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Land, Water And Energy Versus The Ideal U.S. Population

by David Pimentel and Marcia Pimentel

Scientific evidence is mounting concerning rapid population growth in the United States that is causing the deterioration of life-supporting environmental resources (Bartlett and Lytwak, 1995; Grant, 2000, 2003; Pimentel and Pimentel, 2003; Sachs, 2004). Genuine concerns are expressed about future food security, prosperity, quality of human life, and maintaining the personal freedoms Americans now enjoy. The indisputable facts associated with population growth are that more people will require food as well as pure water, energy, and land for all their activities, including urbanization and highways.

Yet as the U.S. population speeds ahead with 3.3 million added people each year, severe soil erosion on croplands continues and further diminishes soil productivity. Fresh water resources even now experience heavy over-use, and conflicts are intensifying, especially between the public and agriculture. Taken for granted are the mostly imported oil and natural gas that power U.S. cars, agriculture, and many other aspects of American life.

Yearly Americans are using twice as much fossil energy as the total solar energy captured by all plants through photosynthesis in the United States each year. Petroleum geologists warn of the approaching end of the petroleum and natural gas era, and even coal reserves are not inexhaustible. Furthermore, uncontrolled U.S. population growth, intensifying soil erosion and degradation on agricultural lands, the overuse of water resources, and pollution combine to reduce the carrying capacity of our ecosystem, not only for humans but for all animals, plants, and microbes.

Population Density and Standard of Living

Humans exhibit a strong will to survive and achieve some level of prosperity and quality of life. Nations as well as individuals differ in their perception of what constitutes an acceptable standard of living. A comparison of some aspects of American and Chinese life reveals startling extremes and helps clarify what future Americans can expect, if our population continues to grow by 3.3 million people each year. Obviously, both birth and immigration rates, as well as the age structure of the population, function in the growth equation.

Annually, approximately 1,700 kg (3,740 lbs) of agricultural products are produced to feed each American, while each Chinese person makes do with 700 kg (1,540 lbs)

Table 1. Foods and feed grains supplied per capita (kg) per year in the U.S., China, and the world. (Pimentel and Pimentel, 2003)

Food/feed	U.S.	China	World
Food grain	92	387	158
Vegetables	191	198	167
Fruits	135	35	60
Meat and fish	91	62	56
Dairy products	272	7	79
Eggs	15	14	8
Fats and oils	31	5	13
Sugar and sweeteners	72	7	25
Nuts	9	NA	1
Total Food	908	715	567
Feed grains	816	70	150
Kcal/person/day	3,800	2,734	2,808

Table 2. Resources used and/or available per capita per year in the U.S., China, and the world to supply basic needs. (Pimentel and Pimentel, 2003).

Resources	U.S.	China	World
Land			
Cropland (ha)	0.50	0.08	0.25
Pasture (ha)	0.83	0.33	0.55
Forest (ha)	0.92	0.11	0.73
Total (ha)	2.25	0.52	1.53
Water (liters X10^6)	1.70	0.46	0.64
Fossil Fuel			
Oil Equivalents (liters)	8,000	700	1,800
Forest products (kg)	1,091	40	70

(Table 1). To produce the food for each American, a total of 1.3 ha (3 acres) of cropland and pasture land is farmed, whereas in China about 0.4 ha (1 acre) per person is required (Table 2). This suggests that each person in China is fed essentially a vegetarian diet. China has nearly reached the carrying capacity of its agricultural system (Pimentel and Wen, 2004).

Especially after 1850, Americans have relied increasingly on the availability of relatively cheap fossil energy sources other than human and draft animals to power their food production. Commercial fertilizers and pesticides made from oil and natural gas, and diesel power machinery have helped farmers diminish the level of personal energy expended to produce crops. **The Chinese have not been as fortunate as Americans and still depend on about 1,200 hours/ha (500 hours/acre) of manual farm labor for cereal grain production, compared with only 8 hours/ha (3 hours/acre) in the United States (Pimentel et al., 2002a; Pimentel and Wen, 2004)**.

