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Has the *World* Really Survived the Population Bomb? (Commentary on "How the World Survived the Population Bomb: Lessons From 50 Years of Extraordinary Demographic History")

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Abstract In his PAA presidential address and corresponding article in *Demography*, David Lam (Demography 48:1231–1262, 2011) documented the extraordinary progress of humankind—*vis-à-vis* poverty alleviation, increased schooling, and reductions in mortality and fertility—since 1960 and noted that he expects further improvements by 2050. However, although Lam briefly covered the problems of global warming and pollution, he did not address several other major environmental problems that are closely related to the rapid human population growth in recent decades and to the progress he described. This commentary highlights some of these problems to provide a more balanced perspective on the situation of the world. Specifically, humans currently are using resources at an unsustainable level. Groundwater depletion and overuse of river water are major problems on multiple continents. Fossil fuel resources and several minerals are being depleted. Other major problems include deforestation, with the annual forest clearing globally estimated to be an area the size of New York State; and species extinction, with rates estimated to be 100 to 1,000 times higher than background rates. Principles of ecological economics are presented that allow an integration of ecology and economic development and better potential for preservation of the world for future generations.

Keywords Population and resources · Water · Deforestation · Biodiversity · Ecological economics

Introduction

In his 2011 PAA presidential address, David Lam (hereafter referred to as "Lam") documented the phenomenal progress of human societies over the past half-century—increases

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in levels of schooling, increases in food production and food per capita, lower proportions of people in poverty, and declining mortality and fertility rates—all in spite of the addition of 3 billion persons to the planet. However, Lam did not fully consider the environmental costs of these trends, although he admitted that "there are many less positive trends that I have not discussed" (Lam 2011:1257). Lam concluded that by the 2050 PAA, "I expect that it [the world] will have improved in many ways, including lower poverty, higher levels of education, and plenty of food to go around" (Lam 2011:1259). Although I have no argument with the data Lam presented, I am less sanguine about the outlook for the next 40 years. Lam's article was titled "How the World Survived the Population Bomb . . . ." But actually, 95 % of the article focuses on *Homo sapiens*, and the rest of the "world" and its ecosystems are relegated to the subsections on food production and one on global warming and pollution.

I focus on two oversights of Lam's world model that are directly related to our recent demographic and development history of very rapid population increase and economic development: (1) our unsustainable use of the Earth's resources, essentially compromising the quality of life of future generations; and (2) our continued negative and often devastating effects on the planetary ecosystem. I cover each of these in turn and then outline a possible framework to better integrate ecology and development.

Unsustainable Use of Resources

The increases in industrial and food production over the past century have required massive inputs of nonrenewable resources. Consumption of fossil fuels increased faster than the population for most years of the twentieth century (Hook et al. 2011) and particularly after 1950. Although the amount of reserves can be only roughly estimated, energy experts tend to agree that we are at or not far from the peak of oil production (Aleklett et al. 2010; Hughes and Rudolph 2011; Seljom and Rosenberg 2011; Sorrell et al. 2012). Going forward, there are likely to be nefarious consequences for the global economy of significantly increased oil prices and particularly rises in the costs of foods like those seen in 2008 (Neff et al. 2011). Similarly, although huge natural gas reserves have been found recently in the United States, the environmental and energy costs of extracting it are large and even these reserves may last only 60 years (Weijermars 2012). Renewable energy resources are being used increasingly, but replacement fuels for heavy vehicles and air transport have yet to be discovered, and historical experience shows that the lag time from discovery to extensive use of a new resource typically is several decades (Hook et al. 2011; Mediavilla et al. 2013).

Increases in food production have required immense inputs of fertilizer, typically produced from fossil fuel (natural gas) and nonrenewable minerals (phosphorus). In addition, much of the increase in food production has been due to a combination of high-yield varieties of wheat with rice and massive irrigation. To provide water for irrigation, farmers around the world have tapped rivers and underground aquifers such that outflow often exceeds inflow. Each aquifer has its own rate of recharge depending on climate, depth, rock formations above it, and so on. The stock of underground water in the world is very difficult to quantify, but the amount of withdrawal and the depletion (when withdrawal exceeds recharge) are better estimated. Global groundwater overdraft is about 160 billion m^3 per year, or about twice the annual flow of the Nile River (Giordano 2009).

