

**WORLD FOOD PROSPECTS :
CRITICAL ISSUES FOR THE
EARLY TWENTY-FIRST CENTURY**

**Per Pinstруп-Andersen, Rajul Pandya-Lorch,
and Mark W. Rosegrant**



FOOD POLICY REPORT

**INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
WASHINGTON , D.C.
OCTOBER 1999**

CONTENTS

Executive Summary	5
Introduction	7
Prospects for Food Security	8
Emerging Issues	19
Conclusions	29
Notes	30

EXECUTIVE SUMMARY

About 73 million people will be added to the world's population every year between 1995 and 2020, increasing it by 32 percent to reach 7.5 billion. Much of this population growth will occur in the cities of the developing world. While its rural population is expected to increase by less than 300 million during this period, the developing world's urban population could double to 3.4 billion in 2020. Per capita incomes are expected to increase in all major developing regions over this period. Meeting the food needs of a growing and urbanizing population with rising incomes will have profound implications for the world's agricultural production and trading systems in coming decades. IFPRI research suggests some of the major developments that will characterize the world food situation during the next two decades to 2020:

- Almost all of the increase in world food demand will take place in developing countries. Developing countries will account for about 85 percent of the increase in the global demand for cereals and meat between 1995 and 2020.
- However, a developing-country person in 2020 will consume less than half the amount of cereals consumed by a developed-country person and slightly more than one-third of the meat products.
- A demand-driven "livestock revolution" is under way in the developing world. Between the early 1970s and the mid-1990s, the volume of meat consumed in the developing world grew almost three times as fast as it did in the developed countries. Demand for meat in the developing world is projected to double between 1995 and 2020.
- In response to the strong demand for meat products, demand for cereals for feeding livestock will double in developing countries. Demand for maize in developing countries will increase much faster than for any other cereal and will overtake demand for rice and wheat by 2020.
- To meet demand, the world's farmers will have to produce 40 percent more grain in 2020. Increases in cultivated area are expected to contribute only about one-fifth of the global cereal production between 1995 and 2020, so improvements in crop yields will be required to bring about the necessary production increases. However, it is worrisome that growth in farmers' cereal yields is slowing from the heyday of the Green Revolution during the 1970s.
- Food production is increasing much faster in the developing world than in the developed world. By 2020, the developing world will be producing 59 percent of the world's cereals and 61 percent of the world's meat.
- Nevertheless, cereal production in the developing world will not keep pace with demand, and net cereal imports by developing countries will almost double between 1995 and 2020 to 192 million tons in order to fill the gap between production and demand. Net meat imports by developing countries will increase eightfold during this period to 6.6 million tons.
- About 60 percent of the developing world's net cereal imports in 2020 will come from the United States. Eastern Europe and the former Soviet Union are forecast to emerge as major net exporters, and the European Union and Australia are projected to increase their net exports as well.
- Food prices will remain steady or fall slightly between 1995 and 2020. The much slower decrease in food prices compared with past trends is due to the

continued slowdown in crop yield increases, as well as strong growth in demand for meat in developing countries.

- With increased production and imports, per capita food availability in the developing world will increase to 2,800 calories per day by 2020, an increase of about 9 percent over 1995.
- In the scenario described here, food insecurity and malnutrition will persist in 2020 and beyond. We project that 135 million children under five years of age will be malnourished in 2020, a decline of only 15 percent from 160 million in 1995. Child malnutrition is expected to decline in all major developing regions except Sub-Saharan Africa, where the number of malnourished children is forecast to increase by about 30 percent to reach 40 million by 2020. With more than 77 percent of the developing world's malnourished children in 2020, Sub-Saharan Africa and South Asia will remain "hot spots" of child malnutrition and food insecurity.

When IFPRI prepared its last Food Policy Report on the world food situation two years ago, it highlighted recent developments and emerging issues influencing prospects for global food security. Many of these issues are still present, and some have escalated in importance. In this report,

we identify and discuss six critical issues that, at the threshold of the next century, could significantly influence the world food situation. First, new information on nutrition is shedding fresh light on which policy-related variables could help improve the nutritional status of children; this could help refocus efforts to eliminate child malnutrition. Second, world market prices for wheat, maize, and rice, adjusted for inflation, are the lowest they have been in the last century. This situation may threaten producer incomes and future food production and stocks. Third, the next round of trade negotiations sponsored by the World Trade Organization will begin in November 1999. Poor countries and poor people risk losing out on the economic benefits embodied in further trade liberalization. To gain from trade talks, developing countries must participate effectively in the negotiations. The last three issues focus on approaches to increasing productivity on small-scale farms in developing countries, in particular on the potential of agroecological approaches, the potential role of modern biotechnology, and the relevance of new information technology and precision farming. These issues are hotly debated at present, and the outcomes of these debates may influence the food security of low-income people for many years to come.

INTRODUCTION

The last IFPRI Food Policy Report on the world food situation, prepared two years ago, highlighted recent developments and emerging issues influencing the prospects for global food security.¹ Many of these issues are still present, and some have escalated in importance. Although concerns about the future Chinese food situation have subsided with two years of surplus grain production in China and net exports, the extent to which the Indian population will expand consumption of livestock products in the future remains unresolved. The future food situation in the former Soviet Union is still unclear, and the success of the economic transformations in that region is uncertain. Although many local successes have taken place, the Sub-Saharan African food situation is still extremely difficult. Large-scale breakthroughs in agricultural productivity and improvements in food security are yet to occur in that region.

Concerns about declining soil fertility in many low-income countries and growing competition over water in many locations have further escalated during the last couple of years, as has the uncertainty surrounding the future use of modern biotechnology for agriculture. The declining trend in food aid availability since 1993 has been reversed, owing primarily to low international food prices and increasing stock levels in traditional exporting countries combined with the emergence of large-scale crises in Indonesia, Russia, and the Balkans during 1998 and 1999. Whether this will be the beginning of an upward trend in food aid or merely a short-term blip will depend largely on what happens to international grain prices and stock levels in industrial nations. Future food aid will be determined primarily by supply since demand far exceeds the likely availability. Food safety concerns, particularly in Western Europe, have exploded during the last two years

partly because of consumer uncertainties and fears about the health risks associated with genetically modified food and partly because of inappropriate government responses to perceived health-threatening occurrences in the food chain.

This report provides a summary of the most recent results from IFPRI projections of the future world food situation. It then identifies and discusses six recent developments and emerging issues that will influence the prospects for global food security. The first of these issues is the nutrition situation, which appears to be deteriorating in some countries, particularly in Sub-Saharan Africa. At the same time, new research is shedding light on how child malnutrition may be reduced in developing countries, which could help refocus efforts to eliminate child malnutrition.

The second issue is grain prices. Two years ago, the discussion focused on the causes and consequences of high prices for maize and wheat. Today, the very low prices for these commodities are a cause of concern, because they may threaten producer incomes and future food production and stocks. Third, the next round of trade negotiations sponsored by the World Trade Organization (WTO) will begin in November 1999, and agriculture is expected to occupy a prominent place in those negotiations. The outcomes of these negotiations will significantly influence food and agriculture production and trading systems around the world for years to come.

The last three emerging issues focus on approaches to increasing agricultural productivity on small-scale farms in developing countries. This report will discuss new evidence on the opportunities offered by agroecological approaches, the potential role of modern biotechnology, and the relevance of new information technology and precision farming for small farmers in

developing countries. These issues are hotly debated at present, and the outcomes of these debates and the related policies

may influence the food security of low-income people for many years to come.

PROSPECTS FOR FOOD SECURITY

Results from IFPRI's revised and updated global food model, the International Model for Policy Analysis of Commodities and Trade (IMPACT),² suggest that under the most likely scenario global demand for cereals will increase by 39 percent between 1995 and 2020 to reach 2,466 million tons; demand for meat will increase by 58 percent to reach 313 million tons; and demand for roots and tubers will increase by 37 percent to reach 864 million tons.³ These large increases in food demand will result not only from population growth but also from urbanization, income growth, and associated changes in lifestyles and food preferences.

About 73 million people, equivalent to the current population of the Philippines, will be added to the world's population on average every year between 1995 and 2020, increasing it by 32 percent to reach 7.5 billion in 2020 (Table 1). An overwhelming

97.5 percent of the increase in population is expected to occur in the developing world,⁴ whose share of global population would increase from 79 percent in 1995 to 84 percent in 2020. Whereas the absolute population increase will be largest in Asia, 1.1 billion, the relative increase will be greatest in Africa, where the population is expected to increase by 70 percent. This rate of increase, however, is less than had been projected in the past, partly because of HIV/AIDS, which is ravaging the African population. One-third of the total population increase is anticipated to occur in just two countries—China and India. However, India's population is growing much faster and is poised to overtake that of China by 2035.⁵ The world's growing population will continue to exert pressure on food supplies.

Much of the population growth is expected to take place in the cities of the develop-

Table 1—World population, 1995 and 2020

Region	Population level		Population increase, 1995–2020		Share of increase
	1995	2020 ^a	(millions)	(percent)	
			(millions)	(percent)	(percent)
Latin America and the Caribbean	480	665	185	38.5	10.1
Africa	697	1,187	490	70.3	26.7
Asia, excluding Japan	3,311	4,421	1,110	33.5	60.5
China	1,221	1,454	233	19.1	12.7
India	934	1,272	338	36.2	18.4
Developed countries	1,172	1,217	45	3.8	2.5
Developing countries	4,495	6,285	1,790	39.8	97.5
World	5,666	7,502	1,836	32.4	100.0

Source: United Nations, *World Population Prospects: The 1998 Revision* (New York: UN, 1999).

^a Medium-variant population projections.

ing world. While its rural population is expected to increase by less than 300 million between 1995 and 2020, the developing world's urban population is projected to double from 1.7 billion to reach 3.4 billion in 2020 (Figure 1). By 2020, about 52 percent of the developing world's population will be living in urban areas, up from 38 percent in 1995.⁶ The rapid urbanization of the developing world and associated changes in lifestyles will have significant effects on food preferences and hence on demand. As people move from rural to urban areas, they tend to adopt more diverse diets, shifting away from coarse grains such as sorghum and millet to rice, and sometimes making secondary shifts from rice to wheat. They also tend to consume more livestock products, fruits, vegetables, and processed foods. Agricultural production and research systems will be challenged to keep abreast of changing dietary preferences in coming years.

