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Pimental, David

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Population Growth and the Environment: Planetary Stewardship

David Pimental
Cornell University

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Introduction

During recent decades there has been a dramatic worldwide population increase. Based on current rates of increase of 1.5% per year, the world population is projected to double to more than 12 billion in about 46 years (Population Reference Board, 1996). The world population adds more than a quarter million people daily and this rapid growth is placing enormous pressure on the environment. The United States population doubled from 135 million to more than 270 million during the past 60 years and is projected to double again to 540 million in the next 70 years based on the current U.S. growth rate of 1% per year (United States Bureau of the Census, 1996). China's population is 1.2 billion and, despite the governmental policy of permitting only one child per couple, it is still growing at an annual rate of 1.1% (doubling time of 60 years) (PRB, 1996).

India has nearly 1 billion people living on approximately one-third of the land of either the United States or China. India's current population growth rate is 1.9%, which translates to a doubling time of 37 years (PRB, 1996). Together, China and India constitute more than one-third of the total world population. Given the decline in resources, it is unlikely that India, China, and the world population in total will double.

In the world today more than 2 billion humans are now malnourished, and this is the largest number of hungry humans ever recorded in history (Neisheim, 1993; Bouis, 1995; World Health Organization, 1995)! Conceivably the numbers of malnourished will reach 3 to 5 billion in future decades.

Reports from the Food and Agriculture Organization of the United Nations and the U.S. Department of Agriculture, as well as numerous other international organization further confirm the serious nature of the global food supply (Royal Society and National Academy of Sciences, 1992; NAS, 1994). For example, the per capita availability of world cereal grains, which make up 80% of the world's food supply, has been declining for the past 15 years (Kendall and Pimentel, 1994; Harris,

1996). These shortages are now reflected in major increases in the price of cereal grains, the basic food for billions of people (United States Department of Agriculture, 1996).

Thus as the world population continues to expand, greater pressure than ever before is being placed on all basic resources that are essential for food production. Unfortunately, while the human population grows exponentially, food production can only increase linearly. Furthermore, degradation of land, water, energy, and biological resources vital to agriculture continues unabated (Pimentel et al., 1997a).

Agricultural Resources

More than 99% of the world's food supply comes from the land, while less than 1% is from oceans and other aquatic habitats (FAO, 1991). The continued production of an adequate food supply is directly dependent on ample quantities of fertile land, fresh water, energy, and natural biodiversity. Obviously as the human population grows, the requirements for all these resources will escalate. Even if these resources are never completely depleted, on a per capita basis, their supply will decline significantly because they must be divided among more people.

Land

Throughout the world fertile cropland is being lost from production at an alarming rate. True for all cropland, it is illustrated by the diminishing amount of land now devoted to cereal grains (Pimentel et al., 1997b). Soil erosion by wind and water as well as overuse are responsible for the loss of about 30% of the world cropland during the past 40 years (World Resource Institute, 1994; Pimentel et al., 1995). Once fertile soil is lost, it takes 500 years or more to form a mere 25 mm of fertile soil. For crop production, at least 150 mm of soil is required. We can not wait even for 25 mm!

Most replacement for eroded and unproductive agricultural land is coming from cleared forest land and marginal land. The need for more cropland accounts for more than 60% of the world's deforestation (Myers, 1994). Despite such land replacement strategies, world cropland per capita is declining and now stands at only about 0.25 ha per capita or half of the 0.5 ha per capita considered the minimum for the production of a diverse diet similar to that of the U.S. and Europe (Lal and Stewart, 1990). China now has only 0.08 ha per capita or about 15% of the 0.5 ha per capita or 15% of the accepted minimum arable

land needs.

Water

Rainfall and its collection in rivers, lakes, and vast underground aquifers provide the water needed by humans for their survival and diverse activities.

Fresh water is critical for all vegetation including crops. All use and transpire massive amounts of water during the growing season. For example, a hectare of corn, producing about 8,000 kg/ha, will transpire more than 5 million liters of water during one growing season (Pimentel et al., 1997c). This means that more than 8 million liters of water must reach each hectare of corn during the season. In total, agricultural production consumes more fresh water than any other human activity. Specifically, about 70% of the world's fresh water supply is consumed, that is used up by agriculture and thus, is unavailable for other uses (Postel, 1997).

