POPULATION INCREASES AND AGRICULTURAL PRODUCTIVITY

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Introduction

The race between agricultural productivity and population increases began in the Middle East approximately 11 thousand years ago. Agriculture made the supply of food more plentiful and secure; it also increased the demand for food by increasing the fertility rates of the Neolithic farmers. At the same time, however, mortality rates began to increase because of zoonotic and other infectious diseases. The small net difference between the increasing Neolithic fertility and mortality rates led inexorably to an increasing world population.

Agriculture caused the first demographic transition; industrialization caused the second. Although the 19th Century populations in industrializing countries continued to grow, their fertility and mortality rates began to slowly fall and today the rates have stabilized at very low rates. It was only in the 1960's, however, when the demographic transition began in the non-industrial countries. It was in these countries where the race between agriculture and people has become most intense. Fortunately, the agricultural sciences have produced one of the most important scientific success stories in the world, especially in many of the developing countries. Only one major area of the world is not yet feeding its populations.

This paper will briefly describe the first and second population transitions. It will then concentrate on sub-Saharan Africa where the demographic transition has stalled and agricultural productivity is the lowest in the world. Therefore, although the race between increasing population size and agricultural productivity began in the Middle East 11 millennia ago its conclusion is likely to be determined in Africa in this century.

The agricultural revolution and the Neolithic population transition

The shift from foraging to farming began in the Neolithic Age in Iran's Zagros Mountains about the same time as it began in Jericho, northern Syria and southeast Turkey. (Willcox 2013) Several anthropological hypotheses suggest that the transition to agriculture was because of local population pressures, technological innovations and climate changes. (Rosenberg, 1998). There is less research, however, on the effects of the agricultural transition on Neolithic population dynamics.

Analyses of 133 ancient cemeteries suggest that agricultural societies significantly increased their population fertility relative to foraging societies. (J-P Bocquet-Appel, 2002, 2011). This was because the agricultural transition resulted in an increased per capita consumption of high calorie grains (such as wheat, lentils, and maize) and high protein milk from domesticated animals. (Pennington 1996). The richer food increased the energy balance of woman of reproductive age, which would have shortened their birth interval and increase their fertility rates. The result was an estimated increase of two children per women in agricultural groups relative to the previous foraging groups in the same area. This is the same phenomenon that occurs today when the nutrition of undernourished women improves. (Martorell 2005).

The increase in fertility rates leveled off about 1,000 years after the introduction of agriculture at a time when mortality rates were increasing. (Bocquet-Appel, 2011). The increased consumption of carbohydrates, which humans metabolize into sugars, led to increases in dental caries and other chronic diseases. In addition the increased density of the agricultural

settlements created reservoirs that both maintained and spread infectious diseases (Larsen 2006).

Of course, Homo sapiens were never free from infectious diseases. These ancient diseases, now called heirloom infections, were caused by microbes that were passed from our primate ancestors to early hominids. If the Garden of Eden existed, Adam may have had herpes cold sores, Eve may have had hepatitis, the mosquitoes circling around them may have been carrying the malaria parasite and the snake was almost certainly carrying salmonella bacteria. Each animal, including humans, harbor their own microbes. Therefore, when hominids began hunting animals, the animals' microbes began hunting the hominids. Most microbes are harmless to other species. But some are not and can cause disease and death in humans. (Torrey 2005)

The domestication of animals in the Middle East during the Neolithic period also led to a new range of infectious zoonotic diseases in the farmers. Domesticated cows gave us rhinoviruses, which still causes our common cold, and measles. Cows and goats gave us tuberculosis; ticks gave us African spotted fever. And sheep are the leading animal candidate for the origin of human helicobacter pylori, which causes stomach ulcers. (Torrey 2005) Today over 60 percent of the microbes that cause human diseases come from animals. (Taylor, Latham and Woolhouse 2001) If we consider all the microbes that came originally from animals and continued to evolve in humans then at least three-quarters of all human infections today are zoonotic.

