Ethical Issues of Global Corporatization: Agriculture and Beyond

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ABSTRACT The world food supply has become inadequate for more than half the world population, as evidenced by a recent report of the World Health Organization that indicated that more than 3 billion people are malnourished. This is the largest number of malnourished ever reported. Per capita food production, especially cereal grains, has been declining for nearly 2 decades, despite new biotechnology and other agricultural technologies. Rapid human population growth, compounded by diminishing availability of fertile cropland, freshwater, and fossil fuels, is intensifying the emerging problems in all food production systems. Numerous ethical issues are related to the problem of malnutrition, including global corporatization.

(*Key words*: agriculture, globalization, natural resources, nutrition, population)

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INTRODUCTION

As the world's population enters this new millennium, stark contrasts become apparent between the availability of the natural resources of our earth and the billions of humans who require them for their survival. Each day about a quarter million people are added to the more than 6.2 billion that already exist (PRB, 2002). Meanwhile, the availability of natural resources that support human life, such as food, fresh water, quality soil, energy, and biodiversity, are being degraded or polluted, and some are being depleted.

Balanced against the natural resources of the earth are the basic life requirements of humans and how their health, quality of life, and survival are threatened. Many of the earth's resources, especially those that are finite, such as fossil fuel, are being depleted either by careless usage or exploitation. The on-going impact of population growth is felt on all life-supporting natural resources.

Global corporations are contributing to the production of relatively inexpensive foods, such as chicken, but also have negative impacts on the environment and public health. These tradeoffs and ethical issues are examined.

MALNOURISHMENT IN THE WORLD

According to the World Health Organization, more than 3 billion people are malnourished (WHO, 1996, 2000). This is the largest number and proportion of malnourished people ever reported. The World Health Organization's assessment of malnutrition includes deficiencies of calories, protein, iron, iodine, and vitamins A, B, C, and D in its evaluation (Sommer and West, 1996; Tomashek et al., 2001). Humans die from shortages of any one of these nutrients or combinations of shortages of these nutrients.

In addition, the current report of the Food and Agricultural Organization (FAO) of the United Nations confirms that food per capita has been declining since 1984, based on available cereal grains (FAO, 1961–1999) (Figure 1). This news is alarming because cereal grains make up about 80% of the world's food supply. Although grain yields per hectare in both developed and developing countries are still increasing, the rate of growth is slowing; however, the world population and its food needs are escalating (FAO, 1961–1999; PRB, 2002). Specifically from 1950 to 1980, US grain yields increased at about 3% per year, but since 1980 the annual rate of increase for corn and other major grains has declined to a yearly increase of only about 1% (Pimentel et al., 2002).

WORLD POPULATION GROWTH

The current world population stands at more than 6.2 billion (PRB, 2002) and has doubled during the last 45 yr. Based on the present growth rate of 1.3% per year, the population is projected to double again within a mere 54 yr (Figure 2).

Many countries and world regions have populations that are experiencing especially rapid growth. For example, China's present population is 1.3 billion and, despite the governmental policy of permitting only one child per couple, its growth continues at an annual rate of 1.3% (PRB, 2002). But China, recognizing its serious overpopulation problem, has recently passed legislation that strengthens its one-child-per-couple policy (China, 2002).

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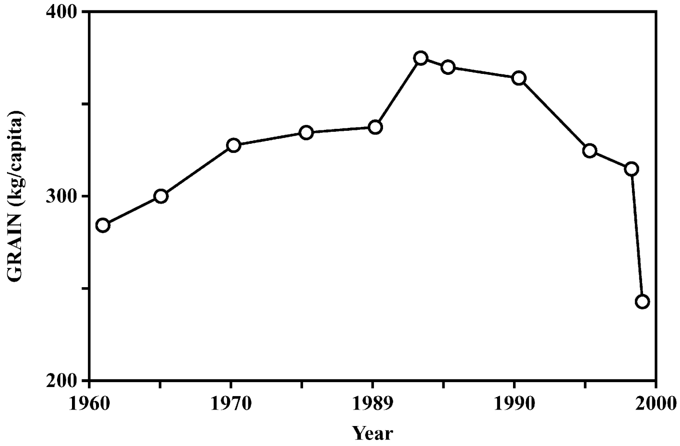

FIGURE 1. Per capita cereal grain production from 1961 to 1999 in the world.