Further, 1.7 billion people live in areas where groundwater resources and/or groundwater-dependent ecosystems are under threat from depletion (Gleeson et al. 2012). Only a small fraction (3 %) of depleted groundwater returns to the groundwater store by recharge, and the remainder ends up in the ocean and contributes to rises in sea level (Wada et al. 2010).

Groundwater use is higher than recharge in large parts of India and China. Half of the wheat production of the North China Plain is threatened because of aquifer overdraft (Giordano 2009). India is now the biggest user of groundwater for agriculture in the world: nearly 90 % of the rural water supply there is from groundwater (Shankar et al. 2011). One-quarter of India's food crop is at risk, as water tables have been falling at rates of 1m or more per year over the last 20 or more years in some states (Giordano 2009). The security of drinking water is also threatened because the source is the same for both irrigation and drinking. Although scarcely reported in the Western media, about 250,000 Indian farmers have committed suicide in the last 16 years, with a great number of these precipitated by financial ruin—the inability to afford the digging of deeper wells (for irrigation) as the water table receded (Center for Human Rights and Global Justice 2011; Gruere and Debdatta 2011). In the United States, water from the Ogallala aquifer in the Midwest is also being used faster than it can be replenished; the U.S. Geological Service (USGS 2013a) estimates that its levels have dropped by an average of 14 f. over the entire region. This, combined with an expected drier climate in the Midwest owing to climate change, as well as demand for agricultural land for cultivation of biofuels, could lead to a significant negative impact on food production (Wada et al. 2012). In addition, groundwater below one's land does not belong to the individual because the water may flow from somewhere quite distant; thus, both surface water and groundwater are in the commons, and cooperative management is essential.

Regarding rivers, "peak renewable water" limits have already been reached for a number of major river basins, including the Nile, the Jordan, and the Yellow Rivers (Gleick and Palaniappan 2010). The Colorado River is also in this category (Gleick 2010); demand for its water has become so great that the amount of water reaching the Pacific Ocean is miniscule compared with that of historical periods (Cintra-Buenrostro et al. 2012). The Rio Grande also suffers severe water scarcity during seven months of the year (Hoekstra et al. 2012). The United Nations anticipates that in 2025, 1.8 billion people will live in countries or regions with absolute water scarcity (United Nations Department of Economic and Social Affairs 2013). Although a potential solution to the problem of water scarcity is desalination of sea water, its practical use on a large scale may be years off because it still requires large energy inputs and has a nontrivial carbon footprint (Elimelech and Phillip 2011).

Lam showed prices of five metals (chromium, copper, nickel, tin, and tungsten) from 1960 to 2010, including the period during which Julian Simon, an economist, and Paul Ehrlich, an ecologist, placed a bet about prices of these metals. (Ehrlich bet that prices would increase as population increased, which together with technological development would lead to an increase in demand over the decade; and Simon bet that they would decline as substitutes would be found. Simon won the bet, although recent analyses show that Simon was lucky in the decade that was picked (Kiel et al. 2010; Lawn 2010)). In the past several years, prices of these nonrenewable resources have been volatile but definitely higher than they were in earlier decades (Kelly and Matos 2013; USGS 2013b), and ore grades are declining (May et al. 2012). Further, it is estimated that at current rates of use and assuming upper bounds on resource stocks, several minerals (zinc, lead, tin, and silver) will last less than 50 years, although presumably recycling can avoid total depletion (Perman et al. 2012). Substitutes for these minerals may be found, but in the meantime exploration for and exploitation of these and other minerals continues apace in places like Mongolia and Afghanistan. Feeding the population has obviously been the priority, but "surviving the population bomb" while leaving reduced stores of minerals and scarce water supplies to future generations is poor stewardship.