The increase in mortality in Neolithic farmers followed closely the increase in fertility, but fertility increased a little faster. (Bocquet-Appel, 2002) The estimated growth rate over the period from 10,000 years ago to 2,000 years ago is estimated to be only 0.05 percent a year. (Haub 2011) People continued to settle in villages and with larger settlements came irrigation and increases in food. And increases in food in turn supported the small but inexorably growing population. Eight thousand years later the world's population had increased 60 fold to 300,000 and was gaining momentum.

[INSERT TABLE 1 approximately here].

The industrial revolution and the second demographic transition

It took all of human history to get to the first billion people by 1800. And just as agriculture had caused the first demographic transition in the Neolithic era, industrialization and urbanization of the 19th and 20th Centuries caused the second. The birth and death rates of the second transition first started to slowly decline in industrial countries, reversing the rising trends of the first demographic transition.

Despite the slow decreases in the birth and death rates the absolute numbers of people kept increasing rapidly. At the beginning of the industrial revolution Thomas Malthus sounded an alarm about the future population disaster. (Malthus, 1798). Despite his warning the world's population grew to two billion in just 130 years. And it took only 30 years for world population to add the next billion. Although many people starved between Malthus' first warning and 1960 the vast majority of people survived to reproductive age and continued having children.

Many scholars in the 20th Century who were worried about the limited carrying capacity of the land echoed Mathus' refrain. (Ehrlich et al, 1977, Raven 1991). But many others realized that with increasing amounts of experience and scientific inputs agriculture would not only keep up with population growth it could improve the supply of food per capita. (Boserup, 1981, Binswanger and Pingali, 1985). And despite unprecedented population growth, agricultural production did mostly keep up with population growth in the developing world. Today much of the world has completed this second demographic transition and has reached or is approaching replacement rate fertility. (Total fertility rate of the world's population today is now 2.5 children per woman). However, the one continent that has just begun the population transition is Africa and it now is the biggest challenge in the struggle between food security and growing populations.

The future sub-Saharan African transition

Africa today has the highest total fertility rates (TFR) in the world, an average 5.1 children per woman; it also has the highest annual population growth rates anywhere in the world (2.5 percent). And the growth in the next 40 years means that they will more than double their population by 2050. (PRB 2012) Africa also has the least productive agriculture and the highest prevalence of under nutrition in the world. (FAO 2006) Therefore, world hunger is increasingly being concentrated in Africa. (Watson and Pinstrup-Anderson 2010).

Ironically, sub-Saharan Africa likely grows enough food today to supply its current population with its biological caloric requirements. But the presence of so much under nutrition means

that the food is not efficiently distributed either spatially or temporally. In the next 40 years The African population will not only increase 150 percent it will also be older than the current population and more urban. Older populations require more food than children and urban populations demand more food than rural ones. Therefore, the demands on agricultural productivity to adequately feed Africa's future population may need to triple. (Torrey 2010).

Many studies have shown that African farmers can double their yields using current technologies, such as GMOs. In order to do it, however, small farmers need better infrastructure, research and development, and improved government institutions and policies. (Pinstrup-Andersen, Schiole, 2001) (Pinstrup-Andersen 1988, 2000, 2001 a,b, 2007 a,b, 2010, 2011.) Although in the last two decades total agricultural factor productivity has increased over 2 percent annually in developing countries in general, it has been below 1 percent in Africa. It would require significantly higher public and private investments especially in research and development to increase agricultural productivity. (Fuglie 2012) A recent article in *Business Daily Africa* stated that "Africa knows what is needed for food security."(Pinstrup-Andersen, 2013) The challenge is to both increase the supply of food and decrease the future demand for it simultaneously.

