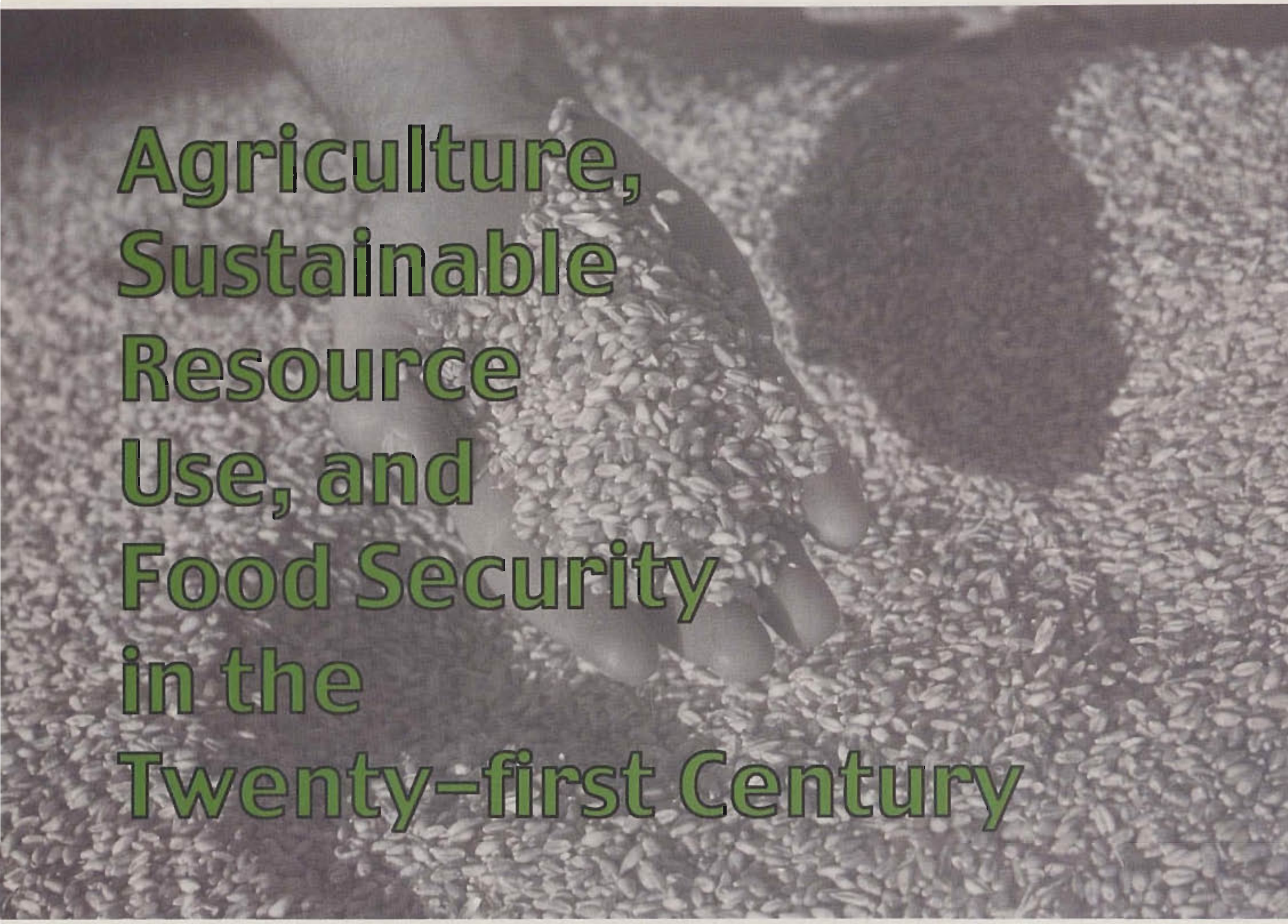

Agriculture, Sustainable Resource Use, and Food Security in the Twenty-first Century

by Keith Wiebe and Pierre Crosson

The twentieth century has seen enormous increases in global population, income, and agricultural productivity. Yet these changes have been unevenly distributed and have brought with them increasing pressures on the earth's land, water, atmospheric, and genetic resources. These changes raise anew old questions about our continued ability to meet economic and environmental objectives in an equitable and sustainable fashion. As we enter a new century, it is appropriate to reconsider these questions.