However, because of the young age structure of the Chinese population, its growth rate will continue to increase for another 50 yr. India, with about 1 billion people living on approximately one-third the land area of the US or China, has a current population growth rate of 1.9%, which translates into a doubling time of 37 yr (PRB, 2002). Taken together, the populations of China and India constitute more than one-third of the total world population.

Also, the populations of most of African countries are expanding. For example, populations in Chad and Ethiopia have such high rates of increase that they are projected to double in 21 and 23 yr, respectively (PRB, 2002). Similarly in Latin America, populations of Paraguay and Mexico are projected to double in 26 and 37 yr, respectively (PRB, 2002). In contrast, the European populations are increasing but at extremely slow rates (PRB, 2002).

The US population, which also continues to grow, currently stands at 285 million and has doubled during the past 60 yr (Figure 3). Based on its current growth rate of more than 1%, it is projected to double to 570 million in just 70 yr (Figure 3).

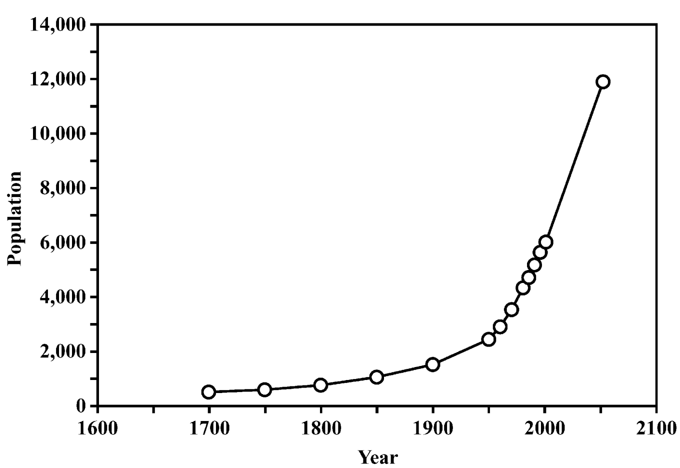

FIGURE 2. World population growth and projected growth based on the current population growth rate of 1.3% per year.

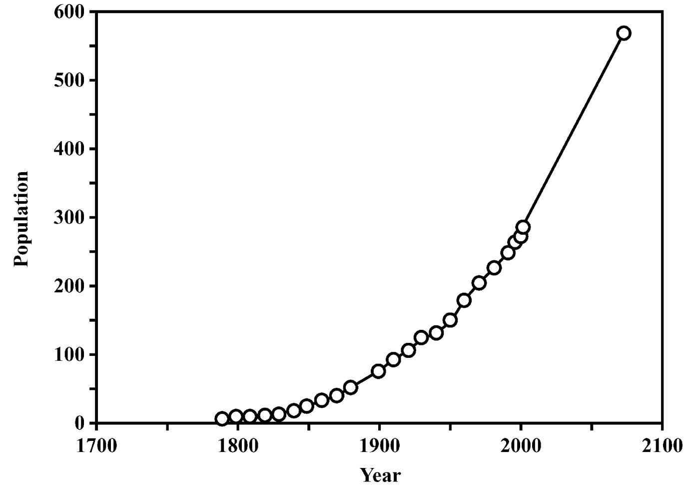

FIGURE 3. US population growth and projected growth based on the current population growth rate of about 1% per year.

The major factor that must be considered is the young age structure of most current populations and the population momentum that it fosters. With ages that range from 15 to 40 yr, reproductive rates are high, and the cycle of increase is perpetuated with each succeeding generation (PRB, 2002). Even if all the people in the world now adopted a policy of 2 children per couple, it would take approximately 70 yr before the world population would finally stabilize at approximately 12 billion or twice the current level (Population Action International, 1993; Pimentel and Pimentel, 2003a) (Figure 4). As the world and US populations continue to expand, all vital natural resources of the world will have to be divided among increasing numbers of people, and per capita availability will decline to dangerously low levels. Then, maintaining prosperity, a quality life, and personal freedoms will be imperiled (Pimentel et al., 1999).