The African fertility rates began to decline in the 1990s, a generation later than in most of the developing countries. But today in sub-Saharan Africa the number of children per woman is still 5.1, 140% higher than is needed to get to a stable replacement rate. In fact, there are 31 countries in the world with fertility rates higher than 5 children per woman. Twenty-nine of those countries are in sub-Saharan Africa; (two are in Asia, Afghanistan and Timor-Leste).

A more disturbing trend is that the decline in African fertility rates may have stalled at 5.1 children per woman, far above the replacement rate of 2.1 percent. And in some countries fertility may have even increased. (Bongaarts, Casterline, 2012) The United Nation publishes country level population projections every two years, which are based on data from demographic surveys, censuses and other health information. While these data are better than many economists think, they are considerably less precise than statistics in developed countries. The most important assumptions about future populations are the current population and the future total fertility rate. And the assumptions are adjusted every two years based on new data and methodologies.

The 2012 United Nations World Prospects projections for sub-Saharan Africa showed a slight downward adjustment to the 2010 population based on recent census and survey information. More troubling, however, there was an upward adjustment in the total fertility rate for 2010 that was 0.3 children larger than had been assumed in the 2010 projections. In 15 high fertility African countries the estimated average number of children has been adjusted upwards by more than 5 percent over 2010 assumptions. (Wilmoth 2013) Since two of those countries have the largest populations in Africa, the effect on the future size of the sub-Saharan African population is dramatic. The 2012 change in current and future fertility rates adds over 100 million more Africans in 2050 and 500 million in 2100 population projections. That means that the race to provide adequate food to the future population is now harder than people thought it was even two years ago. This is like running a race up a hill that is getting steeper at each turn in the road.

[**INSERT TABLE 2** approximately here]

Of course, the fertility trends for sub-Saharan Africa vary by region. In Eastern Africa the increase in U.N. fertility assumptions of .3 children is the net result of 5 countries' fertility assumptions increasing, six remaining the same and six small countries' assumptions declining. (Rwanda had the largest decline in its TFR assumption for the year 2010 from 5.4 to 5.1).

In Western Africa the average increase of fertility assumptions of .2 children is the net result of U. N. assumptions increasing for 10 countries, staying the same for 3 and decreasing for 2. Given current assumptions Nigeria's population is expected to be larger than the US's before 2050 and if their fertility rate doesn't decrease more than the current assumptions then Nigeria could be about the same size as China's population in 2100.

The UN's population projections have incorporated the increased mortality rates due to the epidemic of AIDS. The epidemic was a reminder that zoonotic diseases that increased the mortality rates in the Neolithic period can still have devastating effects on human populations. Sub-Saharan Africa was the hardest hit area of the world. It increased the African death rates in the early years of the epidemic, but today its deadly effects have been lessened because of behavioral and medical changes. Fortunately, the annual incidence rates are decreasing and the development of new medications has made AIDS a chronic disease rather than a deadly one for those who have access to them. (Torrey, 2005) The UN's projections assume that Africa's mortality rates will continue to decline as health care improves and infant and child mortality in particular decline.

Sub-Saharan Africa's population growth will complicate every future attempt to improve the food sufficiency of the continent. The question is what shape Africa's demographic transition will take in the future. Historically, African total fertility rates were higher at every education level than the rates in Asia and Latin America.(Martin, 1995) But it is also true that African countries with a higher level of education in the mid-1970s had an earlier onset of fertility decline. The level of education, however, did not strongly affect the speed of the transition once it had started. (DHS 2012)

Education, economic development, urbanization, contraception prevalence, desired family size, and infant mortality are all correlated with decreasing fertility rates around the world and they are also correlated with each other in Africa. As would be expected the level of education affects positively the other variables. (Bongaarts 2011) Fortunately, education is increasing in Africa. (Lutz 2012). [1] The current average years of schooling in Africa is 5.8 and it is projected to be between 9.7 and 11 years by 2050. Africa is also continuing to urbanize and both trends will have a positive effect on future fertility rates. (DHS 2012). But education and urbanization will not be enough to rapidly reach stable populations, given the demographic momentum that already exists in Africa. Sub-Saharan Africa is now projected to be still growing strongly at the end of this century.