China, with its population of 1.3 billion and a land area similar to ours, already is experiencing diminished per capita supplies of food and is importing more cereal grains than ever before. Similar to the United States, the natural environment in China is deteriorating, as evidenced by the intense soil erosion and loss of forests (Pimentel and Wen, 2004). As the U.S. population continues to grow rapidly, our resources and environment inevitably will come under pressures similar to those now evident in China.

STATUS OF U.S. NATURAL RESOURCES

Although many environmental resources function interdependently, at times they can be manipulated to compensate for a partial shortfall of one or more other resources. For example, to bring desert land into crop production, water can be applied to the land, but only if enormous amounts of fresh water are available and if enormous amounts of fossil energy are accessible to pump and apply the irrigation water. This tradeoff is typical of agriculture in many parts of California and other western states, enabling many of the irrigated agricultural regions to be highly productive. However, this is being achieved at a yearly cost of about $5 billion in taxpayer subsidies, plus causing an alarming draw-down of the Colorado River and over-draft of groundwater resources.

Land Resources — More than 99.7% of all U.S. food comes from the land, while less than 0.3% comes from the oceans and other aquatic ecosystems (Pimentel and Pimentel, 2003). Although aquaculture is expanding rapidly, it still depends on ocean resources. For example, 3 to 5 kg of fish meal are required to produce 1 kg of cultured salmon.

Each American now requires 0.5 ha (1.2 acres) of cropland and 0.8 ha (1.8 acres) of pasture land for food production. Thus, significantly more crop, and pasture, and forest land will be required to meet the diverse needs of the rapidly growing U.S. population. **In addition to more cropland and pasture, each person added to the U.S. population will require approximately 0.4 ha (1 acre) of additional land just for urbanization and highways.**

At present, prime crop and pasture land are lost from production because of severe soil erosion caused by rainfall and wind. Indeed, the soil on U.S. cropland is eroding 10 times faster than sustainable soil replacement (NAS, 2003). Pasture land is also losing soil at 6 to 10 times above sustainability rates. Unfortunately, it takes 500 years to replace 2.5 cm(1 inch) of lost soil. Both on-farm and off-farm impacts of erosion cost the nation more than $45 billion each year (Pimentel et al., 1995). Major efforts are critically needed to conserve the fertile agricultural soils that provide us with more than 99% of our food production now and in the future.

Water Resources — Fresh water is vital to maintaining all life, including crop and livestock production. **The average amount of water pumped per American for personal, irrigation, and industrial use is approximately 1.7 million liters (500,000 gallons) per year** (Table 2).

Agriculture is the largest consumer of water in the nation, consuming approximately 80% of total pumped fresh water (Pimentel et al., 2004a). A corn crop that produces about 9,000 kg/ha (140 bushels/acre) requires about 9 million liters/ha (1 million gallons/acre) of water. A 1 pound loaf of bread requires about 250 gallons of water to produce the grains for the loaf.

The rapid increase in water use in the U.S. is stressing both surface and groundwater resources. Currently, groundwater overdraft is 25% higher than its natural replenishment (Pimentel et al., 2004a). **For example, in some regions of Arizona, water from aquifers is being pumped 10 times faster than it is being replenished (Pimentel et al., 2004a)**.

Associated with both surface and groundwater supplies is pollution, which causes serious public health problems. Waterborne infections account for approximately 940,000 infections and approximately 900 deaths each year (Seager, 1995). Nearly 40% of treated drinking water supply in the U.S. is contaminated with dangerous microorganisms (Platt, 1996). Waterborne disease outbreaks in the U.S. are caused by microbial pollution, like E. coli, characterized by severe diarrhea and occasionally death. In addition, some ground and stream water is more than 90% polluted with significant quantities of harmful chemicals from agriculture and industry. Approximately 80,000 different chemicals are used in the U.S. and many adversely affect human health as well as plants, animals, and microbes.