Can historic production gains be sustained?

Two centuries after the publication of Malthus' *Essay on the Principle of Population*, the world's population has increased sixfold and continues to grow. Yet food production has more than kept pace in recent decades, increasing in per capita terms by 0.9 percent annually on a global scale, and even faster in China, India, and other populous developing countries (figure 1; World Bank 1998). Can these trends be sustained? World population growth rates are declining, but per capita incomes continue to increase, and the share of the world's population living in urban areas is expected to surpass 50 percent by 2005 (FAO 1998).

Crosson (1996) reviewed five recent global demand scenarios based on these trends in population and income and found they projected similar rates of growth in food demand over the next several decades. For example, one of these scenarios, subsequently updated by Rosegrant, Ringler, and Gerpacio, projects an increase of 40 percent in world demand for grain over the period 1993–2020, primarily in the developing countries, where most future population growth will occur and where demand responds most to rising incomes. Such growth in demand, representing an annual increase of 1.3 percent, is well within the range of growth in production and even yields over the past half century (Byerlee, Heisey, and Pingali). To determine whether such growth rates can be sustained into the twenty-first century at socially acceptable economic and environmental costs, however, it is necessary to take a closer look at natural and other resources, including knowledge.

Land and water

The Food and Agriculture Organization (FAO) estimated in 1993 that some 2.5 billion hectares of land in ninety-one developing countries (excluding China) had potential for crop production, of which less than a third was then in crops (FAO 1993). These estimates included any land with the potential to generate yields at least 20 percent of those on the best land already in production, however, implying that the economic costs of bringing additional land into crop production would typically be much higher than for land already in crops (Crosson 1995a). Moreover, FAO took no account of the environmental costs of bringing additional land into crop production. In many cases, such as the clearing of forest land, the costs could be high in terms of lost wildlife habitat and biological diversity, and increased soil erosion and downstream flooding. For reasons such as these, Crosson and Anderson concluded that only relatively small increases in cropland are likely to be achieved at acceptable economic and environmental costs.

Meanwhile, others worry about the degradation of land already in agricultural use. Using the limited data available on a global scale, however, Crosson (1995b) estimated that degradation has reduced global agricultural productivity by just 0.1 percent annually since the mid–twentieth century. Others caution that both productivity and off-site effects may be much more severe in particular areas (Lal, Scherr).

The World Bank and United Nations Development Programme estimated that the amount of additional agricultural land with potential for irrigation was about 50 percent of the 253 million hectares of land actually irrigated in the late 1980s. Crosson (1995a) concluded that this estimate was too high because it, like that of the FAO, did not take adequate account of economic and environmental costs. With rising demand and escalating costs, Rosegrant, Ringler, and Gerpacio argue that water is more likely than land to be a binding constraint on future growth in food production.

Climate

A broad scientific consensus has emerged that the earth's climate will change because of increasing concentrations of carbon dioxide and other "greenhouse" gases in the atmosphere (Intergovernmental Panel on Climate Change). Over the last ten years several studies have estimated the impacts of expected climate changes on agricultural production, both on global and regional scales. In a review of these studies, Crosson (1997) found general agreement that changing patterns of precipitation, temperature, and length of growing season resulting from an equivalent doubling of atmospheric concentrations of carbon dioxide would tend to increase agricultural production in temperate latitudes and decrease it in the tropics. While regional effects and costs of adaptation may be significant, climate change is not likely to threaten food production for the world as a whole (Darwin et al.).