Negative Effects on the Planetary Ecosystem

Lam briefly discussed what is now largely recognized as the growing crisis of global warming[1] resulting from greenhouse gas emissions and correctly identified the problem that markets do not include costs of externalities, stating that "In domains without markets and resource ownership, problems are much more likely" (Lam 2011:1257). We need to consider how unsustainable externalities affect future generations—for example, with regard to climate change, flooding of coastal cities, or complete submersion of some island nations in the South Pacific.

Lam provided two examples in which negative effects of human activities have been markedly reduced: the decline of sulfur dioxide through emissions standards and the decline in ozone-destructive CFCs by international agreement. (Unfortunately, such a global consensus is sorely lacking on limiting greenhouse gas emissions.) However, nowhere did Lam mention deforestation or species loss, which are two major problems confronting us. What follows is documentation of the extent of these two problems resulting in large part from human population growth in combination with the progress Lam described.

Deforestation

The Food and Agriculture Organization (FAO 2013) estimates that the world forest area covers approximately 4 billion hectares (31 % of total land area) but that clearing of forests has been occurring at the rate of about 13 million hectares *per year* during the past decade. (This is an area the size of New York State, amounting to an area the size of 46 football fields being deforested per minute!) This deforestation accounts for as much as 10 % of our greenhouse gas emissions. Brazil and Indonesia account for nearly 30 % of the deforestation and a major reason is conversion of the forest to farming land to feed our growing population (e.g., for soybean production in Brazil). The good news is that recent Brazilian government statistics show a decline in yearly deforestation from 28,000 km^2 in 2004 to 5,000 km^2 in 2012 (Government of Brazil 2013). Such massive deforestation seems a heavy price to pay for the increases in food production that Lam described, and the situation will only worsen with the additional deforestation that will occur by midcentury in order to feed the added 2 to 3 billion persons projected for 2050 (United Nations 2013).

[1] Actually, the more inclusive term used by most scientists now is "climate change," which includes global warming as well as sea level rise and changes in levels and patterns of precipitation (NASA 2013).

Other Species

Scientists have estimated that the rate of extinction of species in the past century has been on the order of 100 to 1,000 times the rates before humans became dominant in the world (Pereira et al. 2010; Ricketts et al. 2005). This is largely due to quadrupling of the number of *Homo sapiens* over the past century and our altering in one way or another of virtually every ecological niche on the planet (e.g., the effects of air or water pollution are measurable almost everywhere). The range of extinction rates is wide partly because the number of species on the planet is unknown. Only about 1.5 million species have been classified, whereas a recent estimate of the number of species on Earth is 8.7 ± 1.3 million (Mora et al. 2011). To illustrate the problem, consider a species of beetles that may exist on only a few acres of the Amazon forest; when those few acres of forest are cut down, that species will become extinct without ever having been classified.

Of species that have been classified, the International Union for the Conservation of Nature (IUCN 2013) documents their status as (1) Critically endangered, (2) Endangered, (3) Vulnerable, (4) Near threatened, (5) Lower risk, or (6) Least concern. The continuously updated compilation of IUCN shows that the number of species at risk of extinction (groups 1–3) continues to grow each year (IUCN 2013: table 2). Human activity (especially development) is the major threat. Among the large primate species ($n = 9$), all except *Homo sapiens* are endangered at this time. (*Homo sapiens* is grouped by IUCN along with animals such as mice, rats, cottontail rabbits, and white-tailed deer in the category "Least concern.") Of all mammalian species ($n = 5{,}501$), 21 % are in categories 1–3, and 4 % are critically endangered. The situation is becoming dire and is very likely to become worse in the years ahead (Pereira et al. 2010) unless preservation of biodiversity is given greater emphasis (Rands et al. 2010). Unfortunately, when a species is gone, it is gone forever.