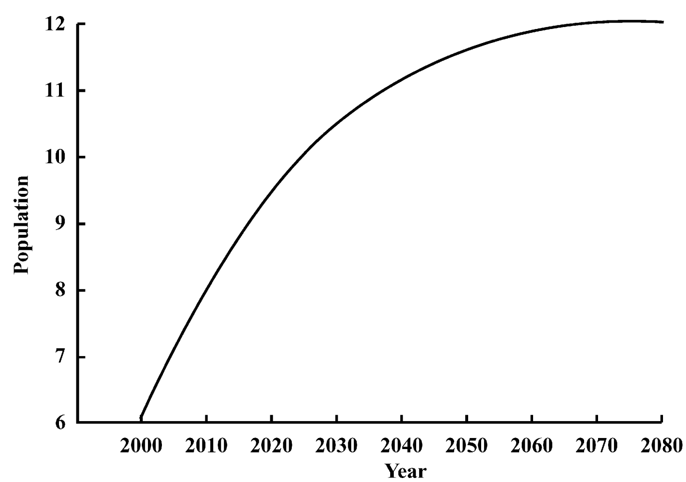

FIGURE 4. Population project stabilization assuming a 2-child average per couple adopted in 2000 (Weeks, 1986; Population Action International, 1993).

WORLD CROPLAND RESOURCES

More than 99.7% of human food comes from the terrestrial environment, whereas less than 0.3% is from the oceans and other aquatic ecosystems (FAO, 1998; Pimentel and Pimentel, 1996). Worldwide, of the total of 13 billion ha of land area, the percentages in use are as follows: cropland, 11%; pasture land, 27%; forest land, 32%; urban, 9%; and other 21%. Most of the other land area (21%) is unsuitable for crops, pasture, or forests because the soil is too infertile or shallow to support plant growth, or the climate and region are too cold, dry, steep, stony, or wet (Buringh, 1989; FAOSTAT, 1994).

Per Capita Cropland

The availability of cropland influences the kinds and amounts of foods produced. For example, currently, agricultural products totalling 1,481 kg/yr per capita are produced to feed Americans, whereas the Chinese food supply averages 785 kg/yr per capita (Pimentel and Pimentel, 2003a). By all available measurements, the Chinese have reached or exceeded the limits of their agricultural system (Brown, 1997). Furthermore, their reliance on large inputs of fossil fuel-based fertilizers to compensate for shortages of arable land and severely eroded soils, plus their limited fresh water supply, suggests severe problems looming in the near future (Wen and Pimentel, 1992). Even now China imports large amounts of grain from the US and other nations and is expected to increase imports of grains in the near future (Alexandratos, 1995).

Loss of Cropland

In addition to the intrusion of humans and their activities on the earth's land area, degradation of soil has emerged as a critical agricultural problem (Lal and Stewart, 1990; Pimentel and Kounang, 1998). Worldwide, current erosion rates are greater than ever previously recorded (Lal and Stewart, 1990; Pimentel et al., 1995).

Worldwide, more than 10 million ha of productive cropland are severely degraded, and they are abandoned each year (Houghton, 1994; Pimentel et al., 1995). To compensate, about 10 million ha of new land are put into production each year to support food production. Most of the replacement cropland yearly comes from the world's forest areas (Houghton, 1994; WRI, 1996). This urgent need accounts for more than 60% of the massive deforestation now occurring worldwide (Myers, 1990).

Soil erosion degrades and diminishes the productivity of cropland and pasture land (Pierce and Lal, 1991; Pimentel et al., 1995). The primary causes of this degradation are rainfall and wind erosion, as well as the salinization and waterlogging of irrigated soils (Kendall and Pimentel, 1994).

Agriculturists know that the fertility of nutrient-poor soil can be improved by large inputs of fossil fuel-based fertilizers that are expensive, especially for poor farmers. This practice, however, increases dependency on the finite fossil fuels stores used in the production of fertilizers. Even with current fertilizer use, soil erosion remains a critical problem in current agricultural production (Pimentel et al., 1995).

