Human Population Growth☆

Anne Goujon, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/OEAW, WU), World Population Programme/International Institute for Applied Systems Analysis, Austria

Glossary

Demographic transition It depicts the transition of a country or a region from a demographic regime of high birth and death rates to one of low birth and death rates.

Second demographic transition It is the phenomenon that occurs in a country or a region where sustained sub-replacement fertility eventually results in declining population if not compensated by new migrants.

Total fertility Rate The number of live children who would be born per woman if all women lived through their childbearing years bearing children according to a current schedule of age-specific fertility rates.

Under five mortality rate It is the number of deaths of infants and children under five years old per 1000 live births.

Human capital It is a collection of traits representing the capacity of the people to be part of the labor force and to produce economic value. In models, it is often operationalized using the parameters of education, skills and health.

Introduction

The sheer number of population has been for long the main (and only) consideration about human population growth in ecological engineering and in other fields that are reflecting on the sustainability of life systems on earth. The inflation in the availability of data on humans' behavioral patterns depending on the characteristics of these humans and their environment should change that. What is important is not only how many people there are or will be but what they do and will do in their everyday life which could impact life systems and how equipped they are and will be to face the challenges of the future. This gap in understanding has been the reason why most of the doom prognosis were not realized—starting with Malthus' theory about population growth outstripping food production. They failed to predict the capacity of humans to innovate and overcome the challenges they were faced with within the limiting capacities of earth boundaries. However, the challenges exist, and in the coming decades, the survival and well-being of humans and the security of environmental resources that support human existence will continue to be challenged by rapid population growth, particularly in less developed regions that are the main contributors to world population that is, sub-Saharan Africa and Southern Asia. Nevertheless it is clear nowadays that almost all societies that all started with patterns of high fertility and high mortality are moving through the demographic transition process. As we enter the new millennium, the capacity of humans to come up with innovations, solutions and adaptive measures will need to be strengthened in order to deal with the stark contrasts between the availability of natural resources and the billions of humans who require them to sustain life. Education will play an essential role in that.

The Demographic Transition Theory

The Demographic Transition Theory is the driving theory of the evolution of human population. Developed by Notestein in 1946, the theory categorized the several stages of historical and present population into a continuum of demographic development. Eventually according to this theory, all societies evolve from a pre-transition situation (stage 1) where fertility and mortality are unchecked and high producing low population growth to a stationary population (accomplished in stage 4) which is realized when a society reaches low levels of fertility and mortality. This is quite certain and the exceptions so far have been only of temporary nature. While fertility decline has stalled at several times and in different settings, for instance as a result of cuts in social government budgets in many sub-Saharan Africa following the implementation of structural adjustment policies by the World Bank and the International Monetary Funds, the fertility decline has resumed thereafter. The main uncertainty is about the pace of the fertility and mortality decline between stage 1 and stage 4, which has many implications for population growth. In the case of most industrialized countries, where the transition was slow and happened over many decades, population growth was not so dramatic. This was the case in many European and other industrialized countries. The situation has been different in countries that started their transition in the second half of the 20th century when many advances had already been made and hence mortality rates dropped relatively abruptly while fertility was kept at quite high level for some time. While it is very likely that the fertility will go down, it is difficult to know how long it will take. Whether for instance Nigeria reaches replacement fertility in 2070–75 according to the low fertility variant of the United Nations or in 2095–100 according to the medium variant, makes a different of about 130 million in 2100 (567 vs. 794 million): the population of Mexico nowadays. As we

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will see in the next section, the pace of the fertility decline has indeed huge bearing on the future number of humans, not only for Nigeria. The second uncertainty, also with important bearings is the number of children the population would eventually have. This goes behind the theory of Notestein, adding a further stage (stage 5), also called the second demographic transition in which fertility is so low that generations do not replace themselves and the population starts declining. Here again, most industrialized countries seem to be on this path. For instance in many Eastern Europe countries, women have less than 1.5 children on average and fertility does not seem to recover to replacement level fertility. In those countries, also with the effect of emigration, population is already declining for example, in Bosnia Herzegovina or in Hungary. Japan is another country where fertility has been declining for some time and since 2010, the population has been declining. Whether all countries that are at present going through the demographic transition will also experience the second demographic transition will also be key to the future number of people on the planet. Some researchers contend that the arrival of contraception has ruptured the evolutionary link that existed between the sex drive and reproduction, the fertility of women and couples will be more and more determined by their individual preferences for children (or not) and by norms that will be culturally ascertained. In that sense, it is not necessary that individuals and couples, and societies at large, will want to replace themselves. We will need a few more decades to see the evolution of that phenomenon and whether some societies are trapped in low-fertility. It is worth noting that the governments in countries that are faced with low levels of fertility most often engage in providing financial and structural benefits to support childbirth that are not crowned with success, for example, in South Korea, tending to support the point about an individualization of the fertility decision process (see also the case of China below).