Water resources are under great stress as populous cities, states, and countries increase their withdrawal of water from rivers, lakes, and aquifers every year. For example, by the time the Colorado River reaches Mexico it has almost disappeared before it finally trickles into the Gulf of California (Sheridan, 1983). Also, the great Ogalla aquifer in the central U.S. is suffering an overdraft rate that is about 140% above recharge rate (Gleick, 1993). Water shortages in the U.S. and elsewhere in the world already are reflected in the per capita decline in crop irrigation during the past twenty years (Postel, 1997).

To compound the water problem, about 40% of the world population live in regions that directly compete for shared water resources (Gleick, 1993). In China, for example, more than 300 cities already are short of water, and these shortages are intensifying as Chinese urban areas expand (WRI, 1994). Competition for water resources among individuals, industries, regions both within and between countries is growing throughout the world community (Gleick, 1993).

Along with the quantity of water, its purity also is important. Diseases, associated with impure water and unsanitary systems rob people of their health, nutrients, and livelihood. These problems are most serious in developing countries. Where about 90 per cent of the diseases can be traced to a lack of pure water (WHO, 1992). Worldwide, about 4 billion cases of disease are contracted from impure water and approximately 6 million deaths are caused by water-borne disease each year (Pimentel et

al., 1997c). Furthermore, when a person is stricken with diarrhea, malaria, or other serious disease, from 5 to 20 percent of an individual's food intake is used by the body to offset the stress of the disease further, diminishing the benefits of his/her food (Pimentel et al., 1997b).

Disease and malnutrition problems appear to be particularly serious in the third world where poverty and poor sanitation is endemic (Shetty and Shetty, 1993). The number of people living in urban areas is doubling every 10 to 20 years, creating other environmental problems, including the lack of water and sanitation, increased air pollution plus increased food shortages. For these reasons, the potential for the spread of disease is great in urban areas (Science, 1995).

Energy

Energy from many sources but especially fossil energy is a prime resource used in food production. Nearly 75% of the fossil energy used each throughout the world year is consumed by populations living in developed countries. Of this, about 17% is expended in the production, processing, and packaging of food products (Pimentel and Pimentel, 1996). In particular, the intensive farming technologies characteristic of developed countries rely on massive amounts of fossil energy for fertilizers, pesticides, irrigation, and for machines that substitute for human labor. In contrast, developing countries use fossil energy primarily for fertilizers and irrigation to help maintain yields, rather than to reduce human labor inputs (Giampietro and Pimentel, 1993).

Because fossil energy is a finite resource, its depletion accelerates as populations expand and their food requirements increase. The U.S. Department of Energy warns that our country will exhaust all of its oil reserves within the next 20 years (British Petroleum, 1994; Youngquist, 1997). Consider that at present, the United States is importing more than 60% of its oil (increased from 50% during 1997). To sustain its energy based activities, U.S. oil imports will have to increase in future decades, further worsening the U.S. trade imbalance. The cost of fuel also will increase. The impact of price increases already is a serious problem for developing countries where the relatively high price of imported fossil fuel makes it difficult, if not impossible, for poor farmers to power irrigation and purchase fertilizers as they try to sustain needed harvests (Pimentel and Pimentel, 1996).

Worldwide, per capita supplies of fossil energy show a decline and this trend can be expected to continue. Furthermore, the current decline in per capita use of fossil energy, caused by the decline in oil supplies and

increasing prices, is generating direct competition between developed and developing countries for fossil energy resources.

Biodiversity

A productive and sustainable agricultural system, indeed the quality of human life, also depends on maintaining the integrity of natural biodiversity that exists on earth. Often small in size, diverse species serve as natural enemies to control pests, help degrade wastes, improve soil quality, fix nitrogen for plants, pollinate crops and other vegetation, and provide numerous other vital services for humans and their environment (Pimentel et al., 1997a). Consider that in New York State on a bright sunny day in July, the wild and other bees pollinate an estimated 1,000,000 million blossoms so essential for the production of fruits and vegetables and other plants. Humans have no technology to substitute for this task and many of the other contributions provided by the estimated 10 million species that inhabit the earth (Pimentel et al., 1997a).

Food Distribution

Assumptions are made by some that market mechanisms and international trade are effective insurances against future food shortages. However, when the biological and physical limits of domestic food production are reached by all nations, food importation will no longer be a viable option for all countries, because at that point, food importation for countries like the rich can only be sustained by starvation of the poor. In the final analysis, the existing biological and physical resource constraints regulate and limit that all food production systems.