In summary, the growing shortage of productive cropland is one of the underlying causes of the current worldwide food shortages and poverty in many regions of the world (Leach, 1995; Pimentel and Pimentel, 1996).

WATER RESOURCES

For survival, all plant and animal life requires significant quantities of freshwater. The *total* amount of water made available by the world hydrologic cycle is sufficient to provide the *current* world population with a minimal amount of fresh water. Yet, world water supplies are concentrated in some areas, and other areas are short of water or outright arid.

Water for Human Consumption

The minimum water requirement for human health, including drinking water, is considered to be about 50 L per capita per day (Gleick, 1996). The US average for all domestic usage, however, is 8 times higher than that figure, or 400 L per capita per day (Postel, 1996). Most Americans use water freely in their homes and gardens, on golf courses, and in their irrigated agriculture.

Rapid human population growth and its associated increased water needs already are stressing the world's water resources. Water use worldwide has doubled in 20 yr, whereas the world population required 50 yr to double. Worldwide, between 1960 and 1997, the per capita availability of freshwater worldwide declined by about 60% (Hinrichsen, 1998).

Water demands already far exceed supplies in nearly 80 world nations (Gleick, 1993). For instance, in China more than 300 cities suffer from inadequate water supplies, and the problem is quickly intensifying as the population increases (WRI, 1994; Brown, 1995).

Water for Food Production

All vegetation requires enormous quantities of water during the crop growing season. For example, an average corn crop that produces about 8,000 kg of grain per hectare uses more than 5 million L of water per hectare during its growing season (Pimentel et al., 1997a). To supply this much water to the crop, approximately 1,000 mm of rainfall per hectare must reach the plants. If irrigation is required, about 14 million L of irrigation water is required during the growing season (Pimentel et al., 1997a).

Sources of Water

Rainfall provides all the water found in streams, rivers, lakes, and oceans and it is a vital part of the hydrologic cycle (Gleick, 1993). Frequently, surface water is not managed effectively, resulting in water shortages and pollution, both of which threaten humans and the aquatic biota. The Colorado River, for example, is used so heavily by Colorado, California, Arizona, other adjoining states, and Mexico that under normal years little or no water reaches the Sea of Cortez. These water shortages and the pollution experienced in the lower Colorado River have destroyed many important aquatic species there.

Similarly, in the US groundwater overdraft is high, averaging 25% greater than natural replacement rates (Pimentel et al., 1997a). A critical problem now is occurring in the vast Ogallala aquifer located under Kansas, Nebraska, and Texas. There the annual depletion rate is 130 to 160% above replacement (Beaumont, 1985). If these rates continue, this large aquifer, which supports major agricultural irrigation and countless communities in central US, is expected to become nonproductive by 2030 (Soule and Piper, 1992).

Obviously rapid population growth and increased total water consumption combine to rapidly deplete water resources. The future availability of adequate supplies of fresh water for human and agricultural needs appears critical in many world regions, especially the Middle East and parts of North Africa where low rainfall is endemic and populations continue to increase (Gleick, 1993, 2002).

Irrigation

Irrigation enables crop production to succeed in arid regions, provided there are adequate sources of fresh water. Currently, approximately 70% of the water removed from all sources worldwide is consumed solely for irrigation (Postel, 1997; White, 2001). Of this volume, about two-thirds is consumed by growing plant life and is nonrecoverable for other uses (Postel, 1997). On average an irrigated corn crop requires about 14 million L of water per hectare and requires about 3 times more energy to produce the same yield as rainfed corn (Pimentel et al., 1997a; Pimentel et al., 2002). Also, the costs of irrigation are high, with the irrigation per hectare costing about $1,000.

Irrigation often results in salinized and waterlogged soils, both of which diminish crop productivity. These problems result from continuous irrigation (Postel, 1997).