But having the two uncertainties in mind, about the pace and the bottom level of fertility that tells us that there is hope that world population will eventually peak and diminish, it is still not automatic; it is also pretty certain that the 21th century will witness continued population increase, and that these will not occur globally but will be concentrated spatially in the poorest socio-economic settings. To halt the growing imbalance between human population numbers and their essential resources, humans must actively conserve cropland, freshwater, energy, and the other basic environmental resources. There is a critical need to alert the public worldwide to the serious issues of overpopulation and natural resource shortages. Education will be key in that both in developed and developing countries. While most of population growth will happen in developing countries, certainly populations in developed countries could contribute to the conservation effort by reducing their high consumption of all resources, especially fossil fuels. Focus is needed on improving food crops, such as developing perennial grains, pest-resistant crops, and improved nutritional makeup of crops. The development of ecological engineering can help encourage the development of sustainable ecosystems and aid human society to make better use of our natural resources. There is a critical need to educate the public worldwide in order to comb overpopulation and natural resource shortages.

In this article we will examine the current world population situation and how it might evolve depending on several scenarios. We will focus on the role that quality education could play in providing humans with the necessary capacity and ecological engineering requirements to deal with present and future environmental challenges.

World Population Growth

Global Picture

World population growth did not receive much attention until the end of the 20th century for several reasons: the first one being the absence of systematic population data collection exercises and the second that world population increase was minimal due to high mortality rates especially among infants and children. Hence it went unnoticed when the world population reached 1 billion at the turn of the 19th century. The current world population of more than 7.6 billion, doubled during the last 46 years. The uncertainties and impact of the several component of population growth are visible in **Fig. 1** showing estimates of the past and the future number of humans based on several scenarios developed by the United Nations. Although, no probabilities are attached to any of them some seem more plausible than others and some more desirable than others. Several lessons can be taken from this graph. The three top scenarios that give the highest population in 2100 are those where fertility stays constant or declines only marginally. According to those variants, the world population would be between 17 billion (high fertility) and 26 billion (constant fertility). These scenarios imply that fertility decline would come to a stall everywhere—which is very unlikely—and would have dire consequences in terms of population growth in poverty stricken countries. The five remaining scenarios all project the world population to be under 11.5 billion in 2015. The most likely one under present circumstances is the medium fertility variant—it shows the population increasing to 11.2 billion by the end of the century with the world population still not having reached a peak (but leveling off convincingly). It is interesting to see the impact of the momentum of population growth that can be seen in one variant showing a peak at 9.3 billion around 2060, and then started declining. Indeed, worldwide, a major obstacle to limiting population growth is the relatively young age structure—especially in the respective female fecund ages between 15 and 49—with high reproductive rate. Even if all the people in the world adopted a fertility pattern of bearing only two children per couple, it would take approximately 40 years before the world population would finally stabilize at approximately 10 billion. The momentum—also called population inertia—becomes also visible in the fact that until 2050, there is little deviation between the global population numbers although they follow different scenarios. While trusting more the five scenarios that result in a lesser population growth, it is still obvious that they lead to a 2–2.5 billion in population increase from today's level by the mid of century. The low fertility variant is interesting and seems the most suitable one from an ecological point of view as it means a world population peak in 2053 at 8.8 billion further declining to 7.3 billion in 2100. It is worth noticing that these scenarios do not and cannot take into account abrupt events that could occur at any time, such as the spread of a new epidemic, a war, or a baby-boom.