These concerns about the future are supported by two observations. First, most of the 183 nations of the world now are dependent on food imports. Most of these imports are cereal grain surpluses produced only in those countries that now have relatively low population densities, where intensive agriculture is practiced and where surpluses are common. For instance, the United States, Canada, Australia, and Argentina provide about 80% of the cereal exports on the world market (WRI, 1992). This situation is expected to change when U.S. population doubles in the next 70 years to 540 million people (USBC, 1996). Then based on this projection, instead of exporting cereals and other food resources, these foods will have to be retained domestically to feed 540 million hungry Americans (Pimentel and Pimentel, 1996). The U.S. along with other exporting countries will cease to be a food exporting

countries.

In the future, when the four major exporting countries retain surpluses for home use, Egypt, Jordan, and countless other countries in Africa and Asia will be without food imports that are basic to their survival. China, which now imports many tons of food, illustrates the severity of this problem. If, as Brown (1995) predicts, China's population increases by 500 million beyond their present 1.2 billion and their soil erosion continues unabated, it will need to import 200-400 million tons of food grains each year starting in 2050. This minimal quantity is equal to more than the current grain exports of all the exporter nations mentioned earlier (USBC, 1996). Based on realistic trends, sufficient food supplies probably will not be available for import by China or any other nation on the international market to import by 2050 (Brown, 1995).

Technology and the Environment

Over time technology has been instrumental in increasing industrial and agricultural production, improving transportation and communications, advancing human health care and overall improving many aspects of human life. However, much of its success is based on the availability of land, water, energy, and biological resources of the earth.

In no area is this more evident than in agricultural production. No known or future technology will be able to double the world's arable land. Granted technologically produced fertilizers are effective in enhancing the fertility of eroded croplands, but their production relies on the diminishing supply of fossil fuels.

The increase in the size and speed of fishing vessels has not resulted in increases in per capita fish catch (Pimentel and Pimentel, 1996). To the contrary for example, in regions like eastern Canada, overfishing has become so severe that about 80,000 fisherman have no fish to catch, and the entire industry has been lost (W. Rees, University of British Columbia, personal communication, 1996).

Consider also the world supplies of fresh water that are available must be shared by more individuals, and for increased agriculture, and for industry. No available technology can double the flow of the Colorado River; the shrinking ground water resources in vast aquifers cannot be refilled by human technology. Rainfall is the only supplier of water.

Certainly improved technology will help increase food production. This includes the more effective management and use of resources, but it

cannot produce an unlimited flow of those vital natural resources that are the raw material for sustained agricultural production. Where is this technology and why has it not been employed, now that cereal grain production per capita has been declining for the past 15 years and continues to decline?

Biotechnology has the potential for some advances in agriculture, provided its genetic transfer ability is wisely used. However, biotechnology that started more than 20 years ago has not stemmed the decline in per capita food production during the past 15 years (Pimentel and Pimentel, 1996). Currently, about 40% of the research effort in biotechnology is devoted to the development of herbicide resistance in crops (Paoletti and Pimentel, 1996). This technology will not increase crop yields, but it will increase the use of chemical herbicides and the pollution of the environment. It will also increase the costs of weed control by farmers.

Planetary Stewardship

Strategies for global food security must be based first and foremost on the conservation and careful management of the land, water, energy, and biological resources required for food production. Our stewardship of world resources will have to change. The basic needs of all people must be brought into balance with the life sustaining natural resources. The conservation of these resources will require the coordinated efforts of all individuals and countries. Once these finite resources are exhausted they cannot be replaced by human technology. Along with this, more efficient and environmentally sound agricultural technologies must be developed and put into practice to support the continued productivity of agriculture (Pimentel and Pimentel, 1996).

Unfortunately none of these conservation measures will be sufficient to ensure adequate food supplies for future generations unless the growth in the human population is simultaneously curtailed. Several studies have confirmed that to enjoy a relatively high standard of living, the optimum human population should be less than 200 million for the U.S. and less than 2 billion for the world (Pimentel et al., 1994). This harsh projection assumes, that from now until such an optimum population is achieved, all strategies for the conservation of soil, water, energy, and biological resources are successfully implemented and an ecologically sound, productive environment is maintained. The lives and livelihood of future generations depend on what the present generation is willing to do now.

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David Pimental, <dp18@cornell.edu>, College of Agriculture and Life Sciences, 5126 Comstock Hall, Cornell University, Ithaca, New York 14853-0901, USA.