Water Pollution

A major threat to maintaining ample fresh water resources is pollution. Although considerable water pollution has been documented in the US (USBC, 2001), this problem is of greatest concern in countries where water regulations are not rigorously enforced or do not exist. This was common in the early 1990s in developing countries which discharge approximately 95% of their untreated urban sewage directly into surface waters (WHO 1993). For instance, of India's 3,119 towns and cities, in the early 1990s only 8 possessed full waste-water treatment facilities (WHO 1992). Downstream, such polluted water is used for drinking, bathing, and washing.

Serious water pollution problems exist in the US. EPA (1994) reports indicate that 37% of US lakes are unfit for swimming because of runoff pollutants and contamination from septic discharge. In addition, pesticides, fertilizers, and soil sediments pollute water resources when they accompany eroded soil into water bodies.

Industries all over the world dump untreated toxic chemicals into rivers and lakes (WRI, 1991). Thus, pollution from sewage and disease organisms, as well as the 100,000 different chemicals used globally, makes water unsuitable not only for human drinking but also for application to crops (Nash, 1993).

Eroded soil sediments washed into reservoirs during rainfall creates another problem. Estimates are that about 1% of the volumes of reservoirs are filled with sediments each year, thereby reducing the volume of water available for irrigation and other purposes (UNEP, 2002). The total cost of sedimentation plus the loss of the water storage capacity of each dam worldwide is estimated to be about $7.5 million per year (White, 2001). To dig and remove the soil sediments deposited in the reservoirs is considered impractical and too costly.

ENERGY RESOURCES

For centuries, humans have relied on various sources of power. Solar energy is vital to the survival of all natural ecosystems. Over time the energy sources have ranged from human, animal, wind, tidal, and water energy, to wood, coal, gas, oil, and nuclear sources for fuel and power. Since about 1700, abundant fossil fuel energy supplies have made it possible to augment agricultural production to feed an increasing number of humans, as well as improve the quality of human life in many ways. In addition, human travel, trade and the transportation of food, and manufactured goods have benefited from the availability of fossil energy. Energy availability has made possible the purification and transport of water and, by plant production, the manufacture of thousands of drugs and pharmaceuticals (Pimentel and Pimentel, 1996).

In essence ample energy supplies, especially fossil energy, have supported rapid population growth, industrialization, transportation, and urbanization (Pimentel and Pimentel, 1996). Worldwide about 412 quads (1 quad = 10^{15} BTU, 0.25×10^{15} kcal, or 433×10^{18} Joules) from all energy sources are used each year (International Energy Annual, 1995). The rate of energy use from all sources has been increasing even faster than world population growth. Thus, from 1970 to 1995, energy use increased at a rate of 2.5% per year (doubling every 30 yr) compared with the worldwide population growth of 1.3% per year (doubling about 54 yr) (PRB, 2002; International Energy Annual, 1995). During the next 20 yr, energy use is projected to increase at a rate of 4.5% per year (doubling every 16 yr) compared with the human population doubling every 54 yr (PRB, 2002; International Energy Annual, 2001).

Although about 50% of all the solar energy captured by worldwide photosynthesis is used by humans, it is

TABLE 1. Resources used or available per capita per year in the US, China, and the world to supply basic needs (Pimentel and Pimentel, 2003b)

Resource	US	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)	3.25	0.52	2.13
Water (liters × 10^6)	1.7	0.46	0.64
Fossil fuel oil equivalents (L)	8,000	700	1,800
Forest products (kg)	1,091	40	70

still inadequate to meet all of human needs for food and other needs (Pimentel, 2001). To make up for this shortfall, about 348 quads of fossil energy, mainly oil, gas, and coal, are utilized worldwide each year for all activities (International Energy Annual, 2001). Of this, 90 quads of fossil energy are utilized in the US (USBC, 2001).

This means that, each year, the US population uses 100% more fossil energy than all the solar energy captured by US crops, forest products, and other vegetation (Pimentel and Pimentel, 1996). Industry, transportation, home heating, and food production account for most of the fossil energy consumed in the US (DOE, 1991, 1995).

Per capita use of fossil energy in the US is 8,000 L of oil equivalents per year, more than 12 times the per capita use in China (Table 1). In China, most fossil energy is used by industry, although a substantial amount, approximately 25%, now is used for agriculture and the food production system (Smil, 1984; Wen and Pimentel, 1992).

