EarthTrends: Featured Topic

Title:	**Inexhaustible Appetites: Testing the Limits of Agroecosystems**
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Progress in Feeding the World Varies by Region

Tallied on a global basis, total food production and per capita food production have both risen significantly from 1960 to 1998, but a regional breakdown shows a more complex picture. In Latin America, both total and per capita production have risen markedly. Meanwhile, in Africa, food needs rose faster than total production, so per capita food production has fallen.

Figure 1a: Trends in World Food Production, 1961-1998

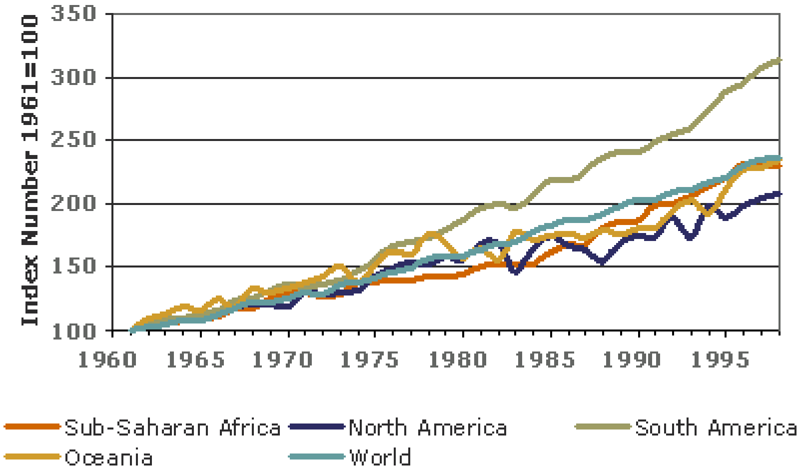
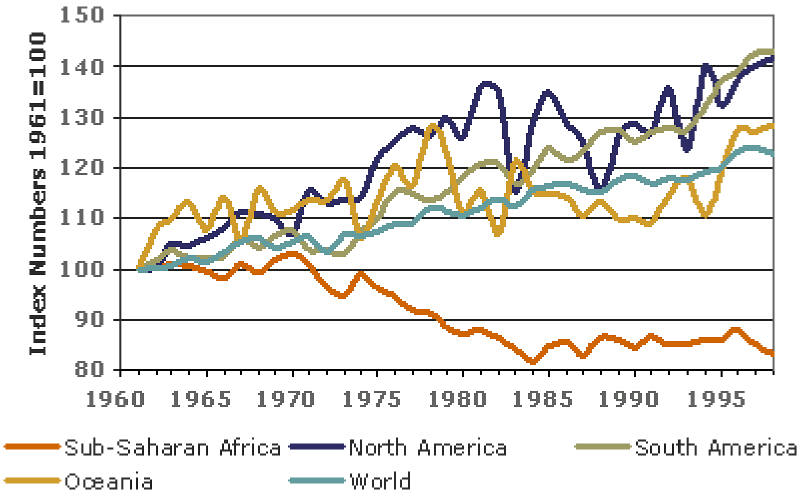


Figure 1b: Trends in Per Capita Food Production, 1961-1998



Note: Figures are indexed to 1961 production levels.

Source: FAO 2001.

Food is one of the most basic needs for human survival, but supplying it remains one of the world's most complex challenges, especially in the face of an expanding population and environmental constraints.

Over the past 40 years, the world has made significant progress toward global food security—a supply of sufficient and affordable food for every human. As the world's population doubled from 3 to 6 billion, global food production more than kept pace. Today's per capita food supply is 24 percent larger than in 1961, and the real price of food fell 40 percent during this period (Wood et al. 2000:4). But even with these positive trends at a global level, food production continues to vary significantly from region to region (see Figures 1a and 1b). Although the number of undernourished people is still tragically high, world nutrition is improving and the incidence of undernourishment has been halved—from 37 percent of the world's people at the end of the 1960s to 18 percent in the mid 1990s (FAO 2000:3).

However, the number of people to feed continues to grow. The global population is currently expanding by about

75 million each year. Population growth rates are declining, but the world's population will still be expanding almost 60 million per year in 2030 (UN Population Division 1998:437). These additional people will require not only the production of more food, but also adjustments to changing patterns of food consumption. Some experts have estimated that global grain production, currently 1.84 billion tons annually, will need to increase by 40 percent to meet demand in 2020 (FAO 2000:4; Pinstrup-Andersen et al. 1999:5).