Conclusion

The agricultural sciences have been extraordinarily successful in developing the agricultural techniques and inputs to feed the nearly ten billion people who were born in the 20th century.

The biggest challenge that remains for the agricultural sciences is to improve the agricultural productivity in Africa faster than its future rapidly growing population. The challenge for the governments of Africa is also to address the future increases of their populations. They have the examples of the other developing countries around the world that are finishing their demographic transitions. Only when the future African populations are well educated and stabilized will the race that started over 11 millennia ago between agricultural productivity and population growth be won by everyone.

Binswanger, H. P. and P.L. Pingali, 1985 Population Growth and technological change in agriculture pp 62-89 in T. J. Davis, ed. *Proceedings of the Fifth Agriculture Sector Symposium: Population and Food.* Washiington, D.C.: World Bank.

Bocquet-Appel, Jean-Pierre 2002. Paleoanthropological Traces of a Neolithic Demographic Transition, *Current Anthropology*, Vol 43 No. 4 (August/October 2002) pp. 637-650.

Bocquet-Appel, Jean-Pierre, 2011. When the World's Population Took Off: The Springboard of the Neolithic Demographic Transition, *Science* 29 July 2011 Vol. 333:560-561. 2011. (Note: Bocquet-Appel (2011) suggests the pre-industrial farming population growth rate was between 0.2 percent and 0.1 percent.)

Bongaarts, John, 2010. Causes of Educational Differences in Fertility in Sub-Saharan Africa, Poverty, Gender, and Youth, *Working Paper No. 20*, Population Council.

Bongaarts, John, John Casterline, 2012. "Is Sub-Saharan Arica Different?" in *Population and Public Policy: Essays in Honor of Paul Demeny*, edited by McNicoll, Geoffrey et al, Population and Development Review A Supplement to Volume 38, Population Council, New York.

Boserup, E. 1970, Present and Potential food production in developing countries in W. Zelinsky et al. eds. *Geography and a Crowding World*. . Pp 100-113 New York: Oxford University Press.

Ehrlich, P.R., A. H. Ehrlich, and J. P. Holdren 1977. *Ecosicence: Population Resources, Envivronment*. San Francisco: Freeman.

Food and Agricultural Organization, 2006. *State of Food Insecurity in the World*, 2006 Rome.

Fuglie, Keith, Sun Ling Wang, 2012. New Evidence Points to Robust but Uneven Productivity Growth in Global Agriculture, *Amber Waves*, U.S. Department of Agriculture, Economic Research Service. Washington D. C. Sept. 2012.

Haub , Carl, 2011. How Many People Have Ever Lived on Earth? www.prb.org/articles/ .

Koning, Niek, Per Pinstrup-Andersen, 2007. *Agricultural Trade Liberalization and the Least Developed Countries*, Springer, The Netherlands.

Larsen, Clark Spencer, 2006. The agricultural revolution as environmental catastrophe: Implications for health and lifestyle in the Holocene, *Quaternary International* 150, 12-20.

Lutz, Wolfgang, Global Human Capital Projections form the Human Core of New IPCC SSP Scenarios*, Popnet* No. 44, Winter 2012/13 Table 2.

Malthus, T. R., 1798. An Essay on the principle of population. Reprinted. Pp. 15-139 in P. Appleman ed. *An Essay on the Principle of Population*. New York: W.W. Norton, 1976.

Martin, Teresa Castro, 1995. Women's Education and Fertility: Results from 26 Demographic and Health Surveys, Studies in *Family Planning* Vol. 26, No. 4, pp. 187-202, Population Council NY.

Martorell R. 1995. Results and implications of the INCAP follow-up study. *Journal of Nutrition* 125 (4 Supplement): 1127S-1138S.