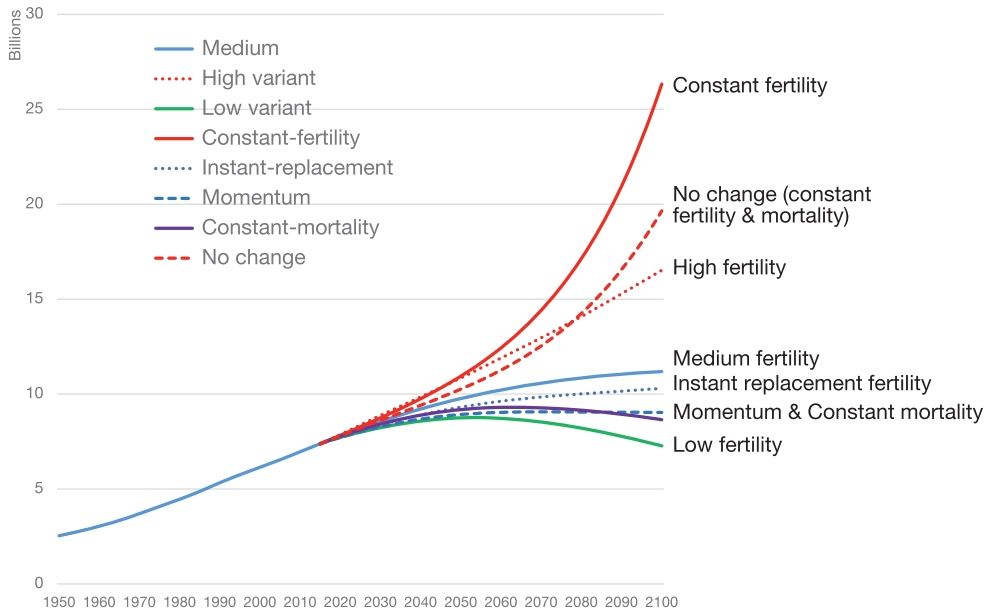

Fig. 1 World population, 1950–2100, estimates and projections according to eight variants. Source: United Nations World Population Prospects (2017).

Regional and Country Level

Global population levels hide important differences in the projected pace of population growth across continents, regions and levels of development (see **Table 1**). In 2010–15, while the world population was increasing at a rate of 1.2%, some regions were shrinking for example, Eastern and Southern Europe or close to stabilization, for example, Western Europe, some others were increasing at a strong rate, for example, Eastern, Middle, and Western Africa. However, population growth rates are on the decline in all countries of the world today—this is visible when comparing for instance the growth rates observed in 2005–10 and 2010–15—and are forecasted to do so in the future as well. **Table 1** shows that at present, less developed regions are the main contributors to world population growth and particularly sub-Saharan Africa and Southern Asia. What is clearly visible is that sub-Saharan Africa would be the main contributor and by far according to the United Nations medium variant in the second half of the century.

The population of China with 1415 million people will keep slowly increasing until 2030 when it would peak at 1441 million and then slowly decline back to 1021 by the end of the 21st century. In 2017, the government ended the one-child policy (that was in effect for more than 30 years) in order to balance rapidly aging population by allowing families to have two children. However, the first year of implementation supports the low-fertility-trap theory that the country has moved to a lower-than-replacement fertility norm and that couples are less likely to wish and bear more children than the previous generation for multiple reasons: strong urbanization and price constraints, women's participation in the labor force, decrease in the preference for boys, etc. India, with 1354 million people, and living on approximately one-third the land either of the United States or China, would keep growing albeit at a slow average annual rate of 0.5% until 2060—surpassing China's population around 2025—and then decline. Total fertility rates have declined very rapidly in all Indian States and in about half of them, women had below replacement fertility in 2016 (e.g., in the highly populated States of Tamil Nadu and West Bengal), and the increase in population is mostly due to the momentum of population growth. At present, the populations of China and India constitute more than one-third of the total world population. They would be around 23% in 2100.