Genetic resources

Genetic resources are used by plant breeders and others to maintain and improve crop yields and to generate other desirable characteristics. All agricultural commodities, including modern varieties, descend from a variety of wild genetic resources. Genetic resources found in the wild also help sustain the larger ecosystem in which agriculture operates. Most of the genetic resources used by breeders are held in national, international, and private gene banks, although such banks hold only a portion of the total diversity of genetic material. The United States holds one of the largest public collections of plant genetic material in the world, funded almost exclusively by the federal government. The U.S. General Accounting Office judged the system's performance to be adequate for some crops at present but noted a 14 percent decline in real federal funding between 1992 and 1996. Funding constraints also raise concerns about degradation of resources held in gene banks in other parts of the world.

In meeting projected increases in food demand in the twenty-first century at acceptable economic and environmental costs, the full potential of genetic resources, like those of land and other natural resources, will only be realized in conjunction with improvements in knowledge to enhance the efficiency with which these resources are used.

Knowledge

Knowledge has been recognized as an economic resource since at least the time of Theodore Schultz's Nobel Prize–winning work on education and human capital. People use the knowledge they acquire, building on the work of those who have gone before, to increase their productivity and that of the resources they use. This suggests two great advantages of knowledge as an economic resource: it is cumulative, and, unlike natural resources, it is not depleted by use. Of course, knowledge becomes obsolete over time, but only because it is replaced by better knowledge, not because its supply has been exhausted.

The power of knowledge as an agricultural resource is best indicated by the fact that cereal yields have more than doubled in the past three decades, with about half of the increase attributable to genetic gains. Yield increases in turn account for nearly 90 percent of growth in cereal production in developing countries since the Green Revolution (Byerlee, Heisey, and

Pingali). Evidence shows that yield growth has slowed in the past decade, however, posing new challenges for knowledge creation and diffusion.

Knowledge is embodied in people and technology as well as in the laws, social norms, and public and private institutions that help markets to function properly (World Bank 1999). The critical question about the adequacy of knowledge resources to meet increased global food demand is whether the necessary investments will be made in education of people, in new technology, and in institutions. Investment in all three is important, but institutional capacity may deserve special priority. Agricultural research institutions historically have focused on knowledge embodied in technology, such as the new seed varieties that launched the Green Revolution, rather than on new institutional capacity. As income levels rise, demand for the environmental services of land and water used in agriculture is likely to increase faster than the demand for food. Both supply- and demand-side reasons thus argue for improved understanding of the institutional challenges associated with generation and sustainable use of natural and other resources.

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Recent trends in global spending on agricultural research raise concerns that future investment in knowledge may prove insufficient. The demand scenario of Rosegrant, Ringler, and Gerpacio assumes that global food supplies will increase enough to meet demand in 2020 at prices slightly lower than those in the early 1990s, but only if global investments in agricultural research continue at the levels of the early 1990s. In fact, investments through the Consultative Group for International Agricultural Research (CGIAR) have stagnated after increasing rapidly from the early 1970s to 1990 (Alston, Pardey, and Roseboom), and in some of the institutions, such as the International Rice Research Institute, they have actually declined (Duvick). Investments in the CGIAR institutions are a small part of global publicly funded agricultural research, but much CGIAR research forms the basis for subsequent adaptive research in the developing countries. In sub-Saharan Africa, where knowledge resources are in particularly short supply, growth in publicly funded agricultural research slowed from 2.5 percent in the 1970s to 0.8 percent per year in the 1980s, while in Latin America and the Caribbean spending actually fell (Alston, Pardey, and Roseboom).

Should the trend toward declining rates of growth continue, such investments could eventually decline in absolute amount in other areas, threatening the assumption on which Rosegrant, Ringler, and Gerpacio based their projections. The likelihood that supplies of knowledge resources will increase enough to sustainably meet that scenario remains problematic.