Pennington, Renee L. 1996. "Causes of Early Human Population Growth, *American Journal of Physical Anthropology* 99:259-274.

Pinstrup-Andersen, Per, Ebbe Schioler, 2000. *Seeds of Contention*, Johns Hopkins University Press, Baltimore.

Pinstrup-Andersen, Per, Rajul Pandya-Lorch, 2001. *The Unfinished Agenda,* International Food Policy Reserch Institute, Washington D.C.

Pinstrup-Andersen, Peter Sandoe, 2007. *Ethics, Hunger and Globalization: In Search of Appropriate Policies*, Springer, The Netherlands.

Per Pinstrup-Andersen, 2010. *The African Food System and its Interaction with Human Health and Nutrition,* Cornell University Press, Ithaca NY.

Pinstrup-Andersen, Derrill D. Watson II, 2011. *Food Policy for Developing Countries*, Cornell University Press, Ithaca: NY.

Pinstrup-Andersen, Per, 2013. "Africa Knows What is Needed for Food Security," *Business Daily Africa* August 31, 2013. www.businessdailyafrica.com/Opinion.

Population Reference Bureau 2012 *World Population Data Sheet*, 2012. Population Reference Bureau, Washington D.C.

Raven, P. H. 1990. Winners and losers in the Twentieth-century struggle to survive. Pp 259-266 in K. Davis and M.S. Berstem, eds. *Resources, Environment and Population: Present Knowledge and Future Options.* A supplement to Vol. 16 *Population and Development Review*. New York: The Population Council.

Rosenberg, Michael, 1998. Cheating at Musical Chairs: Territoriality and Sedentism in an Evolutionary Context, *Current Anthropology* Vol 39 No. 5 Dec. 1998; 653-681.

Torrey, Barbara Boyle 2010. Population Dynamics and Future Food Requirements in Per Pinstrup-Andersen, *The African Food System and its Interaction with Human Health and Nutrition,* Cornell University Press, Ithaca NY.

Torrey, E. Fuller Torrey, Robert H. Yolken, 2005. *Beasts of the Earth: Animals, Humans and Disease*, Rutgers University Press.

Watson, Derrill, Per Pinstrup-Andersen 2010. The Nutrition Situation in Sub-Saharan Africa, in Per Pinstrup-Andersen, 2010. *The African Food System and its Interaction with Human Health and Nutrition,* Cornell University Press, Ithaca NY p.35.

Wiebe, Keith, Nicole Ballenger, Per Pinstrup-Andersen 2001. *Who Will be Fed in the 21st Century Challenges for Science and Policy*, International Food Policy Research Institute. Washington D.C.

Willcox, George, 2013. The Roots of Cultivation in Southwestern Asia, *Science* Vol 341 5 July 2013.

Wilmoth, John, 2013. as quoted in the *UN Press Release* June 13, 2013 Population Division, United Nations, NY.

TABLE 1

ILLUSTRATIVE POPULATION ESTIMATES FROM
THE NEOLOITHIC PERIOD TO THE PRESENT

	Population (in millions)	Births per 1,000	Births Between Benchmarks (in billions)
8,000 BC	5	80	1.1
1 AD	300	80	48
1200	450	60	26.6
1650	500	60	12.8
1750	795	50	3.2
1850	1,300	40	4
1900	1,700	40	2.9
1950	2,500	31-38	3.4
1995	5,800	31	5.4
2011	7,000	23	2.1

Source: Haub, Carl, How Many People Have Ever Lived on Earth, Population Reference Bureau, 2011, www.prb.org/Articles