Together, developed nations annually consume about 70% of the fossil energy worldwide, whereas the developing nations, which have about 75% of the world population, use only 30% (International Energy Annual, 2001) The US, with only 4% of the world's population, consumes about 24% of the world's fossil energy output (Pimentel and Pimentel, 2003b).

Some developing nations experiencing high rates of population growth are increasing fossil fuel use to augment their agricultural production of food and fiber. For example, in China since 1955, there has been a 100-fold increase in fossil energy use in agriculture for fertilizers, pesticides, and irrigation (Wen and Pimentel, 1992).

In general, fertilizer production has declined by more than 17% since 1989, especially in the developing countries, because of fossil fuel shortages and high prices (Vital Signs, 2001). In addition, the overall projections of the availability of fossil energy resources for fertilizers, pesticides, and all other agricultural purposes are discouraging because the stores of these finite fossil fuels are being utilized.

BIODIVERSITY

In addition to crop, forest, and livestock species, human life depends on the presence and functioning of approximately 10 million plant, animal, and microbe species existing in agroecosystems and throughout the vast natural environment (Pimentel et al., 1992; Sagoff, 1995). Although approximately 60% of the world's food supply comes from rice, wheat, and corn species (Wilson, 1988), as many as 20,000 other plant species are used by humans to some extent for human food (Vietmeyer, 1995).

Humans have no technologies which can substitute for the food, medicines, and diverse services that plant, animal, and microbe species provide. For example, one-third of the human food supply relies either directly or indirectly on effective insect pollination (O'Toole, 1993). Each year, honeybees and wild bees are essential in pollinating about $40 billion worth of US crops (Pimentel et al., 1997b); they also pollinate natural plant species. Including pollination, the economic benefits of biodiversity in the US are estimated as $300 billion per year and nearly $3 trillion worldwide (Pimentel et al., 1997b).

Indeed, plants, animals, and microbes also carry out many other essential activities for humans, recycling manure and other organic wastes, degrading some chemical pollutants, as well as purifying water and soil (Pimentel et al., 1997b). Most (98%) of world agriculture depends on introduced species of plants and animals. However, other introduced species are causing extinctions of native species worldwide (Pimentel et al., 2000; Pimentel et al., 2001). In addition, the invasive species are having negative impacts on food production and the economies of nations. For instance, in the US invasive species are causing more than $137 billion in damages each year (Pimentel et al., 2000).

NATURAL RESOURCES AND HUMAN DISEASES

Human health may seem unrelated to natural resources, but upon closer examination it becomes apparent that both the quality and quantity of all natural resources (e.g., food, water, and biodiversity) play a central role in maintaining human health. As populations increase in size, risks to health and productivity grow as well, especially in areas where sanitation is inadequate. In view of rapid population growth, it is not surprising that human deaths due to infectious diseases increased more than 60% from 1982 to 1992 (WHO, 1992, 1995; Murray and Lopez, 1996). Worldwide approximately 50 million deaths are caused by diseases associated with water, food, air, and soil each year (WHO, 1995).

Profound differences exist in the causes of human death between developed and developing regions of the world. Communicable, maternal, and prenatal diseases account for 40% of the deaths in developing regions compared with only 5% in developed regions. Although there is a complex set of factors responsible, inadequate food and contaminated water and soil are the major causes of diseases, especially in developing countries (Pimentel et al., 1998).

About 90% of the diseases occurring in developing countries are associated with the lack of clean water (WHO, 1992). Worldwide, about 4 billion cases of disease are contracted from polluted water (WHO, 1992). Shistosomiasis and malaria, common diseases throughout the tropics, are examples of parasitic diseases associated with aquatic systems.

In part due to malnutrition and overcrowding of the world population, several diseases, such as tuberculosis, malaria, and AIDS, are rapidly increasing. For instance, an estimated 2 billion people are infected with tuberculosis and 2 to 3 billion are infected with malaria (WHO, 2001; Malaria Infections, 2002).