Threats to Biodiversity — The United States is home to about 750,000 species of plants, animals, and microbes. **Most of these natural biota are beneficial and help in recycling of organic wastes, degrading chemical pollutants, pollinating crops and other plants, and/or purifying water resources** (Pimentel et al., 1997). Human population expansion accompanied by the loss of natural habitats due to urbanization, highways, and agriculture is the major cause of biodiversity loss.

Over time more than 50,000 alien species have invaded U.S. ecosystems where they are responsible for an estimated $120 billion in both damage and control costs each year. (Pimentel, 2002). **These invasive alien species are responsible for about 40% of the extinctions of native U.S. species**. Two of the recent introductions, the West Nile Virus and the SARS flu virus, cause severe human illness.

Another major threat to biodiversity is the application of more than 500,000 kg (1 billion pounds) of pesticides each year, applied primarily to U.S. agriculture. Surprisingly little pesticide reaches the target pests (less than 0.01%) — this means that more than 99.9% pollutes the environment where it kills many beneficial organisms (Pimentel, 1995). About 72 million birds are killed by pesticides each year. Pesticides also non-fatally poison 300,000 humans per year in the U.S.

Fossil Energy Resources — Ample supplies of fossil energy have supported all aspects of American life, including its relative affluence and rapid rate of population growth. In addition, fossil energy helps to control human diseases and to increase food production. Specifically, in food production, for each food calorie consumed by humans, approximately 10 calories of fossil energy are expended (about one third each for agricultural production, processing and packaging, and distribution and cooking). In total, the U.S. food system consumes about 17% of fossil fuel (about 400 gallons of oil equivalents per person each year).

In contrast to the U.S. food system, our transportation sector consumes 27% (Pimentel et al., 2004b). Thus far, our government spends $40 billion each year in subsidies to keep fossil fuel prices artificially low. Each U.S. family pays the federal government $410 for this unrealistic subsidy policy (Pimentel et al., 2004b). The subsidized, low gasoline prices encourage Americans to drive large SUVs and pick-up trucks that consume more fossil energy. Further, this high energy consumption speeds the depletion of U.S. oil supply and requires the importation of more oil from Saudi Arabia and other nations.

Transition from Fossil to Solar Energy

The United States is nearing the "bottom of the barrel" relative to oil and natural gas reserves. Nearly 90% of U.S. oil reserves have been pumped out and the U.S. is importing 61% of its oil at an annual cost of $100 billion each year (USBC, 2003). Concurrently, Americans are facing serious shortages of natural gas as reflected in the doubling of natural gas prices in 2003 (USBC, 2003). Experts project that natural gas reserves in the U.S. will be depleted in about 20 years.

Indeed, worldwide reserves of both oil and natural gas are limited. Optimistic projections suggest 40 to 50 years of oil and natural gas reserves (Youngquist, 1997, Youngquist and Duncan, 2003). Nearly 100 years of coal reserves remain, depending on how fast they are utilized as a substitute for oil and natural gas.

Instead of relying on the finite supplies of fossil energy, new research should be focused on practical ways to convert solar energy into usable energy for society. Many solar energy technologies already exist, and should be made more efficient. These include energy from biomass, photovoltaics, solar thermal receivers, wind power, and hydropower.

Based on using combinations of these technologies in suitable geographic regions, an estimated 46 quads of solar energy (mostly as electricity) could be produced each year (Pimentel et al, 2002b). **Note, 46 quads is slightly less than half of the 100 quads of fossil energy currently consumed in the U.S. each year (USBC, 2003)**. Furthermore to produce the 46 quads of solar energy would require the use of a U.S. land area that is nearly equal to total U.S. cropland now in production.

The estimated land area required to produce just the **electricity** used by each American each year ranges from 0.01 ha (0.03 acre) for wind power, parabolic troughs, and photovoltaics to 2 ha (5 acres) for forest biomass. Sustainable forest biomass only collects 0.1% to 0.2% of the solar energy reaching the forest, in contrast to 10% to 20% collected by photovaltaics (Pimentel et al., 2002b).