Another challenge is that more than a third of the grain produced in the next 20 years will support livestock production. In recent decades, demand for meat in developing countries has grown 5-6 percent per year (FAO 2000:8). Increasing affluence and urbanization in developing countries are encouraging the adoption of diets more closely resembling those in industrialized countries, including the consumption of more livestock products and fish as well as fresh fruits and vegetables (See *Carnivorous Cravings: Charting the World's Protein Shift*.) Even in poorer rural areas, diets will incorporate greater amounts of rice and wheat, displacing to some extent traditional grains such as sorghum, millet, and maize (Shah and Strong 1999:19).

Limits to Growth?

Can the world's agroecosystems meet those needs and changing appetites? The experience of the Green Revolution in the 1960s and 1970s seems to suggest that rapid growth in food production is possible. From 1961 to 1979, global grain yields grew 60 percent--even more in developing countries (65 percent)--on a tide of improved seeds, more fertilizers and pesticides, increased irrigation, and new cultivation methods. Strong growth in global grain production continued between 1980 and 2000, with an increase of 33 percent (FAO 2001).

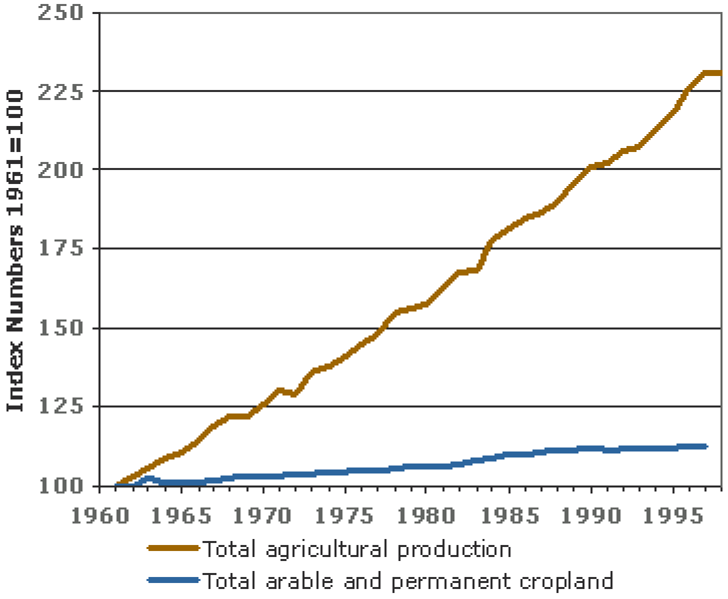
But some researchers suggest that the gains of the Green Revolution will be hard to extend and expand. Experts are concerned that current positive trends in food production may mask negative trends in the physical and biological capacity of the world's farm lands (Wood et al. 2000:4).

A primary concern is that much of the world's best cropland is already under cultivation. Farmers often

More Food, Less Arable Land

Intensification of agricultural lands has been rapid, making it possible to produce much more food on a given hectare of land, but also imposing stresses on ecosystems, from soil erosion and degradation to water shortages. As the world becomes more crowded and limits to intensification are reached, agricultural area will expand through the conversion of forests and grasslands—presenting another host of ecosystem problems.

Figure 2: Trends in Agricultural Production and Cropland Area, 1961-1998



Note: Figures are indexed to 1961 levels.

Source: FAO 2001.

contend with soil erosion and degradation as well as water shortages when bringing new land into production and when trying to increase yields from currently cultivated land. A key challenge, then, is to intensify use of the cropland already under cultivation without further damage to the environment, while slowing the expansion of agriculture into currently forested or grassland areas (see Figure 2).

In fact, there is evidence that limits to agricultural intensification are already being reached. The average annual growth rate of cereal production in developing countries has fallen to 1.0 percent, compared to 2.5 percent per year over the past 35 years (FAO 2000:12). Water scarcity and land degradation are already severe enough to reduce yields on about 16 percent of agricultural lands, especially cropland in Africa and Central America and pasture in Africa (Wood et al. 2000:Intro3).

In addition, the potential gains from using more intensive cropping systems may be minimal. For example, producing more than one crop a year on the same land is already common in most places where possible. At the same time, pesticide resistance among insects, weeds, and disease organisms is slowing the growth of crop yields. Potato growers, for example, are already spraying their fields with pesticides up to 15 times per growing season to control late blight potato disease (Scott et al. 2000:41 citing Hijmans et al. 1999). At the same time, new and more virulent strains of the blight are emerging that heavier applications may not be able to thwart (Scott et al. 2000:41 citing Erselius et al. 1999).