Intestinal parasites introduced into humans through contaminated food, water, and soil impact health by reducing the nutritional status of infected individuals in various ways. This includes the rapid loss of food nutrients through diarrhea or dysentery, impairment of nutrient absorption, alteration of appetite and food intake, and also blood loss (Shetty and Shetty, 1993). For instance, hookworms, which thrive in moist soils of the tropics, can remove up to 30 cc of blood from a person in a single day, leaving the person weak and susceptible to additional diseases (Hotez and Pritchard, 1995). Estimates are that from 5 to 20% of an infected person's daily food intake is metabolized to offset the illnesses and physical stress caused by disease, thereby diminishing the nutritional status and ability to resist other diseases (Pimentel and Pimentel, 1996).

Certainly human nutrition would be improved with a more equitable distribution of the total world food produced. For instance, it might be possible to feed the current 6.2 billion people a minimal but nutritionally adequate diet if all food produced in the world was shared and distributed equally (Cohen, 1995). However, there are problems with this proposal. For example, how many people in developed and developing countries, who have more than their basic food resources, would be willing to share their food and pay not only for its production but also for its worldwide distribution? Also, if the world population doubles to 12 billion within the next 54 yr, this option probably would not be possible because severe shortages of land, water, energy, and other biological resources will curtail the production of adequate food supplies (Abernethy, 1993).

MEAT-BASED DIETS INCLUDING POULTRY

Meat production is a major sector of American agriculture. The average American consumes 124 kg of meat and 20 kg of fish per year (Pimentel and Pimentel, 2003a). Poultry consumed totals 48 kg per person per year (FAOSTAT, 2001). Additional animal protein consumed includes milk and eggs. The daily total calories contributed by meat and fish consumed per day is 480 kcal per person.

Animal protein foods are considered complete protein based on their outstanding amino acid profile which has a biological value of 1.4 times that of grain protein (Pimentel and Pimentel, 1996). In addition, most animal protein foods contribute vitamin B_{12}, many other B vitamins, and minerals to the daily diet. Animal foods vary in their fat content, according to species and feeding procedures.

To provide the feed for animals, pasture and grain crops are required. Land areas committed to providing these feeds amount to 460 million ha and require adequate water, fertilizers, and other inputs (Pimentel and Pimentel, 1996). To produce 1 kg of high quality animal protein, livestock, including poultry, are fed about 6 kg of plant protein. In the conversion of plant protein to animal protein, there are 2 principal inputs or costs: (1) the direct costs of production of the harvest animal including its feed, and (2) the indirect costs for maintaining the breeding stock herds.

Considerable fossil energy is expended in livestock production systems (Table 2). For example, broiler chicken production is the most highly efficient with an input of 4 kcal of fossil energy for each 1 kcal of broiler protein produced. The broiler system is primarily dependent on grain feed. Turkey production, also a grain feeding system, is next in efficiency with a ratio of 10:1. Milk production, based on a feed mixture of two-thirds grain and one-third forage, is also relatively efficient with a ratio of 14:1. Both pork and egg production also depend on grain feed for production (Table 2). Pork production has a ratio of 14:1, whereas egg production has a 39:1 ratio (Table 2).

The 2 livestock systems that depend most heavily on forage but also use significant amounts of grain are the beef and lamb production systems. The beef system has an energy ratio of 40:1, whereas the lamb system has the highest with a ratio 57:1 (Pimentel, 2003). If these animals were fed only on good quality pasture, the energy inputs could be reduced by about half.

The average fossil energy input for all the US animal protein production systems studied is 25 kcal fossil energy input per 1 kcal of protein produced (Table 2). This energy input is more than 11 times greater than that for grain protein production, which averages about 2.2 kcal per kcal of protein produced. This latter calculation is based on corn production and assumes 9% protein content in the corn.

In the US, more than 9 billion head of livestock, including 8 billion chickens, are maintained to supply the animal protein consumed each year (USDA, 2001). This livestock population on average outweighs the US human population by about 5 times. As mentioned, some livestock, such as poultry and hogs, consume only grains, whereas dairy cattle, beef cattle, and sheep (lambs) consume grains and forage. At present, the total US livestock population consumes 250 million tons or more than 7 times as much grain as is consumed directly by the entire American population (USDA, 2001). The amount of grain fed to US livestock is sufficient to feed about 840 million people who are plant-based vegetarians.