As above mentioned, the sub-Saharan Africa sub-continent will experience most of the world population increase in the next decades. According to the medium variant of the United Nations, population in sub-Saharan Africa would more than double from around 1050 million in 2018 to more than 2.5 billion in 2060 and possibly exceed 4 billion in 2100. The strong increase can be explained by two main factors. The first is that against all expectations (in respect of levels of socio-economic development) infant and child mortality rates have recorded a substantial decline of more than 50% between 1970–75 and 2010–15. As a result, life expectancy has increased by more than 20 years since 1950, from 36 to 57 years, despite the HIV/AIDS epidemic that has slowed down and even reversed the progress made in many countries particularly in Southern Africa. The second factor is the fact that fertility has been slowing down at a snail's pace. Women were having on average more than six children between 1950 and 1995. Fertility started declining faster after the 1995 period but it was still around 5.1 children on average in 2010–15. The fact that the demographic transition to low fertility and mortality levels has adopted a slow pace stems from several reasons having to do the persistence of low levels of socio-economic development in mostly rural traditional societies. The pace of future declines will be an important determinant of population growth. Increase in the levels of educational attainment could play an important role, most notably through the impact it has on fertility and mortality (see section below). In some of the largest countries (Nigeria, Democratic Republic of the Congo, Tanzania, Uganda), the population would more than quadruple between now and 2100

Table 1 Contribution (absolute and percentage) of regions to world population growth from 2015 to 2100

		Increase in absolute (in million) between			*Contribution to global increase (in percent) between*		
		2015 and 2030	*2015 and 2050*	*2050 and 2100*	*2015 and 2030*	*2015 and 2050*	*2050 and 2100*
World	World	+1168	+2389	+1413			
Level of development	More developed regions	+37	+45	−13	+3%	+2%	−1%
	Less developed regions	+1131	+2344	+1426	+97%	+98%	+101%
	Least developed countries	+378	+960	+1282	+33%	+40%	+91%
	Less developed regions, excluding least developed countries	+754	+1384	+144	+67%	+59%	+10%
Continent	Africa	+509	+1333	+1940	+44%	+56%	+137%
	Asia	+527	+837	−476	+45%	+35%	−34%
	Europe	−1	−25	−62	0%	−1%	−4%
	America	+126	+226	−3	+11%	+9%	0%
	Oceania	+8	+18	+15	+1%	+1%	+1%
World regions	Sub-Saharan Africa	+449	+1198	+1834	+38%	+50%	+130%
	Eastern Africa	+188	+489	+690	+16%	+20%	+49%
	Middle Africa	+84	+230	+369	+7%	+10%	+26%
	Northern Africa	+60	+135	+106	+5%	+6%	+7%
	Southern Africa	+11	+22	+7	+1%	+1%	+0%
	Western Africa	+166	457	+768	+14%	+19%	+54%
	Eastern Asia	+44	−49	−388	+4%	−2%	−27%
	Central Asia	+13	+26	+6	+1%	+1%	0%
	Southern Asia	+311	+558	−151	+27%	+23%	−11%
	South-Eastern Asia	+93	+163	−26	+8%	+7%	−2%
	Western Asia	+65	+138	+83	+6%	+6%	+6%
	Eastern Europe	−12	−35	−40	−1%	−1%	−3%
	Northern Europe	+8	+14	+9	+1%	+1%	+1%
	Southern Europe	−4	−12	−26	+0%	−1%	−2%
	Western Europe	+7	+7	−5	+1%	+0%	0%
	Latin America and The Caribbean	+86	147	−68	+7%	+6%	−5%
	Northern America	+39	+79	+65	+3%	+3%	+5%

Table 2 Population of the top 10 most populous countries in 2018, at peak and in 2100

Country	*Population in 2018*	*Population at peak*	*Time of the peak*	*Population in 2100*
China	1,415,046	1,441,574	2029	1,020,665
India	1,354,052	1,678,656	2061	1,516,597
United States of America	326,767			447,483
Indonesia	266,795	324,763	2062	306,026
Brazil	210,868	232,845	2047	190,423
Pakistan	200,814	354,297	2090	351,943
Nigeria	195,875			793,942
Bangladesh	166,368	202,970	2057	173,549
Russian Federation	143,965	143,990	2017	124,013
Mexico	130,759	167,327	2063	151,491

according to the medium variant of the United Nations. Nigeria would have a population of almost 800 million in 2100 and Niger, one of the poorest country of the world would multiply its population eight times in the next 80 years (from 22 million today to 192 million in 2100).

