held values. Foresight and action now might make some of the coming trade-offs easier. This perspective differs from the views of those who say that rapid population growth is no problem at all and those who say that population growth is the only problem. The facts should immunize us against both cornucopians and doomsayers.

What could be done now to facilitate future choices? The "bigger pie" school says develop more technology. The "fewer forks" school says slow or stop population growth and reduce consumption per person. The "better manners" school says improve the terms under which people interact (e.g., by defining property rights to open-access resources such as fisheries and groundwater to prevent uneconomic exploitation, removing economic irrationalities, reducing inequities and organized violence, improving governance). All these approaches have value. None is sufficient by itself. Even in combination, they will not eliminate the need to make choices among competing values.

Lack of certainty about future constraints and choices does not justify lack of action now. When I ride in a car, I put on my seatbelt, though I do not expect to be involved in a crash. We need no projections to identify problems that require action today. Today more than 200 million women of childbearing age who are in sexual unions and who say they do not want more children now lack modern means to control their fertility. As of 2013, about 124 million girls and boys of school age were out of school. Three-quarters of a billion people, more or less, were hungry yesterday, are hungry today, and will be hungry tomorrow. Humans leave their mark on the land, sea, air, and other species with which we share the planet. Yes, life is better for many people today than in the past. But yes, for many people life is more miserable than nature requires.

The real crux of the population question is the quality of people's lives: the ability of people to participate in what it means to be human; to work, play, and die with dignity; and to have some sense that one's own life has meaning and is connected with other people's lives.

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