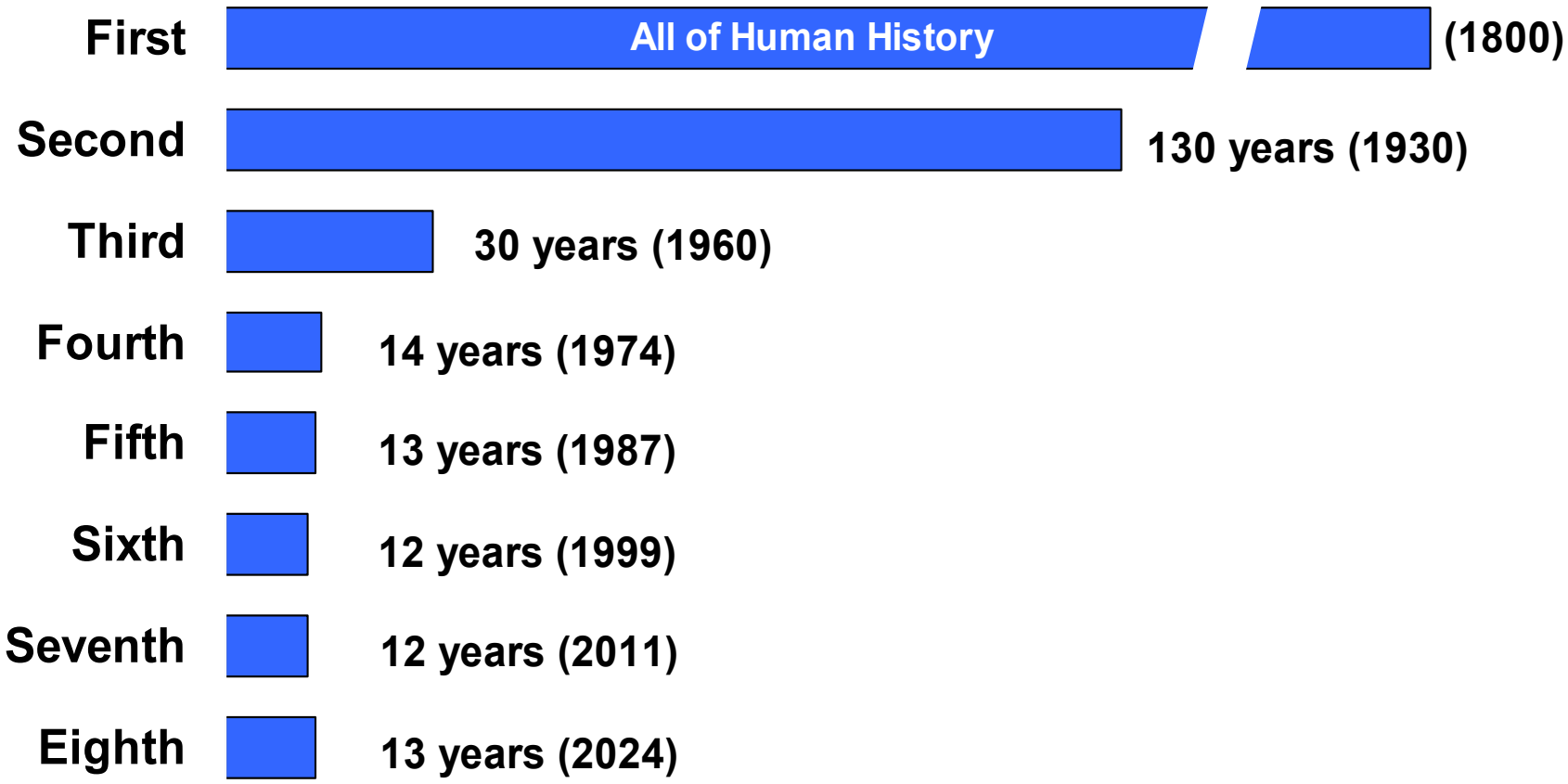
TABLE 2

SUB-SAHARAN AFRICAN POPULATION AND TOTAL FERTILITY RATE PROJECTIONS
UN 2010 AND 2012 PROSPECTS MEDIUM VARIANT

	POPULATION (in millions)		
	2010	2012	Difference
2010 estimate	856	831	-25
2020	1,088	1,077	-11
2030	1,354	1,368	14
2040	1,647	1,704	57
2050	1,960	2,074	114
2100	3,358	3,816	458
	TOTAL FERTILITY RATES CHILDREN PER WOMAN		
2010-2015	4.78	5.11	0.33
2020-2025	4.13	4.45	0.32
2030-2035	3.58	3.88	0.3
2040-2045	3.16	3.42	0.26
2050-2055	2.85	3.04	0.19