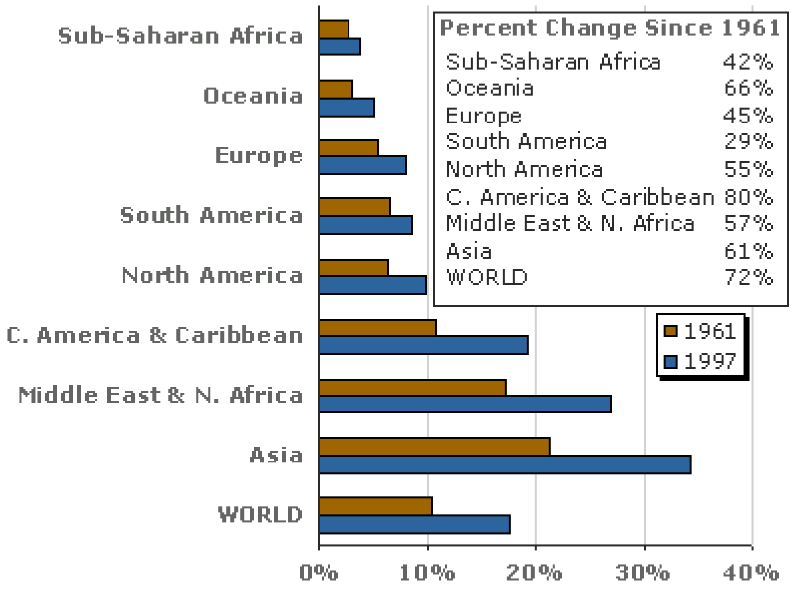
Irrigation Shortfalls

Water scarcity seems certain to constrain further use of one of the hallmarks of agricultural intensification to date: irrigation. Much of the world's cropland falls in climatic zones with highly variable rainfall, and in recent decades, irrigation has expanded quickly to help ensure a reliable water supply and crop production in these areas and to increase production possibilities beyond the rainy season (see figure 3). The area of irrigated cropland expanded by 72 percent between 1966 and 1996. Although just 17 percent of all cropland is now irrigated, these lands account for an estimated 30-40 percent of crop production (Wood et al. 2000:6).

However, irrigation can lead to water logging of soils, salinization (accumulation of dissolved salts in soil), depletion of groundwater and surface waters, and chemical contamination of waterways (Wood et al. 2000:58-59). Plus, withdrawals of water for irrigation have been rising at twice the rate of population growth. Water sources are

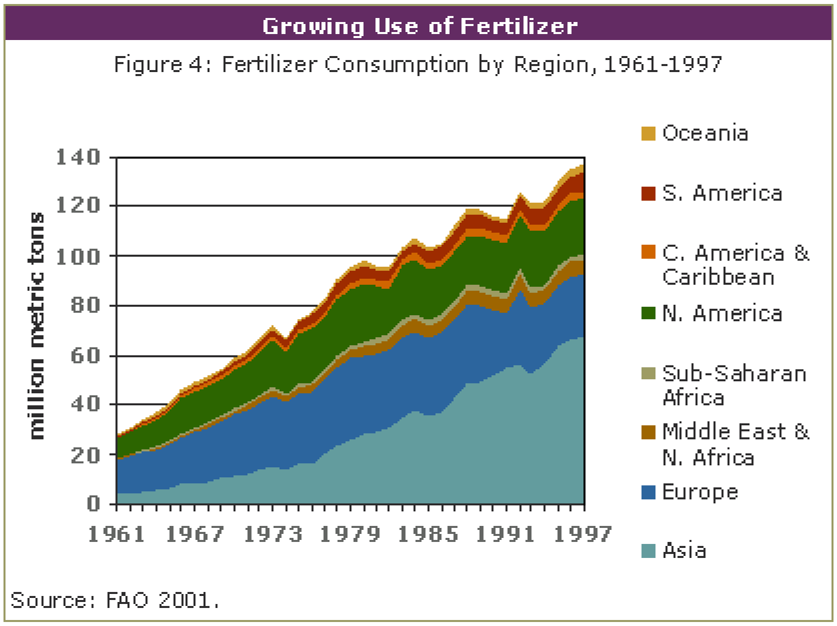
Food Supply Increasingly Relies on Irrigation

Figure 3: Irrigated Land as a Percentage of Agricultural Land



Note: "Agricultural land" refers to both arable and permanent cropland.