The United States population is also still growing and currently stands at nearly 327 million, having doubled during the past 60 years. Based on the current trend, it is projected to reach 400 million by 2060 and 450 by the end of the century. Out of the ten most populated countries shown in **Table 2**, the United States and Nigeria are the only countries that are not forecasted to attain a maximum over the century. The population of the Russian Federation has peaked in 2017 according to the estimates/projections and is shrinking.

As world populations continue to expand, all global resources will have to be divided globally among increasing numbers of people and per capita availability would decline to ever lower levels. However and as already mentioned, the population pressure

will not be the same everywhere. At the level of less developed countries where this kind of pressure will be the strongest, improving personal health, and achieving prosperity, a suitable quality of life, and personal freedom will be more difficult and will require innovation and leadership. Population models and ecological engineering taken up by education may help people and governments better understand the critical situation and what, if anything, can be done to address the challenge.

The challenges that earth systems will face with an increasing population are serious and of different kinds. Malnourishment is one of them. In 2016, in a world where there is enough food to feed each and every one, about 815 million people (11% of the world population) were affected by hunger and for the first time, after declining over a decade, global hunger was on the rise again according to the 2017 United Nations State of Food Security and Nutrition in the World report. The increase is due to the proliferation of conflicts in combination with severe drought and flood episodes. Providing enough food to meet the nutritional need of the 2.5 billion people that will be added between now and 2060 is one of the biggest challenge of the century. Achieving food security requires a multi-sectoral approach from conflict resolution to strengthening the productivity of small-scale food producers, improving the resilience of food production systems and the sustainable use of biotechnology and genetic resources.

Education

Some population growth is certain. While many scientists including ecological engineers research on the way to optimize and increase the resources in terms of cropland, water resources, energy, while at the same time preserving biodiversity and avoiding as much as possible climate change, some other academic research focuses on the pathways to influence the number of human population and secondly the behavior of the population. Scientific findings tend to demonstrate that in both education has a role to play (Goujon, 2003).

Education and Sustainable Development

The transformative channels through which formal education affects demographic parameters are well known. Formal education is mostly important for its influence on the fertility of women that have been through the education system and on the mortality of children born to those women. The mechanisms are multiple: girls who go to school first of all are exposed to the environment and society outside of their own household and often of their neighborhood, breaking their isolation. There is often already a large difference between the number of children born to a woman who had been to primary school, even if she has not completed all grades and a woman who has never been to school; the difference is as large as two children on average in Kenya and in the Dominican Republic. If girls stay in school, they will delay marriage and hence the onset of fertility. Furthermore, having an education increases the chance of finding employment outside of the house and therefore increases the opportunity cost of having children. The more education a woman has the more likely she is to use modern contraceptives, space the birth of her children. By increasing her autonomy, education will increase her say in household (including fertility) decisions. The transition to lower fertility supposes that there is a time when fertility is not given anymore but becomes within the calculus of choice of couples, particularly women. Education is one of the most influential factor that will make sure that this happens. **Fig. 2** shows the difference in the number of children born to women with a higher education (any studies beyond upper-secondary) and those born to women who have never been to school (or less than a year). Differences are larger in sub-Saharan Africa and can exceed four children like in Angola (more than five-child difference), Mozambique and DR Congo.

As well, education will have an impact on the number of surviving children of these women. This is important for the demographic transition as limiting the number of surviving children will first occur when the probability of child survival increases. **Fig. 3** shows that the chance of survival to the 5th year is much higher for children born to mothers with a high education (secondary or higher) than to mothers who have a low education (primary or less) in many developing countries in recent years. For instance, in Burundi, the mortality rate of children born to mothers with a primary education or less was as measured in 2010 more than twice that of children born to mothers with a secondary or higher education (132 vs. 47 deaths for 1000 live-births). Many surveys confirm that maternal education is the single most significant determinant of child mortality. Educated mothers are more likely to seek treatment for their sick infant or child and break with tradition about illness. Having gained autonomy through education, educated women will be more apt to challenge their mother in law or the head of the household. The education of women is also likely to affect beneficial changes in nutrition that play a part in a decline in infant and child mortality.