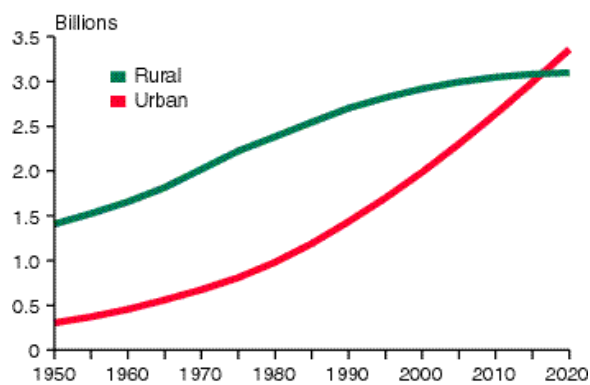
Prospects for economic growth appear favorable in the developing world, and like urbanization, rising incomes will push people toward more diversified diets. IMPACT projects total income in the developing world to increase at an average of 4.3 percent annually between 1995 and 2020, which would double per capita incomes to more than US\$2,200 (Table 2). Per capita

incomes in all major developing regions, including Sub-Saharan Africa,⁷ are expected to increase over this period. However, even by 2020 Sub-Saharan Africa's per capita income is projected to be less than a dollar a day; poverty of this magnitude will condemn many people in this region to food insecurity.

Although many millions of people could remain mired in absolute poverty, meeting the food needs of a growing and urbanizing population with rising incomes will have profound implications for the global agricultural production and trading system in coming decades. Some of the major developments that will characterize the world food situation during the next two decades to 2020 are the following:

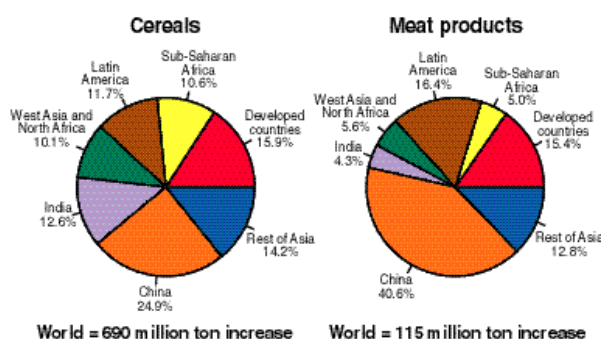
Almost all of the increase in world food demand will take place in developing countries. Developing countries will account for about 85 percent of the 690 million ton increase in the global demand for cereals between 1995 and 2020 (Figure 2). Surprisingly, they will account for a similarly large share of the 115 million ton increase in the global demand for meat products over the same period. China alone is forecast to account for one-quarter of the global increase in demand for cereals and for two-fifths of the increase in demand for meat. Although India's population is projected to

Figure 1—Urban and rural population levels in developing countries, 1950–2020



Source: United Nations, *World Urbanization Prospects: The 1996 Revision* (New York: UN, 1996).

Figure 2—Share of increase in global demand for cereals and meat products, 1995–2020



Source: IFPRI IMPACT simulations, July 1999.

Table 2—Income levels and growth, 1995–2020

Region	Annual income growth rate, 1995–2020	Per capita income level	
		1995	2020
	(percent)	(1995 US\$ per person)	
Sub-Saharan Africa ^a	3.40	280	359
Latin America and the Caribbean	3.59	3,590	6,266
West Asia and North Africa	3.83	1,691	2,783
Southeast Asia	4.44	1,225	2,675
South Asia	5.01	350	830
East Asia	5.12	984	2,873
Developed countries	2.18	17,390	28,256
Developing countries	4.32	1,080	2,217
World	2.64	4,807	6,969

Source: IFPRI IMPACT simulations, July 1999.

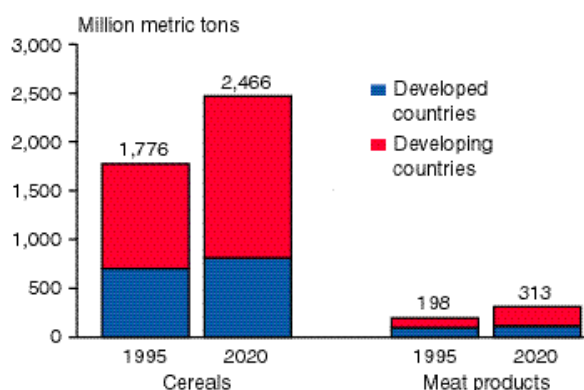
^a Excluding South Africa.

increase much faster than that of China between 1995 and 2020, its share of the global increase in demand for cereals is expected to be about half that of China's while its share of the global increase in demand for meat is expected to be only one-tenth that of China. India is currently in a period of economic transition; should policy reforms result in much faster economic growth than currently expected, the demand for meat and other livestock products, including milk, could expand much faster in that country.⁸ Also, it is still not clear whether poverty or culturally based food preferences are the primary reason why meat consumption in India is so low. There are indications that a large share of the Indian population would prefer to eat more meat if their income were to rise. By 2020, developing countries as a group are forecast to demand twice as much cereals and meat products as developed countries (Figure 3).

However, a developing-country person in 2020 will consume less than half the amount of cereals consumed by a developed-country person and slightly more than one-third of the meat products.

Per capita demand for cereals and meat products in developing countries will continue to lag far behind that in developed countries, although the gap will begin to narrow in the case of meat products (Figure 4). The disparities in demand can be explained partly by lower incomes and greater dependence on roots and tubers for sustenance in developing countries (see Box 1) and by much heavier use of cereals for feeding livestock in developed countries. Within the developing world, increases in per capita demand for cereals (food and feed) and meat products in East Asia will far outstrip those in other regions. This is not surprising given that income levels are already relatively high in East Asia and are projected to continue to grow rapidly in the next two decades, triggering massive increases in demand. In the case of cereals, for instance, while per capita demand in Sub-Saharan Africa is projected to increase by 13 kilograms between 1995 and 2020 to reach 156 kilograms in 2020, in East Asia it is projected to increase by 66 kilograms to reach 373 kilograms in 2020, driven to a large extent by increases in demand for feedgrain.

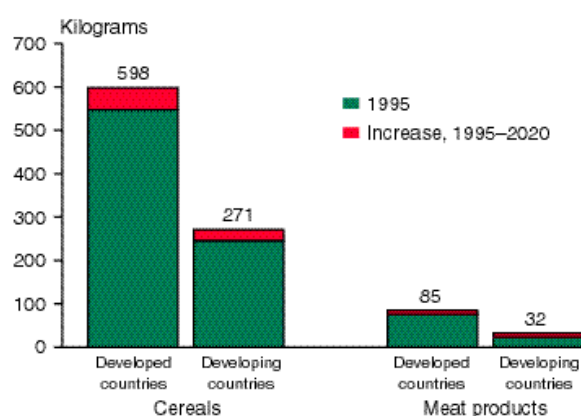
Figure 3—Total demand for cereals and meat products, 1995–2020



Source: IFPRI IMPACT simulations, July 1999.

A demand-driven “livestock revolution” is under way in the developing world, with profound implications for global agriculture, health, livelihoods, and the environment. Between the early 1970s and the mid-1990s, the volume of meat consumed in the developing countries grew almost three times as much as it did in the developed countries.⁹ With continued population growth, urbanization, income growth, and changes in lifestyles and food preferences, we project that meat demand in the developing world will double between 1995 and 2020 to 190 million tons and increase by 25 percent in developed countries to 122 million tons. Demand for meat will grow much faster than for cereals in the developing world, by 2.8 percent per year for meat compared with 1.8 percent for cereals. In per capita terms, demand for meat in developing countries will increase by 40 percent between 1995 and 2020, whereas it will increase by only 10 percent for cereals. Worldwide, demand for poultry meat is projected to increase by more than 85 percent between 1995 and 2020, for beef by 50 percent, and for pigmeat by 45 percent. Nevertheless, demand for pigmeat will continue to exceed demand for the other meat commodities. In the developing world, demand for poultry meat is expected to increase fastest, at an average annual rate

Figure 4—Per capita demand for cereals and meat products, 1995–2020

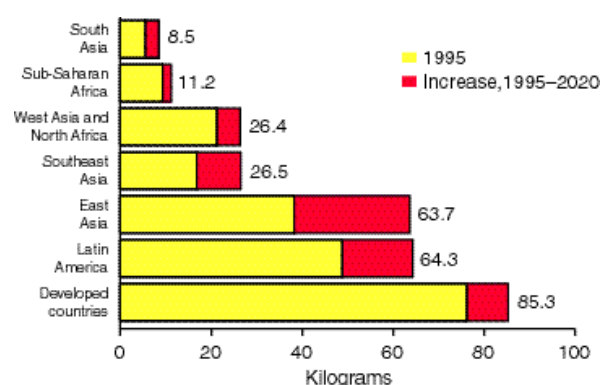


Source: IFPRI IMPACT simulations, July 1999.

of 3.6 percent, compared with 2.8 percent for beef and 2.3 percent for pigmeat. East Asia’s per capita demand is projected to increase most, and Sub-Saharan Africa’s and South Asia’s least; by 2020, East Asia’s per capita demand for meat could be as much as seven times that of South Asia (Figure 5). It is crucial that governments and industries prepare for this ongoing livestock revolution in order to meet consumer demand while alleviating stresses on public health and natural resources (see Box 2).

Demand for cereals for feeding livestock will double in developing countries. In response to the strong demand for meat products, developing countries’ demand for

Figure 5—Per capita demand for meat products, 1995–2020



Source: IFPRI IMPACT simulations, July 1999.

Box 1 The Contribution of Roots and Tubers

Many of the developing world's poorest farmers and food-insecure households are highly dependent on roots and tubers as a significant, if not principal, source of food and income. In many parts of Sub-Saharan Africa, roots and tubers account for about 20 percent of calorie consumption. In Asia and Latin America, they provide an important supplemental source of carbohydrates, vitamins, and amino acids in food systems that are dominated by other commodities. The production and processing of roots and tubers, which tend to be very labor-intensive, are also important sources of employment and income. Production of roots and tubers tends to be concentrated in countries with lower per capita incomes and, within the low-income countries, they are typically located in remote, often marginal, areas with particularly low levels of income and limited access to farm inputs. These characteristics make roots and tubers an important crop for low-income smallholders in the marginal areas of Africa, Asia, and Latin America.