Source: FAO 2001.



Growing Use of Fertilizer

Figure 4: Fertilizer Consumption by Region, 1961-1997

Source: FAO 2001.

being depleted in many parts of Asia, North Africa, and North America. Almost 40 percent of the global population now experiences serious water shortages (Revenga et al. 2000:26-27). (See *Will There Be Enough Water?*)

Water scarcity is expected to spread dramatically in some regions, and irrigated agriculture will be competing with urban and commercial water users. Currently, agriculture uses 75-90 percent of commercial water in low-income countries, usually at far below market rates; thus policy makers are under pressure to shift available water toward higher-paying domestic users. South Africa, for example, aims to reduce agriculture's share of water use from 70 percent to 50 percent over the next decade or two (IFAD 2000:90-91). Experts have identified looming shortages—a "world water gap" in which demand for irrigation water in 2025 will exceed available supplies by at least 17 percent, even if significant efficiency improvements are made (Shah and Strong 1999:21). Currently, irrigation efficiency is very low, with less than half the irrigation water on average actually reaching the crop and an estimated 30-60 percent returned for downstream use (Wood et al. 2000:57 citing Seckler et al. 1998:25).

Irrigation also leads to other problems. Fertilizer and pesticide residues, along with animal waste, leach into waterways and degrade water quality (see Figure 4). Agricultural runoff is already creating serious water pollution problems in the Mediterranean Sea, the Black Sea, and the Gulf of Mexico near the mouth of the Mississippi River (Wood et al. 2000:Intro3). The OECD predicts that by 2020, fertilizers, organic contaminants, and other pollution from agriculture will saddle waterways in OECD countries with a 25 percent increase in nitrogen loads and demand for oxygen. A 100-200 percent increase is expected in non-OECD countries (OECD 2001:90-91).

Soil Degradation and Other Factors

Another limit to agricultural intensification is soil degradation. Human-induced soil degradation has been rising since the 1950s. About 85 percent of agricultural land contains areas judged to have been degraded by erosion, salinization, compaction, and other factors (Wood et al. 2000:49). Soil degradation has already reduced global agricultural productivity by 13 percent in the last 50 years (Wood et al. 2000:5).

Natural soil constraints such as a lack of sufficient nutrients, poor drainage, high acidity, or salinity also plague the world's agricultural lands. In fact, only 16 percent of the world's agricultural soils are free of such constraints. Most of these favored soils lie in temperate areas, especially parts of the United States, Canada, Russia, Argentina, Uruguay, Brazil, India, and China. Only 15 percent lie within the tropics--the location of many of the nations with the most serious food security problems (Wood et al. 2000:47). Unfortunately, agricultural practices in many parts of the developing world are exacerbating natural soil deficiencies. For example, a recent analysis of cropping systems in Latin America and the Caribbean region showed that crops are removing significantly more nutrients from the soils than are being replenished either naturally or with fertilizer—an unsustainable situation. Previous analyses have shown similar trends in Africa (Wood et al. 2000:5, 52-53).

Climate Change

Climate change could have a large effect on farm productivity. Rising temperatures, changes in precipitation patterns, and a higher incidence of extreme weather events such as severe thunderstorms or hurricanes could affect crop production in a number of ways. The extent of the effect will depend on adaptations by humans and natural systems, inherent soil properties, and a host of other variables. However, broadly speaking, climate models predict that if warming is modest—limited to a few degrees Celsius—climate change will produce higher yields in higher latitude cropland zones by virtue of longer growing seasons and the availability of additional carbon dioxide to enhance photosynthesis (IPCC 2001:6). In the United States, for example, climate change could mean 15-20 percent higher yields for commercial crops like wheat, rice, barley, oats, potatoes, and most vegetables. This assumes a doubling of atmospheric CO_2 and sufficient nutrients and water (National Assessment Synthesis Team 2000:90). Those calculations do not consider the possible negative effects of climate change, including increases in pests and diseases, increased soil erosion due to heavier rainfall, and rising levels of ozone (smog) (IFPRI 2001:6).

On the other hand, tropical and subtropical areas could face a general reduction in crop yields (IPCC 2001:5). In Africa, for example, climate change could worsen an already bleak food outlook, given the continent's heavy reliance on rainfed agriculture, its vulnerability to frequent droughts and floods, and the fact that many African crops are already near their maximum temperature tolerance. A lack of economic resources and technology also limits Africa's capacity to adapt to climate change through the use of better weather forecasting, new crop varieties, and improved water supply and drainage systems (IPCC 2001:14).