In recent decades, changes in the technologies of crop and animal production have been expanding. The small family farm is disappearing and being replaced by large farms (USDA, 2001). These "factory farms" dominate the poultry industry, with about 98% of all poultry produced by large corporations (Farm Aid, 2003). The result is low price chicken to the consumer.

TABLE 2. Grain (USDA, 2001) and forage (Morrison, 1956; Heitschmidt et al., 1996) inputs per kilogram of animal product produced and fossil energy inputs (kcal) required to produce 1 kcal of animal protein

Livestock	Grain (kg)	Forage (kg)	Input (kcal)/ protein (kcal)
Lamb	21	30	57:1
Beef cattle	13	30	40:1
Eggs	11	—	39:1
Beef cattle	—	200	20:1
Swine	5.9	—	14:1
Dairy (milk)	0.7	1	14:1
Turkeys	3.8	—	10:1
Broilers	2.3	—	4:1

When managed successfully, corporations can set and monitor high sanitary standards as well as control environmental pollution. Unfortunately there are examples of increased odor as well as land and water pollution associated with large livestock production facilities (NAS, 2003). State and Federal authorities are strengthening the regulations of these giant producers as evidenced by fines and required upgrades of waste management associated with these large farms. Indeed, a Goldsboro, North Carolina, hog farm illustrates how secure controls of sanitation throughout the entire production system pays off in safe, disease-free animals (Biological Threat, 2001). This is not only an asset for the livestock producer, but it helps reduce pollution and protects the consumer from microbe contaminants and foul odors.

On the negative side of the large corporation production is the problem of water and land pollution (NAS, 2003). For example, hog waste produced in North Carolina is about 4 times that produced by the total human population of 8 million in North Carolina (Factoryfarm, 2003; Eatraw, 2003). The large factory farms and increased pollution associated with these farms has increased foodborne diseases in humans in the US. For example, claims are made that 76 million humans in the US suffer from foodborne infections each year, resulting in about 5,000 deaths (DeWaal et al., 2000).

From the US livestock population, a total of about 8 million metric tons of animal protein is produced annually. Assuming an average distribution, this protein is sufficient to supply about 77 g of animal protein daily per American. With the addition of about 35 g of available plant protein consumed per person, a total of 112 g of protein is available per capita in the US per day (USDA, 2001). Note that the dietary guidelines for an adult per day is 56 g of protein for a mixed diet. Therefore, it is apparent that each American consumes about twice the needed protein. In addition to consuming too much protein, people on average are consuming about 1,000 kcal too much per day per capita (CDC, 2002; Surgeon General, 2002).

CONCLUSIONS

In conclusion, balancing the population-resource equation worldwide will be difficult because overpopulation, uneven distribution of resources, and environmental degradation have reached unsustainable levels. The growth in human numbers is relentless, and its adverse affect on the earth's resources mounts each day and year.

Meanwhile, the world population is projected to increase from the current 6.2 billion to 12 billion in about 54 yr, based on the current growth rate. Despite all projections about human population growth, no one really knows exactly how large the human population will be in 50 yr. We do know the 6.2 billion people already on earth are stressing the earth's land, water, and biological resources and polluting the environment and that more than 3 billion malnourished people are too many.

Clear evidence documents that major difficulties exist in providing a healthy food supply for the expanding human population. Cereal grain production worldwide, which provides most of the world's food, is increasing per hectare, but per capita cereal grain production has been declining for nearly 2 decades. In the US, livestock production, including poultry, has been increasing. As this has occurred, a large portion of this production has been by large corporations gradually replacing family farms.

Basically the success of agriculture depends on vast amounts of cropland, water, and fossil energy. Vegetable protein food requires less land, water, and energy than animal protein, because most livestock are fed grains.

All agriculture must seek ways to protect the vital resources required for crop and livestock production. Pollution of air, water, and soil must be reduced. Those farmers who produce livestock products have the added challenge of managing animal wastes safely to prevent the contamination of air, water, and land resources.

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