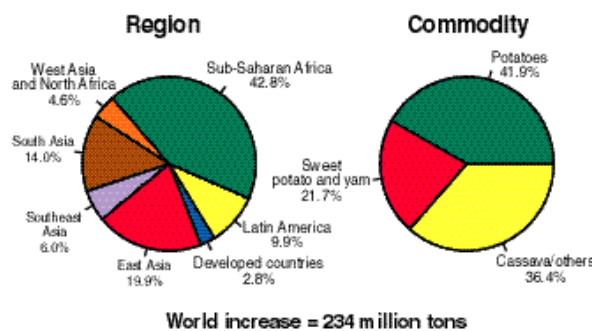
While much of the focus in developing-country food production in recent years has been on cereals, similarly large rates of increase in production occurred for potatoes and yams, although growth was much lower for cassava and sweet potatoes. By 1995, about 630 million tons of roots and tubers were produced on 49 million hectares worldwide, with 70 percent of the production taking place in developing countries. The estimated annual value of the major roots and tubers produced in the developing world in 1995–97 amounted to about US\$40 billion.

IMPACT projections suggest that global demand for roots and tubers will increase by 37 percent between 1995 and 2020 to reach 864 million tons, with more than 97 percent of the increase in production occurring in the developing world (see figure). Sub-Saharan Africa alone will account for more than two-fifths

of the increase in demand. Worldwide, demand for cassava and other minor roots and tubers is projected to increase by 49 percent, for potatoes by 40 percent, and for sweet potatoes and yams by 30 percent between 1995 and 2020. A rapid expansion in the demand for roots and tubers for livestock feed has been under way for some time, particularly in Asia, and is likely to continue as demand for meat products grows rapidly in coming years.

Average yields for roots and tubers in developing countries are well below those in developed countries, 11.6 tons per hectare versus 16.7 tons in 1995, and are far below technically feasible levels. Potential is great for increasing production through improved varieties and other farming innovations as well as improved policies. Better yields for these crops would bring significant benefits to the food systems in developing countries, particularly to poor producers and consumers. The important continued and future role of roots and tubers in the food systems of developing countries has potentially far-reaching implications for investments in agricultural research at both the international and national levels.

Share of increase in global demand for roots and tubers, 1995–2020



Source: IFPRI IMPACT simulations, July 1999.

Note: This box is drawn from information generated by IMPACT simulations as well as from G. J. Scott, M. W. Rosegrant, and C. Ringler, "Roots and Tubers for the 21st Century: Trends, Projections, and Policy for Developing Countries," Draft 2020 Vision for Food, Agriculture, and the Environment Discussion Paper (International Food Policy Research Institute, Washington, D.C., photocopy).

feedgrain is projected to double between 1995 and 2020 to 445 million tons, while demand for cereals for direct human consumption is projected to increase by 40

percent to 1,013 million tons (Figure 6). By 2020, 27 percent of the cereal demand in developing countries will be directed to animal feed, compared with 21 percent in

Box 2 Preparing for the Livestock Revolution

The Livestock Revolution is a term used by the authors of a recent 2020 Vision Discussion Paper, *Livestock to 2020: The Next Food Revolution* by Christopher Delgado, Mark Rosegrant, Henning Steinfeld, Simeon Ehui, and Claude Courbois, to describe the massive increases in demand for foods of animal origin fueled by population growth, urbanization, and income growth in developing countries over the next 20 years. Like the Green Revolution, the Livestock Revolution involves the large-scale participation by developing countries in transformations that had previously occurred mostly in the temperate zones of developed countries.

The Livestock Revolution encompasses seven distinct trends: (1) rapid worldwide increases in consumption and production of livestock products; (2) a major increase in the share of developing countries in total livestock production and consumption; (3) an ongoing change in the status of livestock production from a small-scale local activity to a global activity; (4) increased substitution of meat and milk for grain in the human diet; (5) rapid rise in the use of cereal-based feeds; (6) greater stress on grazing resources and more intensive production closer to cities; and (7) the emergence of rapid technological change in livestock production and processing in industrial systems.

While increased consumption of livestock products among high-income people in developed countries who regularly consume excess calories could lead to health problems, including cardiovascular diseases, increased consumption of even relatively small amounts of meat and milk among low-income people in developing countries could contribute to improving their nutritional status by supplying necessary proteins and micronutrients as well as calories. Similarly, while rapidly increasing livestock production can cause serious damage to the environment, when appropriate types and

levels of production are in place it can be harmonious with the environment.

The Livestock Revolution will undoubtedly stretch the capacity of existing production and distribution systems and exacerbate environmental and public health problems. It presents many opportunities and dangers that suggest it would be unwise for developing countries to adopt a *laissez-faire* policy for livestock development. Governments and industry must prepare for this continuing transformation with long-run policies and investments that will satisfy consumer demand, improve nutrition, direct income growth opportunities to the poor, and alleviate environmental and public health stress. Delgado and his coauthors suggest four broad pillars on which to base a desirable livestock strategy for developing countries. These are:

- Removing policy distortions that promote artificial economies of scale in livestock production;
- Building participatory institutions of collective action for small-scale farmers that allow them to be vertically integrated with livestock processors and input suppliers;
- Creating the environment in which farmers will increase investment in ways to improve productivity in the livestock sector; and
- Promoting effective regulatory institutions to deal with the threat of environmental and health crises stemming from livestock.

The Livestock Revolution is a structural phenomenon that is here to stay. As in the case of the Green Revolution, the stakes for the poor in developing countries are enormous. How good or bad the Livestock Revolution will be for the people of developing countries depends on how these countries choose to approach it. Lack of policy action will not stop the Livestock Revolution but it will ensure that the form it takes is less favorable for growth, poverty alleviation, and sustainability in developing countries.

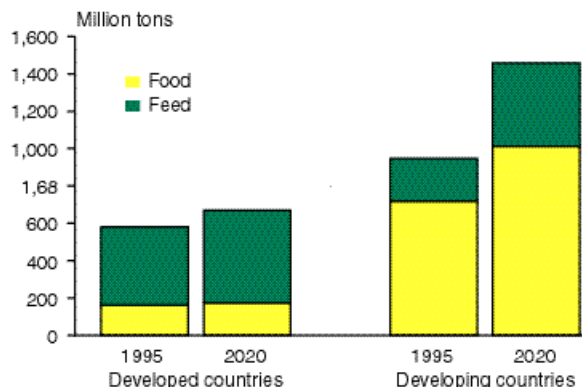
Note: This box is drawn from C. Delgado, M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois, *Livestock to 2020: The Next Food Revolution*, 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 28 (Washington, D.C.: International Food Policy Research Institute, 1999).

1995. In developed countries, feed for livestock will account for over 70 percent of the cereal demand, and the increase in cereal demand for feed will far outstrip the increase

in demand for food between 1995 and 2020.

By 2020, demand for maize in developing countries will overtake demand for rice and wheat (Figure 7). Essentially, as

Figure 6—Demand for cereals for human food and animal feed, 1995–2020

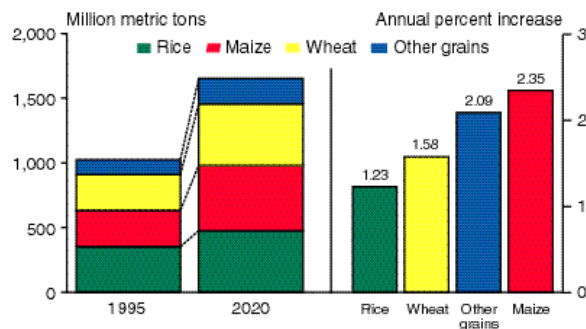


Source: IFPRI IMPACT simulations, July 1999.

incomes rise, per capita demand for rice is beginning to plateau, but demand for maize for feed purposes is growing substantially; this development has major implications for the world's agricultural production and research systems. Driven by the increased demand for animal feed, demand for maize in developing countries will increase much faster than for any other cereal, by a projected 2.35 percent per year between 1995 and 2020 compared with 2.09 percent for other grains, 1.58 percent for wheat and 1.23 percent for rice. About 64 percent of the maize demand will go toward feeding livestock compared with 8 percent of wheat and 3 percent of rice in 2020. In China, where total demand for meat is projected to double between 1995 and 2020, demand for maize is forecast to increase by around 2.7 percent per year whereas demand for rice, the most important staple for human consumption, is projected to increase by only 0.6 percent per year.

The world's farmers will have to produce 40 percent more grain in 2020, most of which will have to come from yield increases. IMPACT projections suggest that farmland cultivated with cereals will increase by only 7.4 percent or 51 million hectares by 2020, with much of the growth concentrated in the relatively low-yielding cereals of Sub-Saharan Africa. A modest expansion in cereal area is forecast for Latin America, but

Figure 7—Increase in demand for major cereals in developing countries, 1995–2020

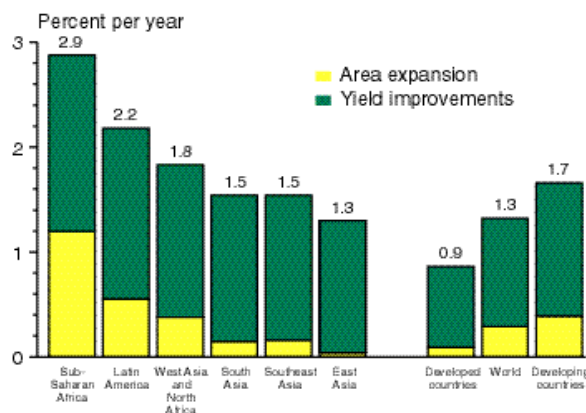


Source: IFPRI IMPACT simulations, July 1999.

virtually no growth is projected for Asia or the developed countries. IMPACT projections suggest that global cereal production will grow at an average annual rate of 1.3 percent between 1995 and 2020 (Figure 8); increases in cultivated area are expected to contribute only one-fifth of the global cereal production needed to meet demand between 1995 and 2020. Therefore, improvements in crop yields will be required to bring about the necessary production increases.