What could be the impact of strong increases in educational attainment on future population growth is shown in **Fig. 4** which compares the results of two scenarios. The left-hand side graph assumes a future in which the world is moving toward a more sustainable path (so called "Sustainable world" scenario). It assumes that educational and health investments accelerate the demographic transition, leading to a relatively low world population with increased well-being. As a result in 2100, the world population is already shrinking and the vast majority is well educated. The graph on the right hand side refers to a fragmented world with an emphasis on security at the expense of international development. In this divided world, population growth is assumed to be high in developing countries and low in industrialized countries (so called "Fragmented world" scenario). As a result the world population is high at the turn of the century and population growth is unabated. Moreover large segments of the population particularly in less developed countries have low levels of educational attainment.

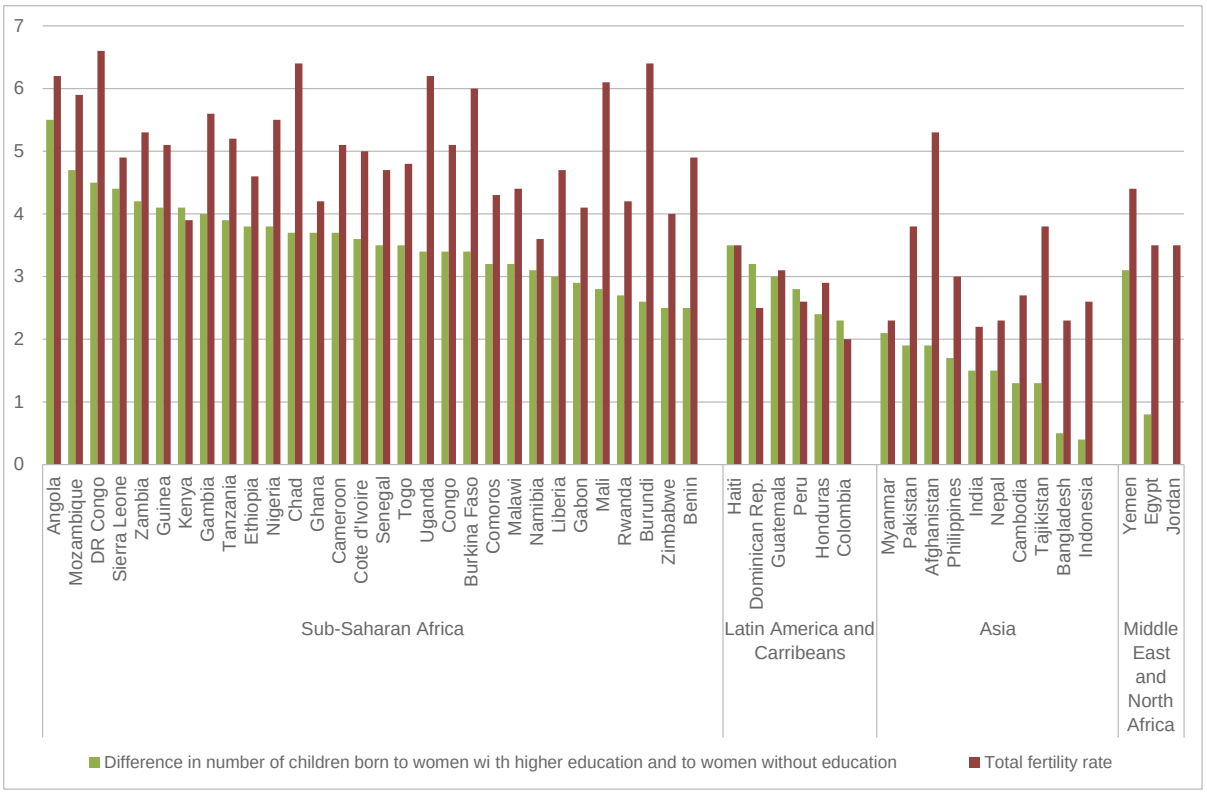

Fig. 2 Difference in the number of children born to women with a higher education and to women without education and total fertility rates, selected less developed countries, since 2010. Source: ICF International, (2015). The DHS Program STATcompiler. Funded by USAID. https://www.statcompiler.com, (February 9, 2018).