If the present population of Americans were to rely fully on the 46 quads of solar energy, each person's energy consumption would have to be reduced by one-half. Could this be accomplished and still provide a relatively high standard of living? The answer is yes, based on the fact that Europeans enjoy a high standard of living, even though they consume about half the energy of Americans per capita.

Toward a Sustainable Agriculture

Faced with ever increasing numbers of people in the U.S. to feed, the serious question is how can agricultural production be made ecologically sound and sustainable? The critical first step is to conserve soil and water resources by employing such well-proven technologies as crop rotations, cover crops, strip crops, grass strips, no-till, and combinations of these technologies. For example, employing crop rotations would help reduce insecticide use in crops while at the same time increasing crop yields (Pimentel and Lehman, 1993). These technologies not only help conserve soil and water resources, but enhance crop yields and economic benefits (Pimentel et al., 2004a).

Legislation is needed to support the return of livestock production to grain farms where it was located prior to 1950. Currently, separated livestock production leads to manure that is under utilized, wasted, or allowed to pollute water resources (NAS, 2003). This is a costly loss.

Prosperity and Population

If the U.S. were to move to a solar energy-based economy and become self-sufficient, what would be our options and levels for prosperity? Even with self-sustaining solar energy systems replacing our current dependence on fossil energy, the energy available would be less than one-half of our current consumption level. If the U.S. population remained at its current level of nearly 300 million, a significant reduction in our present standard of living would follow. This would occur, even if all the energy conservation measures known today were adopted.

If, however, the Americans wish to continue their current high level of energy use and standard of living and prosperity, then its ideal population should be targeted at about 50 million people. This is, of course, unlikely to occur.

Future Prospects

The current population of the U.S. of nearly 300 million is projected to double to about 600 million in less than 70 years, based on the current growth rate of 1.1% per year. At present there is no indication that the growth in the U.S. population will be slowed, and unless this growth rate changes within 140 years the U.S. population will equal the present day population of China. In fact, the U.S. population is now increasing at a rate twice as fast as that of China. Comparisons to China emphasize why the U.S. will be unable to maintain its current level of prosperity and high standard of living if population numbers continue to rise .

Our American society does not seem to understand how overpopulation adversely impacts our environment and finite natural resources that support all U.S. life. Our record of effectively conserving and protecting essential environmental resources from over-exploitation is poor.

When decisions concerning the environment and natural resources are made in the United States, they are often **ad hoc** decisions, designed only to protect a particular aspect of human well-being and/or the environment at the moment. All too often solutions are sought only after a problem reaches a crisis. For example, the alarming U.S. water resource problem in the Cuyahoga River in Ohio was not acted upon until water pollution was so severe that the river was burning! As Benjamin Franklin wrote long ago in *Poor Richard's Almanac*, "it is not until the well runs dry, we know the worth of water."

Based on past experience, it will not be until the pressure of the U.S. human population on the environment and natural resources becomes intolerable that some corrective action will be taken by individuals and the government. Then it may be too late to avert further poverty and disease in the U.S. These devastating situations already exist in many parts of the world. According to the World Health Organization more than 3 billion are malnourished or more than half of the world population (WHO, 2003). This is the largest number and proportion of malnourished people ever reported! The World Health Organization in assessing malnutrition includes deficiencies in calories, protein, vitamins A, B, C, D, and E, and iron, and iodine. Note, many people die from deficiencies from any one or a combination of these nutrient shortages. We need to prevent this from happening in America and elsewhere in the world.

Reducing the U.S. population to 200 million, while reducing the consumption of energy and other resources by one-half, is a first difficult step. Then, with the effective development of solar energy technologies, a quality of life similar to that of our European friends would be possible. The United States has been fortunate to have abundant land, water, solar energy, and biological resources, but we must balance population size with our natural resources. Let us not waste time and undertake positive steps to ensure that our next generation will have the opportunity to enjoy an ample food supply and the personal freedoms that we have treasured.

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