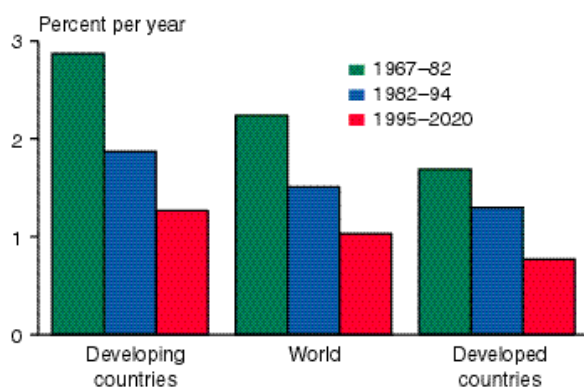
However, growth in farmers' cereal yields is slowing. In both developed and developing countries, the rate of increase in cereal yields is slowing from the heyday of the Green Revolution in the 1970s (Figure 9). This is due partly to reduced use of

Figure 8—Sources of growth in cereal production, 1995–2020



Source: IFPRI IMPACT simulations, July 1999.

Figure 9—Annual growth in cereal yields, 1967–82, 1982–94, and 1995–2020

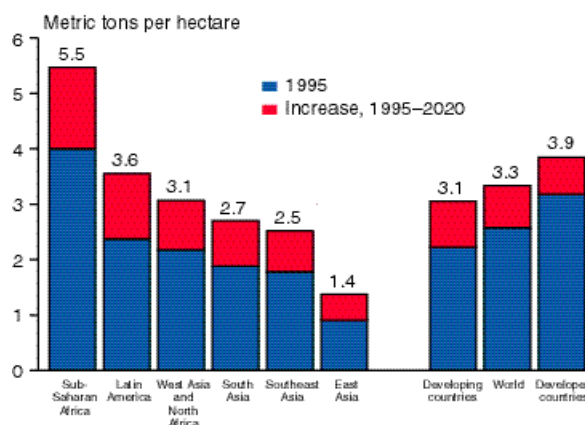


Source: 1967–82 and 1982–94; Food and Agriculture Organization of the United Nations, FAOSTAT database <<http://faostat.fao.org>>, accessed March 1997; 1995–2020: IFPRI IMPACT simulations, July 1999.

inputs like fertilizer, reflecting low and falling cereal prices, and partly to low levels of investment in agricultural research and technology. Poorly functioning markets and lack of appropriate infrastructure and credit are also contributing factors. Without substantial and sustained additional investment in agricultural research and associated factors, it will become more and more difficult to maintain, let alone increase, cereal yields in the longer term. The gap in average cereal yields between the developed and developing countries is slowly beginning to narrow, but it is widening considerably within the developing world as Sub-Saharan Africa lags further and further behind the other regions, particularly East Asia (Figure 10).

Food production will increase much faster in the developing world than in the developed world. Between 1995 and 2020, cereal production in the developing world is projected to increase by 51 percent from 965 million tons to 1,460 million tons, whereas in the developed world cereal production is projected to increase by only 24 percent from 812 million tons to 1,006 million tons. By 2020, the developing world will be producing 59 percent of the world's cereals, up from 54 percent in 1995. While both the developing and the developed world were each produc-

Figure 10—Cereal yields, 1995–2020

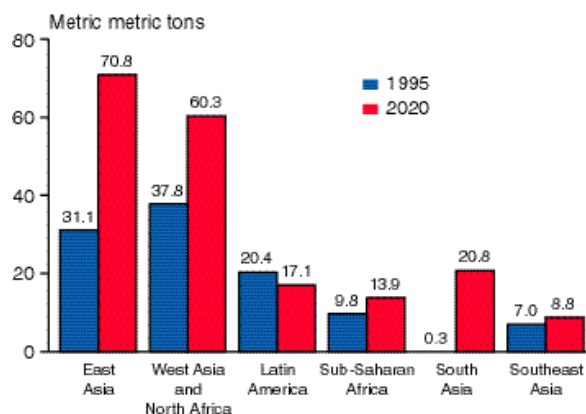


Source: IFPRI IMPACT simulations, July 1999.

ing about the same volume of meat in 1995, about 99 million tons, the developing world is projected to almost double its production between 1995 and 2020 to 191 million tons while the developed world is projected to increase its production by only 24 percent to 123 million tons. By 2020, the developing world will be producing 61 percent of the world's meat, up from 50 percent in 1995.

Nevertheless, net cereal imports by developing countries will almost double to fill the gap between food production and demand. Despite large increases, cereal production in the developing world will not keep pace with demand. IMPACT projections suggest that the developing world's net cereal imports will increase by 80 percent between 1995 and 2020 to reach 191.6 million tons. With the exception of Latin America, all major regions are forecast to increase their net cereal imports (Figure 11). The massive increase forecast in South Asia's net cereal imports from 0.3 million tons in 1995 to 20.8 million tons in 2020 will arise because domestic production in the region will not keep up with income and population growth. In Pakistan, problems with salinity and waterlogging in the main cereal production areas will limit crop yield growth, while population growth will be rapid. India is projected to shift from moderate cereal exports to moderate imports,

Figure 11—Net cereal imports of major developing regions, 1995 and 2020

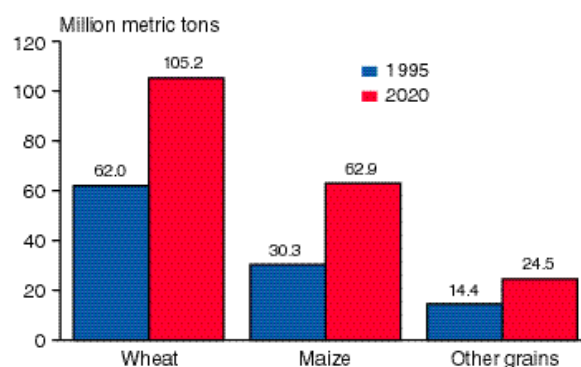


Source: IFPRI IMPACT simulations, July 1999.

owing to declining growth in cereal yields and relatively rapid income growth. Sub-Saharan Africa's net cereal imports are expected to remain low because of lack of foreign exchange and entrenched poverty. Wheat will constitute more than half of the developing world's net cereal imports, but the share of maize is projected to rise from 28 to 33 percent between 1995 and 2020 (Figure 12). Trade in rice is forecast to remain small. About 12 percent of the developing world's cereal demand is projected to be met through net imports from the developed world, up from 10 percent in 1995.

Net meat imports by developing countries will increase eightfold between 1995 and 2020. Although trade in meat products is much smaller than in cereals, IMPACT projects that developing countries will increase their net meat imports from 0.8 million tons to 6.6 million tons. The proportion of the developing world's meat consumption that will be met through net imports is forecast to rise from 0.8 to 3.3 percent. Latin America will remain a net exporter while South Asia will switch from being a net exporter to a net importer (Figure 13). East Asia is projected to increase its net meat imports 28-fold, albeit from very low levels, primarily because of the massive increases expected in meat demand in China. Poultry meat is expected

Figure 12—Composition of net cereal imports of major developing regions, 1995 and 2020

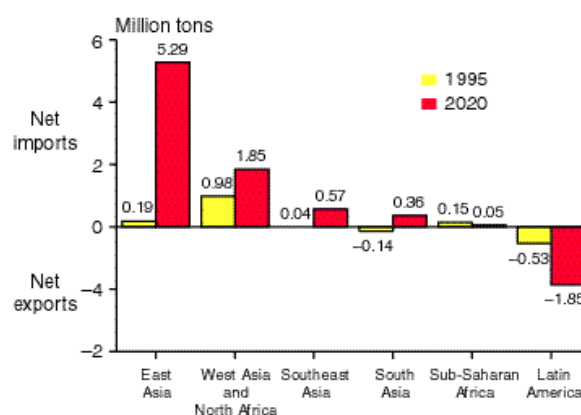


Source: IFPRI IMPACT simulations, July 1999.

to constitute 55 percent of the developing world's net meat imports in 2020, followed by pigmeat at 28 percent and beef and sheepmeat at 9 percent each.

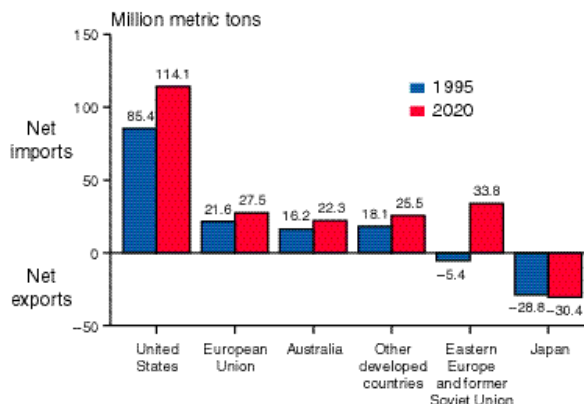
About 60 percent of the developing world's net cereal imports in 2020 will come from the United States. With a 34 percent increase projected in its net cereal exports between 1995 and 2020, the United States will continue to capture a large share of the increased export market for cereals (Figure 14). However, with the projected emergence of Eastern Europe and the former Soviet Union as major net exporters of cereals and the increase in net exports fore-

Figure 13—Meat trade of major developing regions, 1995 and 2020



Source: IFPRI IMPACT simulations, July 1999.

Figure 14—Net trade in cereal of developed countries, 1995 and 2020



Source: IFPRI IMPACT simulations, July 1999.

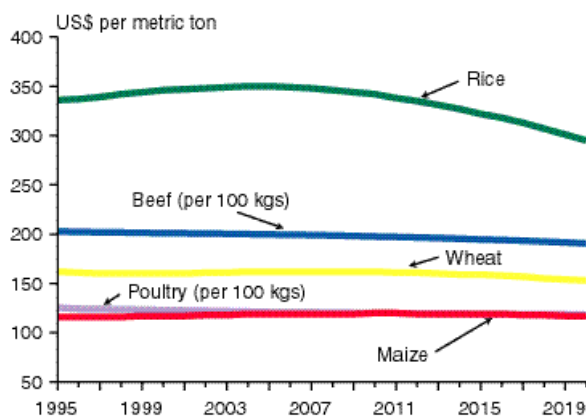
cast for the European Union and Australia, the market share of the United States in the net cereal exports of the developed world is projected to decline from 80 percent in 1995 to 60 percent in 2020. The outcomes of the upcoming WTO negotiations and related changes in domestic subsidies in the United States and the European Union, as well as developments related to biotechnology and genetically modified foods, may influence trade patterns.