Beyond the purely demographic effect of education on the number of people, it is clear that education is key to development. It increases the innovation capacity which will be necessary to face the challenges. It also increases the resilience and adaptive capacity of humans in case of a disaster (such as a Tsunami) or another triggered climate change extreme event. The effect goes beyond the mere survival to extreme events as it was shown in a study of population in Thailand in the aftermath of the 2012 Indian Ocean earthquakes. Living in a community with a higher proportion of women with high education increased preparedness through community engagement of the more educated and carrying out disaster risk reduction measures. Overall the more educated have a longer time planning horizon, which is also the reason why they adopt healthier behaviors (related to nutrition, sport practice and smoking behavior for instance) and tend to be more supportive of environment-friendly behavior (vegan diet, consuming bio-product, biking to work, etc.).

Education for Sustainable Development

Education for sustainable development (ESD) was introduced as part of the targets of Sustainable Development Goal four on education (in Targets 4.7). It is accompanied by an approach to promote the Global Citizenship Education (GCED) within education for sustainable development. The main idea is that transformative ideas are better learned at young ages—the same as other competencies such as riding a bicycle or politeness. This will mean changing the curricula in many countries to have more global components and as well developing cross-cutting sustainability competencies in pupils. This would enable individuals to contribute to sustainable development by promoting societal, economic and political change as well as by transforming their own behavior. Educated people are also more likely to live in democracy and in less corrupted regimes as they may influence the system. Whereas the physical constraints of the planet are more or less set, the future innovative capacity and behavior of its inhabitants are not known. Education may be in this sense the missing link to sustainability.

Why Prediction of Human Dooms Were Wrong (Until Now)?

Along the centuries, concerns were often raised by scientists who were the witness of rapid population growth. The most cited essay by Malthus (1798) warned against the danger of exponential population growth that would ensue out of the evolution of the