Public funding is particularly important since certain genetic enhancements have many of the characteristics of a public good. Examples include gene bank storage, long-term basic research, and publicly released varieties particularly important in developing countries—returns to each of which may not justify sufficient private investment. Research and development on issues relating to environmental quality and food security also involve benefits that, while large, may not be privately appropriable and thus may require public support. Whether public or private, the World Bank (1999) also notes in its recent *World Development Report* on knowledge that per capita expenditures on research and development vary widely across regions, more so even than does income, heightening concern about future disparities in agricultural performance.

In light of these resource patterns and trends, does the potential exist to produce sufficient food to meet growing needs in the twenty-first century? Despite problem areas, we conclude that the answer is yes. Whether markets will perform in such a way as to achieve this potential equitably and sustainably is a more fundamental question.

How will markets respond?

The ability of markets to achieve this potential will depend on two realities. First, global food and resource-related processes are driven ultimately by the choices made by individual decision makers who clear land, draw water, plant crops, and raise livestock to meet their own goals. And second, these choices are influenced in turn by the ways in which property rights and institutional systems structure markets to balance the interests of individual decision makers with those of their neighbors, near and far in both time and space.

Without stable institutions, markets are unlikely to offer sufficient incentives for investment in the sustainable use of natural resources or in the creation or adoption of knowledge and other produced resources. It is notable that per capita food production has fallen most markedly in recent decades in two relatively land-abundant but institutionally turbulent regions: sub-Saharan Africa and the countries of the former Soviet Union (figure 1).

Without appropriate institutions, markets are also unlikely to offer incentives for the protection of resources without prices. These include resources for which property rights may be imperfectly defined or enforced—whether on a local scale, such as grazing lands traditionally managed under a common-property regime that has subsequently disintegrated in the face of changing market or political conditions, or on a global scale, such as the earth's atmosphere (Dasgupta and Mäler). Where tenure systems are absent or function poorly, development of well-defined and carefully enforced institutional arrangements will be necessary to permit sustainable use of natural resources. Examples ranging from ongoing discussion of an international system of marketable permits for greenhouse gas emission to Zimbabwe's efforts to accord wildlife rights and tourism revenues to local communities suggest that the costs of such institutional development are potentially quite high (Wiebe and Meinzen-Dick).

Without appropriate institutions, markets are likewise unlikely to adequately recognize the interests of people with little income or wealth. This brings us finally to the relationship between sustainable resource use and food security. Food security is generally defined in terms of "access by all people at all times to sufficient food for an active and healthy life" (World Bank 1986, World Food Summit). Based on Sen's landmark study of entitlements, this focus on access represents a significant advance over earlier definitions that focused on global food availability. The need for such improvement is apparent in the failure of increases in per capita food production (figure 1) to correlate with patterns of nutritional status (figure 2), except in sub-Saharan Africa. Yet careful consideration of food security requires moving beyond even food access and recognizing the choices that households and nations face when incomes fall short (Dasgupta, Mink, Wiebe). Of particular concern are the trade-offs that low incomes may force between meeting current consumption needs and protecting the natural and other resources required to meet consumption and other needs over the longer term (Maxwell and Wiebe).

The role of policy and research

As Alassane Ouattare of the International Monetary Fund notes, the structure of property rights and the performance of markets are fundamentally political issues, but they have profound economic