Several Other Negative Effects of Humans on Ecosystems

Deforestation and species loss are only two of many major negative effects of humans on the environment we inhabit. Briefly, three others are as follows:

1. Overfishing. Depletion of stocks of cod, haddock, and herring, for example, have occurred because of lack of regulation (until recently) of the commons that is the ocean (Petitgas et al. 2010).
2. Nitrogen pollution of streams, estuaries and the seas. "Dead zones" in coastal oceans are areas where dissolved oxygen levels are so low that most life dies; these zones exist mainly because of nitrogen runoff predominately from fertilizers. Dead zones are present in more than 400 areas covering over 245,000 km^2 (Diaz and Rosenberg 2008).
3. Mountaintop removal in Appalachia. Scores of mountaintops have been and are being blown off in West Virginia, Kentucky, and elsewhere to obtain coal relatively easily; entire local ecosystems are irreparably destroyed (Mitchell 2006).

Although *Homo sapiens* has done well, as Lam described, the rest of "the world" has suffered from the success of our species. In fact, some scientists label the current geological age the "anthropocene" or "homocene" because our species has altered the

Earth on a planetary scale (Myers 2003; Steffan et al. 2011). Recently, 2012 was shown to be the hottest year on record in the United States (Gillis 2013), extreme weather events are occurring with increasing frequency all over the world (Lyall 2013), and groups of scientists say we are approaching a dangerous tipping point in the biosphere (Barnosky et al. 2012; Ehrlich and Ehrlich 2013; Ramanathan and Feng 2008; Rockstrom et al. 2009; Solomon et al. 2009). On another front, humans appropriate approximately 30 % to 40 % of net primary production of the planet (Erb et al. 2009; Haberl et al. 2007). As another example, the mass of water impounded behind reservoirs—estimated at 8,300 km^3 (Hoff 2009)—has measurably (albeit slightly) altered the tilt and rotation of the Earth (Chao 1995).

Potential Framework to Integrate Ecology and Development

Ecological economics, a transdisciplinary field that addresses the relationships between ecosystems and economic systems (Costanza et al. 1991; Shmelev 2012), provides a good framework for considering these matters and what to expect between now and 2050. Three key propositions from ecological economics are as follows.

First, the natural world provides our life support systems, and the human economy is not separate from but *embedded within* nature (Burger et al. 2012; Ropke 2005; The Royal Society 2012). These life-support systems include the hydrological cycle, renewable and nonrenewable resources, photosynthesis, atmosphere and climate, pollination, waste absorption, and the nitrogen cycle. We must establish safe minimum standards and precautionary principles for protecting these systems (Ehrlich 1994; Saltelli and Funtowicz 2004).

Second, sustainable development "is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987:41). Note that if a single process is unsustainable, the whole system is unsustainable (Schilling and Chiang 2011). A necessary condition for sustainability is that future generations do not forfeit freedom of choice as a result of the activities of the present generation. It is prudent to assume that future generations' needs for natural resources (soil, air, water, forests, fisheries, plant and animal species, energy, and minerals) will not be markedly less than ours (Goodland and Ledec 1987). In operational terms, sustainability means that (a) humans must place a limit on environmental appropriation that occurs at the expense of the rest of the biological community, and more specifically population growth must be limited and eventually reach zero growth (e.g., a stationary population); (b) "harvesting rates of renewable natural resources should not exceed regeneration rates"; (c) "waste emissions should not exceed the assimilative capacity of the environment"; and (d) "non-renewable resources should be exploited, but at a rate equal to the creation of renewable substitutes" (Berkes and Folke 1994:130).

Third, ecosystems typically respond nonlinearly to perturbation. For example, gradual increases in salinity may go unnoticed by farmers for years but then reach crisis levels. Biological resources that we presently take for granted could become subject to rapid and unpredictable transformations within the span of a few generations (Barnosky et al. 2012). Thus, because of the uncertainty in our understanding of ecological processes, it is prudent to avoid courses of action that could lead to dramatic and irreversible consequences (Daily et al. 2000).

In conclusion, Lam provided a nice overview of human progress from 1960 to 2010 and was optimistic about the next 40 years. However, he did not do justice to the looming major ecological problems that have been the result of this human progress. Will birth cohorts of 2040–2050 look back and wish our generation had done more to preserve the world that was bequeathed to us? I do believe so.

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