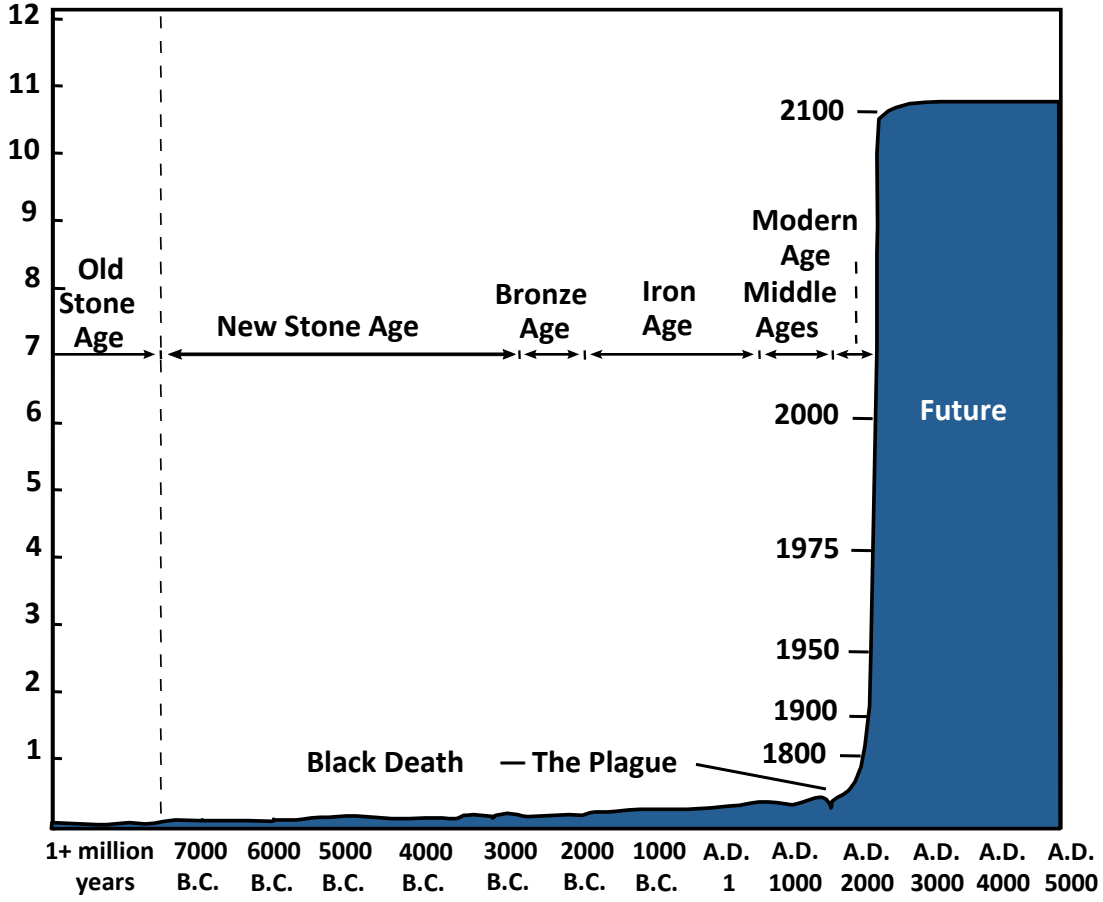
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: 2010 and 2012 Revision.

Years to Add Each Billion to World Population



Sources: UN Population Division and Population Reference Bureau.