Overcoming Constraints to Feeding the World

Scientists and agricultural engineers are exploring how to overcome these constraints to long-term agricultural productivity growth. One priority is to increase the efficiency of water use. One study estimated that about half of the expected rise in water demand could be met by improvements in irrigation efficiency (Shah and Strong 1999: 41). For example, drip irrigation--a technique that could boost the sustainability and efficiency of irrigation----is currently used in less than 1 percent of the world's irrigated areas (OECD 2001:91). Such improvements would also reduce water logging, salinization, and other environmental damage caused by inefficient irrigation. Competition with other sectors is also likely to drive the use of recycled water, such as industrial and domestic wastewater (Wood et al. 2000:6).

Biotechnology may hold promise for raising the ceiling of crop yields—for example, by increasing the efficiency of plants' photosynthetic process and increasing plants' resistance to pests. It could also help cut agricultural water demand by optimizing a plant's internal water use so that it transpires less (Conway 2000:14). Genetic transformation of plants could enhance their ability to counter harsh growing conditions, such as the soil toxicity caused by excessive aluminum levels in many tropical areas (Shah and Strong 1999:36). Examples of successes attributed to biotechnology include 5-15 percent yield increases from the use of bioengineered rice in the Shanghai region of China (Conway 2000:14); 10 percent yield improvements in the United States using genetically engineered Bt corn (Sittenfeld et al. 1999:79); and 40 percent increases in yields of cardamom in India using tissue cultured plants (Sharma 1999:52).

The growth in acreage devoted to transgenic crops exploded in the past 5 years--from 1.7 million hectares in 1996 to 40 million in 1999, with 85 percent of that total in the United States, Canada, Australia, France, and Spain (Persley 1999:9; Sittenfeld et al. 1999:79 citing Sassen 1999). However, agricultural biotechnology has created a firestorm of protest from consumers (especially in Europe) as well as proponents of organic farming and small farmers over the potential long-term impacts of releasing genetically altered organisms into the environment. Still an inexact science, the risks that genetic engineering poses to human health (like increased allergenicity, food intolerances, antibiotic resistance, and toxicity) and to the environment (including threats to biodiversity and the buildup of resistance in insect populations, for example) are not well understood (Persley 1999:12-13).

In developing countries, there is also a growing divide between policy makers who consider biotechnology to be a tremendous potential source of help in meeting food needs and small farmers who are alarmed by the potential for biotechnology to enrich multinational corporations at their expense. In coming decades, aggressive marketing by such corporations of a small number of bioengineered, global “super crops” could imperil agricultural biodiversity by eroding important genetic resources contained in thousands of traditional crop varieties cultivated by villagers throughout the world. Richer, more developed countries are better equipped to evaluate the risks that genetically engineered crops pose to human health and the environment than are poorer, less developed countries. Even in rich countries a vocal contingent believes that governments inadequately regulate the use and impacts of genetically engineered crops.

There is also hope that the so-called "information revolution" may gradually transform the way we produce our food. Farmers have begun to apply “precision agriculture” tools like digital sensors, communication links, global positioning systems, and computers to match agricultural inputs and practices to variable conditions within a field. For example, digital control systems on a tractor can determine how much fertilizer and pesticide to apply and put them exactly where needed. The benefits are higher yields, cost savings for fertilizers and pesticides, reduced environmental impact, and higher quality produce (Pierce 2000). The downfall is that these sophisticated technologies primarily serve large-scale commercial farmers.

The initial costs of applying precision agriculture techniques can be high, and their impact is still very limited. Currently, only about 4 percent of farms in the United States and a very limited number of farms in western Europe have adopted these practices (Pierce 2000). In the developing world, precision agriculture’s impact is even more restricted, and will probably remain so for some time, due to its expense, limited digital access in rural areas, and the need to adapt these tools for the very small farms prevalent in many rural districts. Eventually, however, these precision tools could help extend the Green Revolution’s gains into a new era of intensive agriculture by giving poor farmers better access to information on crop varieties, soil conservation and water systems, and other techniques that industrialized countries enjoy (Shah and Strong 1999:42). Today, just the leading edge of the information revolution has already begun to bring change. In rural Bangladesh, for example, access to phone service has enabled farmers to get fairer prices for their crops (Hammond 2001).

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