Food prices will remain steady or fall slightly between 1995 and 2020. Real world prices of food are projected to decline, but at much slower rates than in the past two decades (Figure 15). Cereal prices on

average are projected to drop by about US\$19 per metric ton by 2020 (about 17 percent). The much slower decrease in food prices, compared with past trends, is due to the continued slowdown in crop yield increases, as well as strong growth in demand for meat in developing growth countries. Real cereal prices are expected to increase slightly through the year 2010. It is only after 2010 that the continued decline in the rate of population growth, combined with declining income elasticities of demand for cereals, will reduce demand growth enough to cause cereal prices to resume their long-term downward trend. By comparison, between 1982 and 1995, real world wheat prices dropped by 28 percent, rice prices by 42 percent, and maize prices by 43 percent.

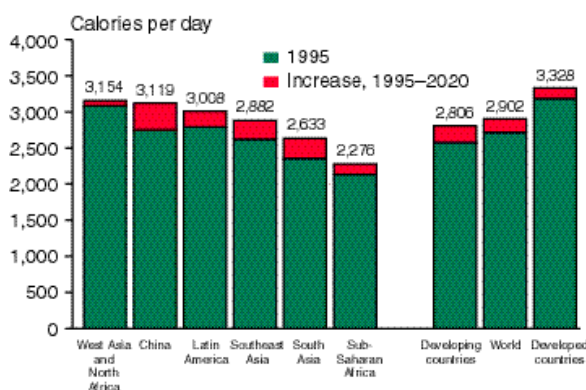
With increased production and imports, per capita food availability in the developing world will increase. IMPACT projections indicate that about 2,800 calories will be available per person per day in the developing world by 2020, an increase of about 9 percent over 1995. Increases in per capita food availability are expected in all regions. China is projected to experience the largest increase, and West Asia and North Africa the smallest increase, albeit from already high levels (Figure 16). At less than 2,300 calories per person per day, average food availability in Sub-

Figure 15—World prices of major commodities, 1995–2020



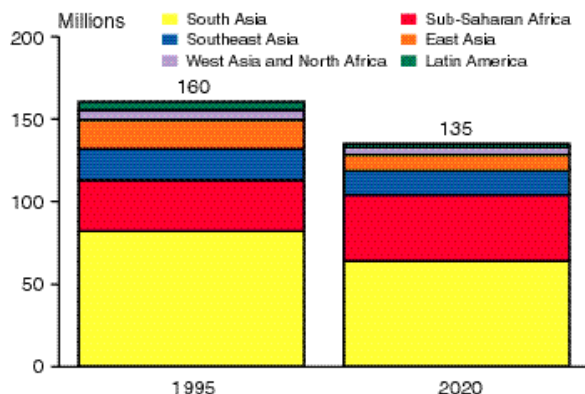
Source: IFPRI IMPACT simulations, July 1999.

Figure 16—Daily per capita calorie availability, 1995 and 2020



Source: IFPRI IMPACT simulations, July 1999.

Figure 17—Number of malnourished children, 1995 and 2020

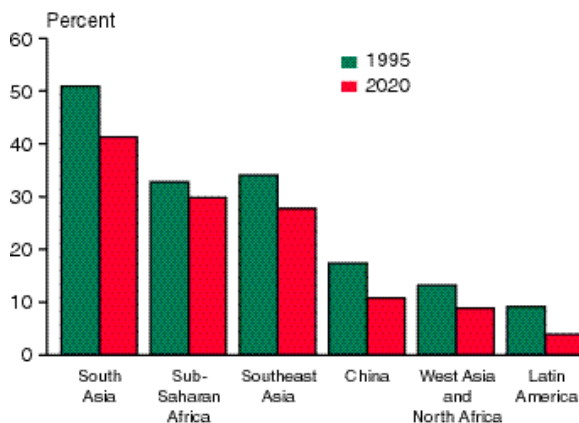


Source: IFPRI IMPACT simulations, July 1999.

Saharan Africa will barely meet the requirements for a healthy and productive life. And since available food will not be equally distributed, many Africans will have less than the minimum required.

In the scenario described here, food insecurity and malnutrition will persist in 2020 and beyond. Under the most likely scenario, IMPACT projects that 135 million children under five years of age will be malnourished in 2020 (Figure 17).¹⁰ This represents a decline of only 15 percent from 160 million in 1995. Hence, one out of every four children in developing countries will still be malnourished in 2020 compared with every third child in 1995. Child malnutrition is expected to decline in all major developing regions except Sub-Saharan Africa, where the number of malnourished children is forecast to increase by about 30 percent to reach 40 million by 2020. In South Asia, despite a reduction in the number of malnourished children by 18 million, as many as two out of five children will still be malnourished in 2020 (Figure 18). With more than 77 percent of the developing world's malnourished children in 2020, up from 70 percent in 1995, Sub-Saharan Africa and South Asia will remain "hot spots" of child malnutrition and food insecurity. Many of the countries in these two regions are among the least-developed countries in the world; they will require spe-

Figure 18—Percentage of malnourished children, 1995 and 2020



Source: IFPRI IMPACT simulations, July 1999.

cial assistance to avert widespread hunger and malnutrition in the years to come.

In summary, the world food situation at the threshold of the 21st century is mixed: astonishing advances in agricultural productivity and human ingenuity have not yet translated into a world free of hunger and malnutrition. Dramatic changes in food production, processing, and trade in recent decades have resulted in enough food to meet the basic needs of each and every person in the world. Doubling grain production and tripling livestock production since the early 1960s has made available about 2,700 calories per person per day. Yet, about 820 million people lack access to sufficient food to lead healthy and productive lives,¹¹ and about 160 million children are seriously underweight for their age.

This mixed outlook for the world food situation could be significantly worse with increased policy complacency or greater than anticipated constraints in or deterioration of key variables such as water availability, land quality, human resource development, and technological innovations. On the other hand, with concerted political will and appropriate investments, a food-secure world is within reach. Ultimately, our behavior, priorities, and policies will determine the nature of the world food situation in the 21st century.

EMERGING ISSUES

Described here are six critical recent developments or emerging issues that could significantly influence and alter the outlook for the world food situation in the early years of the next century.

New Evidence on Nutrition and Policy

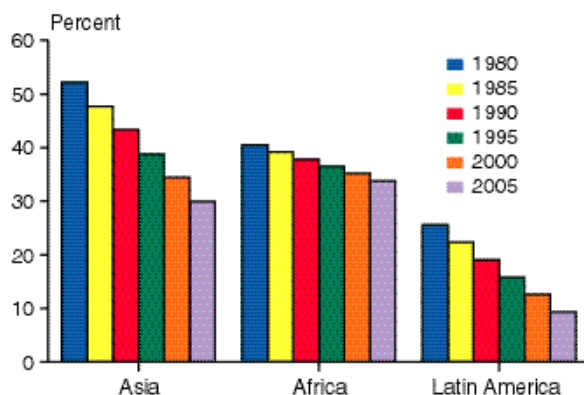
New information confirms that while the global nutrition situation is improving, nutritional status is deteriorating in several countries, particularly in Africa. Research shows that about 33 percent of preschool children in the developing world will be stunted by 2000.¹² This is a significant decline from the prevalence rate of 47 percent just 20 years ago. In terms of numbers, about 182 million children are expected to be stunted in 2000, down from 221 million in 1980. Although the prevalence of stunted children has decreased and is expected to continue to do so beyond 2005 in the three major developing regions (Figure 19), the number of stunted children has increased significantly in Africa, from less than 35 million in 1980 to

45 million in 1995, and is projected to reach 49 million in 2005 (Figure 20). While the number of stunted children is higher than the number of malnourished children presented in the previous section, Sub-Saharan Africa is clearly a region of grave concern for both.

New evidence shows that low birth weight continues to be a major contributor to child malnutrition and premature death.¹³ About one in four children born in 2000 is expected to suffer from insufficient fetal growth and resulting low birth weight. The poor fetal growth and low birth weight are caused by mother's poor nutrition both before conception and during pregnancy.

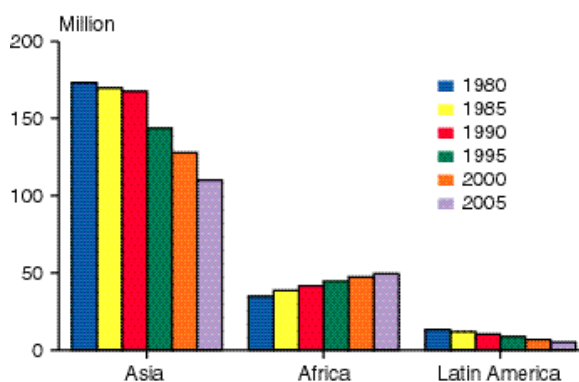
New information on consumption of micronutrients such as vitamins and minerals confirms that anemia stemming from insufficient iron intake is widespread among women, particularly pregnant women, and children (Figure 21). About 2 billion people suffer from iron deficiency anemia.¹⁴ Similarly, data from a large number of countries show that vitamin A deficiencies are widespread. Recently updated information

Figure 19—Estimated prevalence of stunted children, 1995–2020



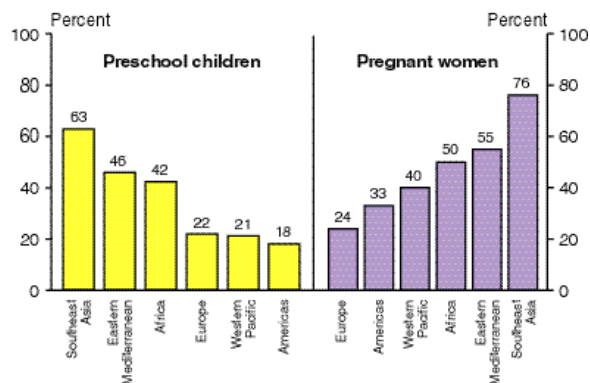
Source: Subcommittee on Nutrition of the United Nations Administrative Committee on Coordination/International Food Policy Research Institute (SCN/IFPRI), "Fourth Report on the World Nutrition Situation" (SCN/IFPRI, Washington, D.C., July 1999, photocopy).