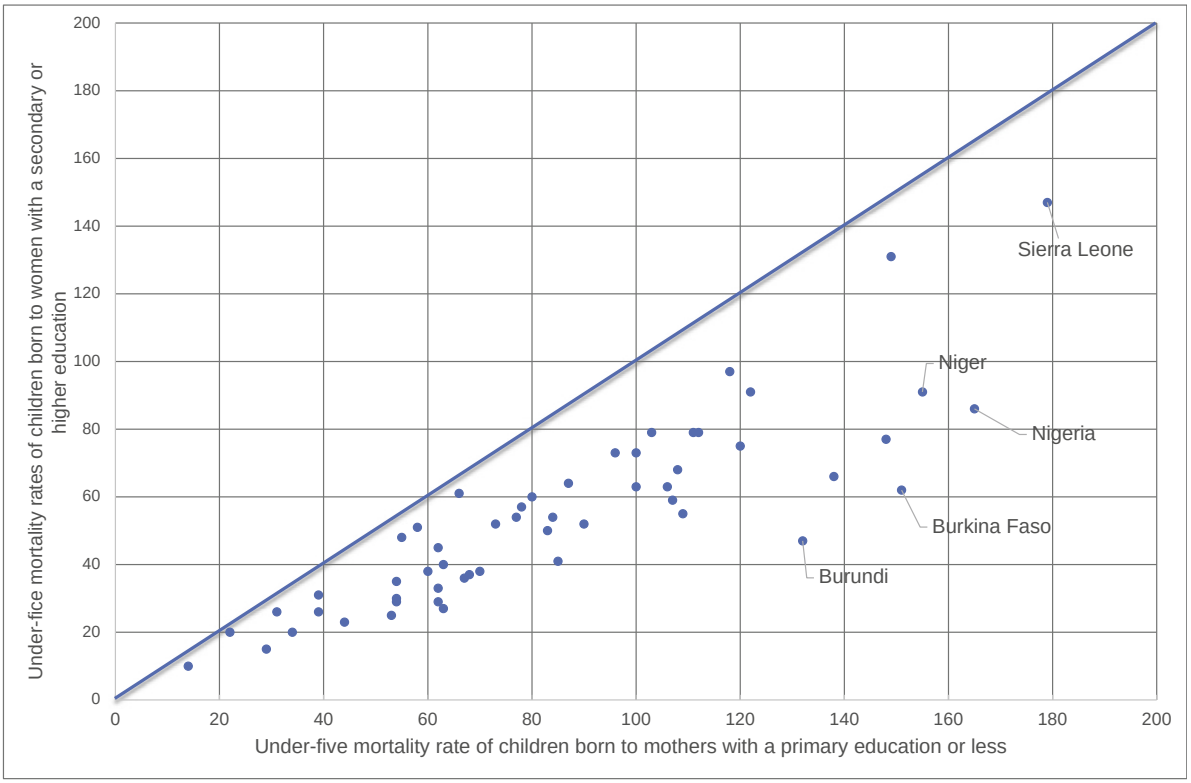

Fig. 3 Comparison in 54 countries of the under-five mortality rates of children born to mothers with a primary education or less (*x*-axis) and those born to women with a secondary education or more (*y*-axis). Note: Probability of dying before the fifth birthday (in the 10 years preceding the survey (5 years for total)) per 1000 live births. Source: ICF International, (2015). The DHS Program STATcompiler. Funded by USAID. https://www.statcompiler.com, (February 9, 2018).

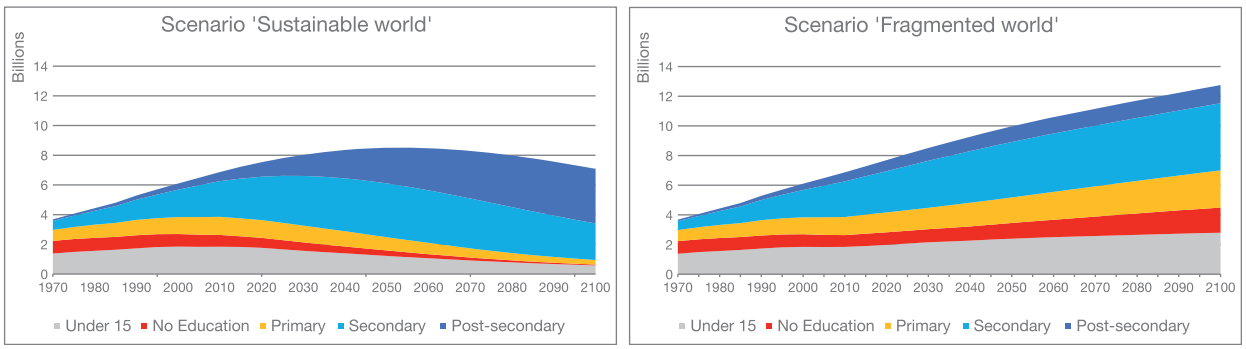

Fig. 4 World population in 2100 according to two scenarios. Note: Scenario "Sustainable world" is based on SSP1 scenario and "Fragmented world" on SSP2. Source: Wittgenstein Centre for Demography and Global Human Capital. (2015), Wittgenstein Centre Data Explorer Version 1.2. Available at www.wittgensteincentre.org/dataexplorer.

different components of population growth in the presence of limits to food production. At this time, the agricultural and industrial revolutions had improved the living conditions and healthcare in Europe, mortality rates were declining and fertility rates were unabated. This essay was the first of many alarmist theories by scientists such as "The Population Bomb" book authored by Paul Ehrlich in 1968 that predicted famines and civil-war in the 1970s and 1980s as a result of population growth. This book was a precursor to the "The Limits to Growth" report published in 1972 which projects the combined impact of exponential population growth with a finite supply of resources. So far those predictions have proved wrong because they take humans as irrational being incapable of changing and adapting to circumstances. Already at the time of Malthus, Condorcet (1743–94) was pointing at the power of an improved intellect. Democratic governance, access to family planning, and the education and economic empowerment of women has proven so far to be able to curve population growth.

The merit of these alarmist scientific works is that they brought to a wide audience, awareness about population and environmental issues.

Conclusion

While it seems almost certain that the world population will peak within the next 100 years, it will be preceded by the probable addition of 2–3 billion people. Most importantly these people will be born in countries that are at the moment most stricken by poverty. While this is a challenge for humanity and for the ecosystems surrounding them, it is also evident that it does not have to be a failure. There is a need for action at present and in the future for influencing the behavior of the people who live on the planet. Education might be key in bringing the change that will help societies to face the global challenges.

See also: Global Change Ecology: Urbanization as a Biospheric Process: Carbon, Nitrogen, and Energy Fluxes. Human Ecology and Sustainability: Urban Systems; Human Ecology: Overview; Limits to Growth; Urban Metabolism

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