Figure 1. Growth in Per Capita Food Production, 1980–1995

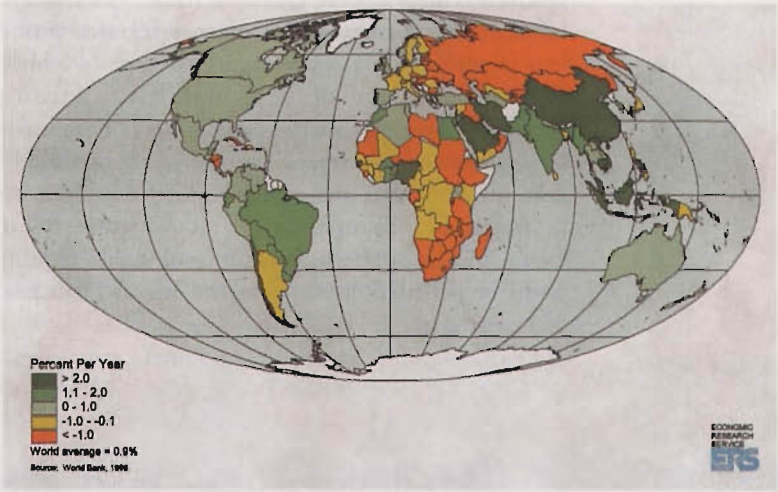
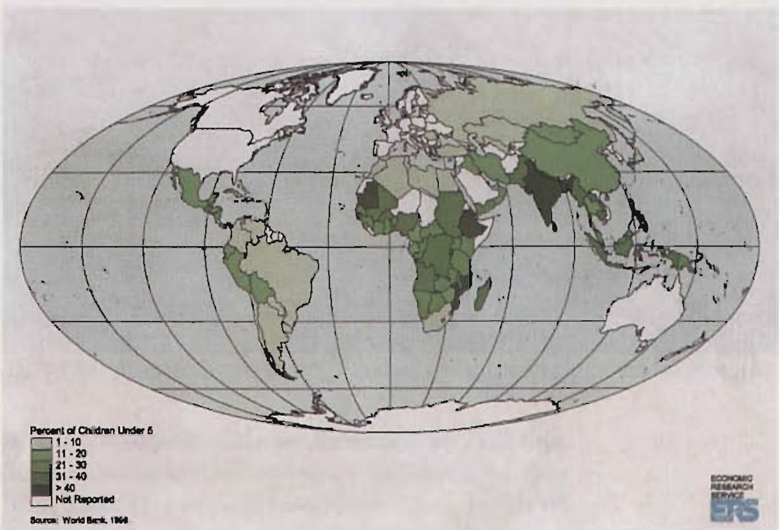


Figure 2. Prevalence of Child Malnutrition, 1996



(and environmental) consequences. The challenge for policy makers is to structure markets and other institutions in such a way that they maintain an appropriate balance between public and private economic and environmental interests over the short and long run. The challenge for researchers is to help discern that balance by identifying and valuing those diverse and complex interests. Emerging parallels between the analysis of resources and the analysis of food security deserve mention here. Just as the concept of food security has evolved from a relatively static focus on food availability to incorporate longer-term concerns about access, so has interest grown (see, for example, World Bank 1997) in understanding economic growth in ways that move beyond current income to reflect longer-term changes in the quality and quantity of natural and other resources.

While these two processes emerged from different concerns—the former primarily with hunger at the household and local levels; the latter largely with environmental degradation at the national and global levels—they are closely related. Specifically, both represent components of an integrated problem in resource management, at the core of which lies the concept of sustainability. "Strong sustainability" requires that each kind of resource be maintained intact, while "weak sustainability" requires only that the total value of resources be maintained, regardless of its composition (Serageldin). An alternative approach would require both the maintenance of total wealth and concern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A researcher checks growth and genetic traits of soybeans in an experimental field, 1933.

with the composition of wealth, recognizing that it may be necessary to define and maintain critical levels of each resource category (Pearce and Atkinson, Serageldin).

Such a definition begins to sound very much like evolving notions of food security, which increasingly recognize the need to meet both food and nonfood requirements in order to sustain human and other resources over time. A review of resource trends suggests that the potential exists to meet these requirements in the twenty-first century. Whether this potential is realized equitably and sustainably will depend on the choices made by farmers and policy makers. Recognition of the links between sustainable resource use and food security will strengthen the important role that researchers can play in understanding these choices. ■

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Comments from Kelly Day-Rubinstein, Paul Heisey, and additional anonymous reviewers, as well as GIS assistance from Vince Breneman, are gratefully acknowledged.

The views contained here are those of the authors, and may not be attributed to Economic Research Service or Resources for the Future.

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