Figure 20—Estimated number of stunted children, 1995–2020



Source: Subcommittee on Nutrition of the United Nations Administrative Committee on Coordination/International Food Policy Research Institute (SCN/IFPRI), "Fourth Report on the World Nutrition Situation" (SCN/IFPRI, Washington, D.C., July 1999, photocopy).

Figure 21—Prevalence of anemia in preschool children and pregnant women by region

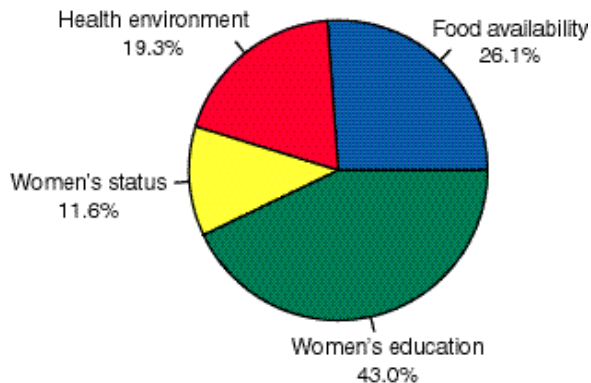


Source: Subcommittee on Nutrition of the United Nations Administrative Committee on Coordination/International Food Policy Research Institute (SCN/IFPRI), "Fourth Report on the World Nutrition Situation" (SCN/IFPRI, Washington, D.C., July 1999, photocopy).

on iodine deficiency disorders (IDD) indicates that this is a public health problem in 130 countries around the world, with more than 2 billion people at risk of IDD and about 740 million people affected with goiter.¹⁵

Researchers have been working to identify which policy-related variables are likely to help improve the nutritional status of children. New IFPRI research finds four critical reasons why child nutrition improved in the developing world between 1970 and 1995: improvements in women's education accounted for almost 45 percent of the total reduction in child malnutrition during this period, followed by improvements in per capita food availability, improvements in the health environment, and improvements in women's status relative to men (Figure 22). This research suggests that investments in these four areas could significantly reduce child malnutrition but warns that these investments will make little difference without improvements in national incomes and democracy.¹⁶ For Sub-Saharan Africa and South Asia—where the proportion and number of malnourished children are highest—improving per capita food availability and women's education offers the best hope for

Figure 22—Estimated contribution of major determinants to reductions in child malnutrition, 1970–95



Source: L. Smith and L. Haddad, "Overcoming Child Malnutrition in Developing Countries: Past Performance, Future Possibilities," Draft 2020 Vision for Food, Agriculture, and the Environment Discussion Paper (International Food Policy Research Institute, Washington, D.C., photocopy). Note: Malnourished children refers to underweight children.

reducing child malnutrition in the future, the study concludes.

Comparing African countries that showed improved child malnutrition with those that showed worsening malnutrition leads to similar conclusions. The countries with improved nutritional status had larger increases in the enrollment of women in secondary school, in per capita food consumption, and in per capita incomes.¹⁷ Furthermore, although women's status deteriorated in both groups, it deteriorated much more in countries where the nutritional status worsened. The data do not establish strict causality, but this analysis provided strong indications that women's schooling, women's status, per capita food intake, and per capita incomes are important determinants of child nutrition in Africa.

The presence of civil conflict increases vulnerability to food insecurity, and vice versa.¹⁸ Recent information from the Food and Agriculture Organization of the United Nations vividly demonstrates that the incidence of undernourishment or food insecurity is highest in countries with a high incidence of civil conflict. For example, 56 percent of the countries where more than

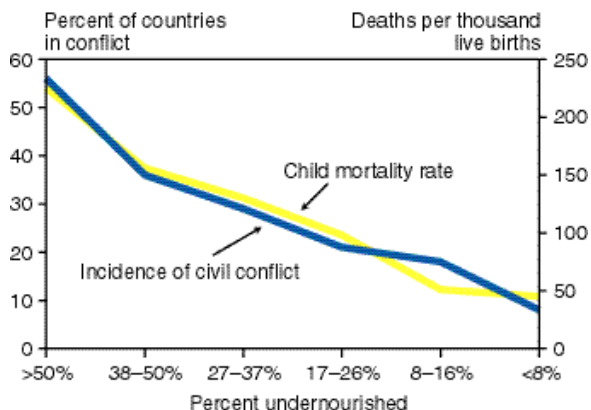
half of the population was undernourished were experiencing conflict while only 8 percent of the countries with the lowest incidence of undernourishment were mired in conflict (Figure 23). Similarly, child mortality rates are highest in those countries where a larger proportion of the population is undernourished; in other words, child mortality rates decline as the prevalence of food insecurity declines.

The large numbers of malnourished children and the upward trend in Sub-Saharan Africa make it more urgent than ever for research and government policy to address this unfolding human tragedy. A conference held at the International Rice Research Institute (IRRI) on October 5–7, 1999, explored opportunities for enhancing the nutrition impact of the research conducted by the research centers of the Consultative Group on International Agricultural Research (CGIAR) and national agricultural research systems. It is critical that every reasonable effort be made to assure that future CGIAR priorities reflect the widespread human suffering and economic losses associated with malnutrition and the urgency of reducing and eventually eliminating such malnutrition.

Low Food Prices: What Will the Future Bring?

World market prices for wheat, maize, and rice, adjusted for inflation, are the lowest they have been in the last century (Figure 24). Prices fell dramatically in the 1980s, although some adjustments in the early 1990s resulted in a relatively large price increase for wheat and maize during 1995 and the first half of 1996. Since then, the real international prices for wheat, maize, and rice have once again dropped significantly to the current very low levels. The severity of the price fluctuations since the mid-1990s is illustrated by the prices received by United States farmers (Figure 25). Maize and wheat prices increased about 70 and 50 percent,

Figure 23—Food security, civil conflicts, and child mortality, 1990–96

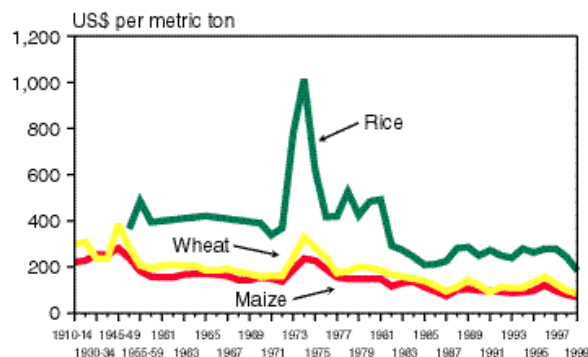


Source: Food and Agriculture Organization of the United Nations, *Assessment of the World Food Security Situation*, Report No. CFS:99/2 of the 25th Session of the Committee on World Food Security, Rome, May 31–June 2 (Rome: FAO, 1999).
Note: Countries grouped by prevalence of undernourishment.

respectively from April 1995 to April 1996. By April 1999, they had dropped to less than half of the 1996 level. U.S. soybean prices are expected to fall to their lowest level since 1972/73, and the stock is likely to double from last year.¹⁹ The fluctuation in the rice price was considerably less.

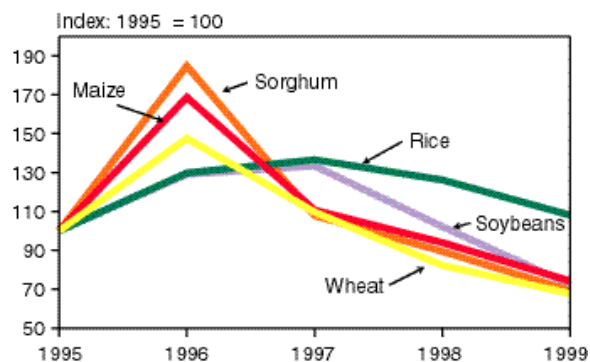
Why these severe price fluctuations? As further discussed elsewhere,²⁰ a number of factors coincided in 1995 to raise prices: adverse weather conditions in Canada and

Figure 24—Real export prices for wheat, maize, and rice in selected years, 1910–1999



Source: D. Gale Johnson, "The Growth of Demand Will Limit Output Growth for Food over the Next Quarter Century," *PNAS Online* 96 (11, 1999): 5915-5920; USDA, <<http://www.usda.gov>> (accessed August 1999); U.S. Department of Labor, <<http://www.dol.gov>> (accessed August 1999); World Bank, <<http://www.worldbank.org>> (accessed August 1999).

Figure 25—Average real prices received by U.S. farmers, 1995–99



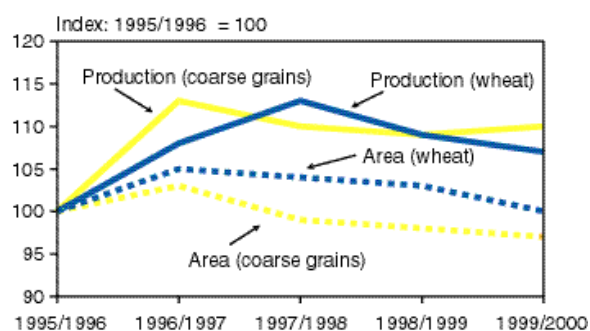
Source: IFPRI calculations from U.S. Departments of Agriculture and Labor data.

Note: For 1995–97, preliminary April averages are used. For 1998–99, actual April averages are used.

the United States, drought and civil conflict in Sub-Saharan Africa, stagnating grain yields in Asia, set-aside programs and reduced subsidies in the European Union, and decreased food production in the former Soviet Union and China. Some countries buffered both consumers and farmers from the higher grain prices, but in countries that did not, farmers expanded the area of land cultivated with grain. World-wide, the wheat and coarse grain area increased by 5 and 3 percent, respectively, between 1995/96 and 1996/97. As prices began to drop, farmers cut back area, and it is expected that by 1999/2000, the wheat area will be back to the 1995/96 level, while the coarse grain area will be 3 percent below the 1995/96 level (Figure 26). The area adjustments in the world's largest grain exporter, the United States, were considerably greater: U.S. farmers increased the wheat area by close to 9 percent between 1995/96 and 1996/97 and cut it back by 16 percent during the subsequent three years. The maize area was increased by 11 percent and has stayed at that level since 1996/97.