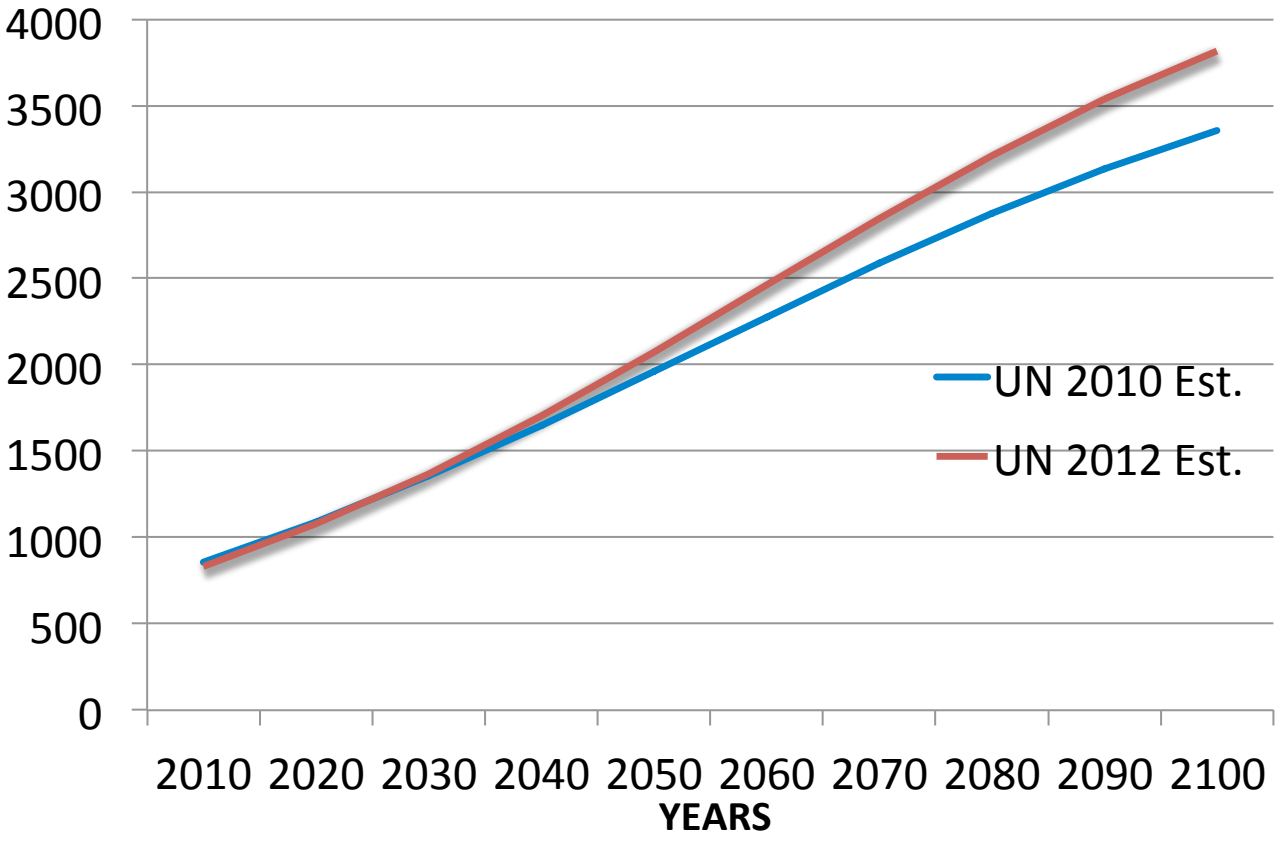
World Population Growth Through History



Source: Population Reference Bureau; and United Nations, *World Population Projections to 2100* (1998).

UN POPULATION PROJECTIONS FOR SUB-SAHARAN AFRICA

(in millions)



Source: World Population Prospects, The 2010 and 2012 Revisions United Nations New York, 2011, and 2013.