Despite declines in the area planted to wheat and maize, yield increases due to past investments in improved technology have kept total production on the rise since 1996/97. Thus, farmers are expected to pro-

Figure 26—World area and production for wheat and coarse grains, 1995–2000



Source: United States Department of Agriculture, *Agricultural Outlook, August*, Publication No. AGO-263 (Washington, D.C.: Economic Research Service, USDA, 1999).

Note: Coarse grains include maize.

duce 7 percent more wheat in 1999/2000 than they did in 1995/96, on the same amount of land. Similarly, although the global maize area is expected to fall by 3 percent from its 1995/96 level, global production is expected to be 10 percent higher. U.S. maize production is expected to be 30 percent larger in 1999/2000 than it was in 1996/97. The increase in global maize production is influenced not only by productivity-increasing technologies but also by the larger share of the global maize area occupied by the United States (where yields are higher).

So why have grain prices fallen so severely since mid-1996? The answer comes straight from basic economics: The production increases exceeded demand at existing prices. Even after it became obvious that the high prices of early to mid-1996 could not be maintained, farmers did not cut area planted sufficiently to compensate for the long-term trend in productivity increase. Favorable weather in major producing areas also contributed to production increases. While production was rising, demand was falling. As a result of their economic crisis, Asian countries sharply reduced their imports of livestock products and grain, and a deepening crisis in the former Soviet Union reduced imports of grain and livestock products by that region. China switched from being a major net grain

importer in 1995–96 to being a net exporter in 1997–98.

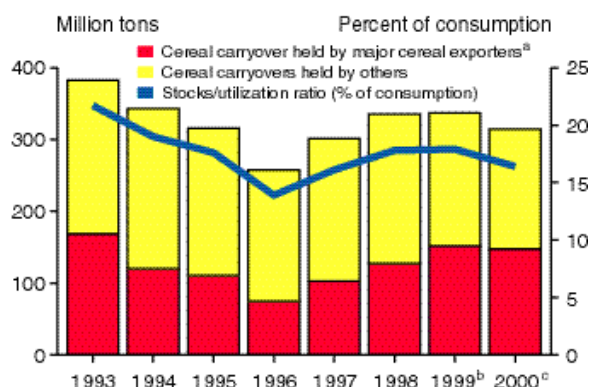
As grain prices fell, the low world grain stock of 1996 was rebuilt and reached 337 million tons in 1999, corresponding to 17.9 percent of expected annual consumption (Figure 27). The stock adjustments in response to the high prices in 1995–96 and the falling prices since then occurred primarily in the major exporting countries.

What does the future hold? There is little doubt that the current maize and wheat prices are below the long-term trend. It is difficult to predict how long it will take to return to the trend. Although increased climatic variations may cause larger production fluctuations in the future, current large grain stocks and the continued productivity increases make it difficult to believe that prices will spike significantly in the next few years. However, the current low grain prices are causing large income losses among farmers in countries where international prices are transmitted to them. This is the case in the United States and most other traditional grain exporters. Further cuts in area planted to wheat and maize, along with reduced fertilizer use, is likely. Additional decreases in grain production could result if the European Union and the United States decide to reintroduce or expand area set-aside programs. A return to rapid economic growth in Asia would increase grain and livestock consumption and imports, as would improvements in the economic situation in the former Soviet Union. Depending on how these factors play out, and barring unprecedented bad weather in the major producing areas, it seems reasonable to expect that real grain prices will stay below the trend for at least the next couple of years.

Trade Negotiations: Preparing for the Next WTO Round

Recent analyses reported in various IFPRI publications, including the annual report and a collection of 2020 policy briefs, indicate

Figure 27—World cereal stock carryover, 1993–2000



Source: Food and Agriculture Organization of the United Nations, <<http://faostat.fao.org>> (accessed August 1999).

^a Argentina, Australia, Canada, European Union, and the United States.

^b Estimated.

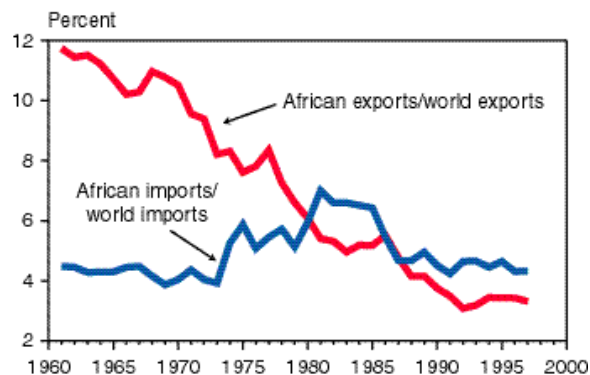
^c Forecast.

that in the upcoming WTO round of agricultural trade negotiations, expected to begin in November 1999, poor countries and poor people risk losing out on the economic benefits embodied in further trade liberalization.²¹ To gain from trade talks, developing countries must participate effectively in the negotiations. Among other things, developing countries should pursue better access to markets in industrial countries for their agricultural commodities. However, without appropriate domestic economic and agricultural policies, developing countries in general and poor people in particular will not be able to capture fully the potential economic benefits from international trade liberalization.

According to FAO, the most frequent problems confronted by developing countries in their participation in the debate on international agreements related to agriculture and trade are inadequate administrative and legal capacity to meet WTO requirements; insufficient national policy formulation capacity; limited scientific, administrative, and infrastructure capability to deal with food standards; and lack of plant variety protection.²²

As shown in Figure 28, the African share of world agricultural trade continues to decline rapidly. While it is too early to estimate the impact of the Uruguay Round on

Figure 28—African share of world agricultural trade



Source: N. Mukherjee and R. L. Harris, "Getting Ready for the Millennium Round Trade Negotiations: African Perspective," 2020 Vision Focus 1, Brief 4 (Washington, D.C.: International Food Policy Research Institute, 1999).

Africa, research results indicate that the round will have adverse economic effects for most of the countries in Sub-Saharan Africa. The negative effects can be large and will be worse in countries that fail to undertake the necessary domestic policy reforms. Without such reforms, these countries are less able to respond effectively to opportunities arising from more liberalized agricultural trade. Failure to participate as the rest of the world moves toward a more liberalized trade regime may isolate Africa from the mainstream world economy.

The only real option for African and other low-income developing countries is to try to strengthen their bargaining position and pursue a set of key goals for both domestic policies and international trade arrangements. The most important issues include the following:

- Continue to pursue domestic policy reforms that remove distortions adverse to small farmers and the poor while facilitating access to the benefits from more open trade;
- Gain better access to industrial-country markets, particularly free entry for goods from the least-developed countries and the elimination of tariff escalation;
- Eliminate export subsidies in industrial countries and export taxes and controls

that exacerbate price fluctuations in world markets;

- Obtain technical assistance and financial support from industrial countries to develop the agricultural sectors in low-income developing countries;
- Continue a strong sanitary and phytosanitary framework domestically and seek technical support to help produce at the standards expected in developed-country markets; and
- Gain adequate levels of food aid targeted to poor groups, in ways that do not displace domestic production.²³

The Potential of Agroecological Approaches

Although the Green Revolution technologies have been responsible for enormous productivity increases among small-scale farmers in Asia, Latin America, and a few countries of Sub-Saharan Africa, many farmers have been bypassed. The desire to find ways of assisting these farmers, combined with concerns about excessive dependence on external inputs such as fertilizers, pesticides, and irrigation water embodied in the Green Revolution technologies, has stimulated interest in alternative or complementary approaches, including the so-called "agroecological approach."

The agroecological approach aims to reduce the amount of external inputs that farmers have to use. Instead, it relies heavily on available farm labor and organic material, as well as on improved knowledge and farm management. Thus, while the agroecological approach needs more external inputs in the area of knowledge and management, physical external inputs such as fertilizers, pesticides, and irrigation water are reduced. A large number of nongovernmental organizations have dedicated themselves to providing such knowledge inputs in direct collaboration with farmers and farmer representatives. The agroecological approach also focuses on farm-level research and experimentation

rather than dependence on the more formal agricultural research structures. Use of locally available materials such as crop residues, farm manure, and compost to improve soil fertility is an important part of the agroecological approach, as is integrated pest management. While the definition of the agroecological approach does not exclude the use of chemical fertilizers and chemical pesticides, it argues that such chemical inputs should be used only as a last resort.

Agroecological approaches tend to be very labor demanding, and the returns to labor from many agroecological activities tend to be low. Therefore, as agricultural development increases the opportunity cost of labor, agroecological approaches will need to adjust to reduce labor requirements. This will probably mean moving away from such activities as mulching and composting toward chemical fertilizers and other inputs that enhance labor productivity. Many agroecological approaches, such as the production of green manure, tend to be land using. While this may be appropriate in certain communities where land is abundant, it may be inappropriate in areas with severe land scarcity.

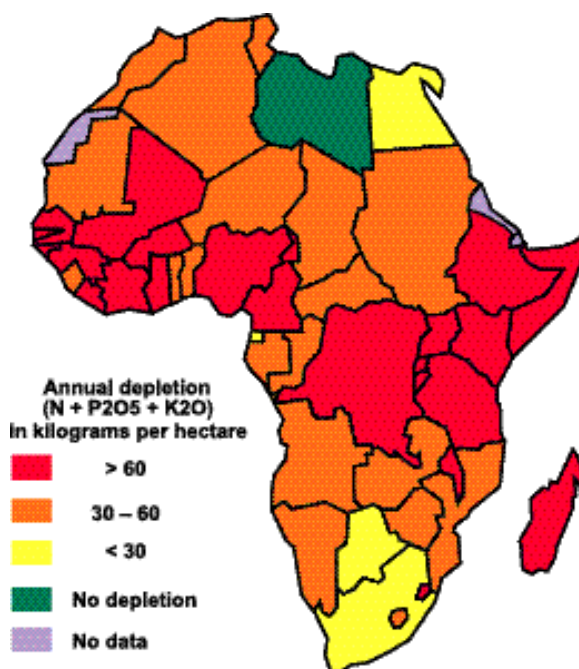
Low and declining soil fertility is a serious problem in many low-income countries, including most of Africa. Figure 29 shows the average annual nutrient depletion in Africa during the early to mid-1990s. About 86 percent of the countries in Africa show negative balances of nutrients greater than 30 kilograms of NPK per hectare per year. The cost of eliminating this nutrient depletion by using fertilizer would amount to US\$1.5 billion per year.²⁴ Although improved soil conservation measures, recycling of crop residues, better rotation schemes, and use of nitrogen-fixing legumes as well as farm manure are important to deal with soil fertility problems, expanded use of chemical fertilizers will be necessary to effectively solve the soil fertility problem in most of the low-income countries.

The current average consumption of chemical fertilizers in Africa is 10–15 kilo-

grams per hectare, and its use is heavily concentrated on a small number of export crops. Failure to combine expanded use of chemical fertilizers with agroecological methods is likely to result in further declines in soil fertility and crop yields to the detriment of the livelihoods of small-scale farmers in Africa. Furthermore, opportunities for using modern biotechnology to develop cereal varieties that could fix nitrogen from the air and extract phosphorus from acid soils should be explored.

One of the great strengths of the agroecological approach is that it promotes sustainable management of natural resources and active participation by farmers in identifying problems as well as designing and implementing appropriate solutions at the farm and community levels. Such participatory technology development can be extremely effective in finding the most appropriate solutions to production problems.

Figure 29—Average annual nutrient depletion (NPK) in Africa, 1993–95



Source: J. Henao and C. Baanante, "Nutrient Depletion in the Agricultural Soils of Africa," 2020 Vision Brief 62 (Washington, D.C.: International Food Policy Research Institute, 1999).

A large number of projects and initiatives have successfully applied agroecological approaches to expand yields and improve the livelihoods of farm families.²⁵ Illustrations from more than 30 African, Asian, and Latin American countries demonstrate the tremendous potential of agroecological approaches to promote sustainable productivity increases in small-scale agriculture. While some approaches will have to change in response to increasing agricultural development and changes in farmer incomes and opportunity costs, such changes should come about easily as a result of farmer participation and leadership. Therefore, it is critical that farmers are, in fact, put in decisionmaking roles and that they are informed about their options for improving productivity, reducing risks, and increasing the well-being of the farm family. Such options should include access to external inputs and appropriate technologies to complement agroecological approaches. Farmers should not be made to suffer from the current debate among professionals over which approach is the most appropriate. Farmers should be able to put together the most appropriate components from each of the various “approaches” in order to develop their own solutions. Attempts to persuade farmers to pursue one approach over another, rather than combining the most appropriate elements of the various approaches, is not in their best interest. For example, combining certain agroecological approaches with access to chemical fertilizers to supplement available organic matter and access to improved seeds containing characteristics such as drought tolerance and resistance to certain pests is likely to be the most appropriate way to assist certain small-scale farmers. Although on-farm experimentation should be an important part of the overall agricultural research effort, both the public- and the private-sector agricultural research systems have a role in developing technology that would be of interest to small-scale farmers.

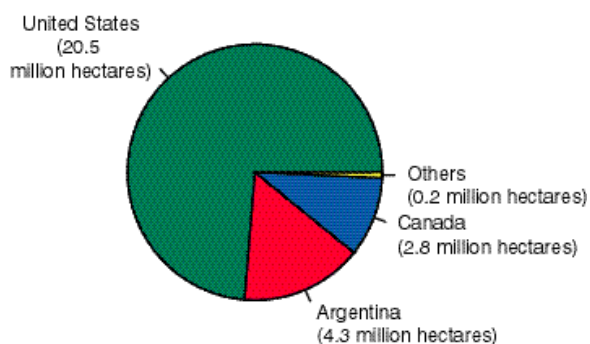
The Potential of Modern Biotechnology

The extent to which modern biotechnology will contribute to the achievement of food security for all is still an open question. While molecular biology-based science is moving at great speed, its application to agriculture has been mostly limited to solving problems facing farmers in the industrial countries and large farmers in a few developing countries. Most of the commercialization of transgenic seed has occurred for soybeans, maize, and cotton in the United States, and to a lesser extent in Argentina, Canada, Mexico, China, and South Africa (Figure 30).

Strong opposition to genetically modified food (GM food) in the European Union has resulted in severe restrictions for modern biotechnology for agriculture. The opposition is driven in part by the perceived lack of consumer benefits of the transgenic foods available to date, uncertainty about possible negative health and environmental effects, and a widespread perception that a few large corporations will be the primary beneficiaries of modern biotechnology for agriculture.

Consumers, who in most European countries outnumber farmers by a factor of more than 20, see few if any benefits or potential benefits from GM foods. The benefits from the current generation of transgenic crops, which are resistant to herbicides and

Figure 30—Area of transgenic crops, 1998



Source: C. James, *Global Review of Commercialized Transgenic Crops: 1998*, ISAAA Brief 8 (Ithaca, N.Y., U.S.A.: International Service for the Acquisition of Agri-biotech Applications, 1998).

certain pests, accrue primarily to farmers. Consumer benefits might include reduced pesticide residues in the food as chemical pesticides are replaced by pest-resistant varieties. Even when biotechnology helps lower the unit costs of production, existing EU price and subsidy policies may prevent consumers from seeing lower prices. Even if they did, food occupies a small share of the consumer budget, and price falls would not be of great importance to European consumers. At the same time, an effective campaign by advocacy groups in some EU countries, fueled in large measure by the news media, has emphasized the potential risks associated with GM foods. Even though the evidence of these risks is weak, the uncertainty in the minds of many is real. Given that the expected benefits are small, opposition is perfectly reasonable.

The situation is very different for poor people in the developing countries. First, 60–70 percent of the poor live in rural areas and depend directly or indirectly on productivity increases in agriculture to get out of poverty. Biotechnology, if appropriately focused on solving small farmers' problems, together with traditional research methods, better agronomic practices, and better markets and policies, may help these farmers to increase productivity. Second, biotechnology may help farmers reduce production risks by making available crop varieties that are drought tolerant, pest resistant, and able to capture nitrogen from the air. Third, biotechnology to increase the content of iron or vitamin A or to make other nutritional improvements in foods may address serious and widespread nutritional problems among the poor in developing countries. Fourth, increased productivity will, in most developing countries, result in both higher incomes for small farmers and lower food prices. This is important for the poor, who typically spend 50 percent or more of their incomes on food.

Although much of the past molecular biology-based research should be useful as a starting point for the development of biotechnology suited for small farmers in

developing countries, very little adaptive research has been undertaken. Except for a few of the larger or better-off countries such as Brazil, China, Egypt, India, Mexico, and South Africa, most of the developing countries are unable or unlikely to mount effective agricultural biotechnology research programs without support or partnerships from outside the country. The CGIAR centers are well placed to bridge the gap between biotechnology research in industrial countries and the needs of the small farmers in developing countries, but only a small share of their budget is spent on such adaptive research. The large life-science corporations, which are responsible for most of the applied agricultural biotechnology research to date, focus on industrial-country agriculture, where they can expect to recuperate the costs of the research. With some exceptions, small farmers in developing countries do not offer a profitable market at this time. Yet, the social benefits of developing and applying appropriate biotechnology for small farmers are likely to be high. They include reduced risks from biotic and abiotic factors, increased yields, foods that are more nutritious and easier to store, development of edible vaccines in staple foods, and protection of the environment through reduced use of fertilizers and pesticides and reduced pressure on land currently not under cultivation. As usual, in cases where the private sector cannot capture large social benefits, the public sector needs to either invest or introduce policies that will assure that enough of the social benefits can be captured by the private sector to warrant investment.

Delivering the potential benefits of agricultural research in general and biotechnology in particular to small farmers and poor consumers in developing countries will require a combination of expanded public investment by developing countries and the CGIAR as well as public-private partnerships. Governments in industrial and developing countries also have an important role to play in regulating the biotechnology

industry. They must develop effective biosafety regulations, create and enforce appropriate intellectual property rights legislation, and enforce antitrust legislation to counter excessive concentration in the life science and seed industry. Relevant information on these issues must be made available to the public. If these steps are not taken, modern biotechnology will bypass the poor; opportunities for reducing poverty, food insecurity, and child malnutrition will not become reality; and the productivity gap between developing and industrial countries' agriculture will widen. A fuller discussion of biotechnology for developing countries is forthcoming from IFPRI.²⁶

Information Technology and Precision Farming: Relevance for Small Farmers

The revolutionary developments in information and communication technology (ICT) during the last few years have resulted in dramatic falls in the cost of processing and transmitting information.²⁷ The price of bandwidth has been dropping by a factor of 100 every 10 years,²⁸ and digitalization and compression have reduced the amount of bandwidth needed for both wired and wireless telecommunications.²⁹ The widespread belief that modern information and communication technology is relevant only for rich countries and nonpoor people is not only incorrect, but dangerous, because it may become a self-fulfilling prophecy. To view ICT as irrelevant for poor people will further exclude them from the mainstream of society, increase the gap between poor and nonpoor, and forgo opportunities for alleviating poverty. It will also expand the gap between rich and poor nations. ICT, like electricity, is a key generic technology. Its utility for the poor will be determined by how it is used and the related institutions and policies, not by the nature of the technology as such.

ICT offers tremendous opportunities for reducing rural poverty in developing

countries. Traditional information and communication technologies, such as wired telephones, fail to reach a large share of the rural poor partly because the wires are either not in place or not maintained in many rural areas and partly because existing institutions and rationing systems favor the nonpoor. Satellite-based cell phones and internet access can bypass the rationing system and, possibly, the existing antipoor institutions. At the same time, dramatic decreases in the cost of solar panels and wind energy make it feasible for the rural poor to power ICT, including cell phones, internet access, radio, and television, with solar and wind energy. The massive capital investments in, for example, electrical and telephone wiring may no longer be needed.

Access to ICT and energy opens up new opportunities for education, primary health care, and agricultural extension as well as for conveying information on markets, transport options, road conditions, employment opportunities, and other issues important to the rural poor. It will help not only farmers but also traders and rural wage laborers.

Access to ICT by rural people in developing countries is currently constrained by high costs and lack of appropriate institutions and policies. Where facilitating institutions have been developed, collective use of ICT, such as cell phones, internet, and e-mail, at the village level is becoming economically feasible as costs continue to fall. The Grameen Bank has initiated a community-based cell phone project in rural areas of Bangladesh, and village kiosks, cybercafes, and individual low-income people are offering ICT-based services in several African countries.³⁰ Farmers in parts of Africa are beginning to use ICT to get market information and thereby improve the competition in agricultural input and output markets. Almost all African countries are now connected to the internet, but access in rural areas is still limited.

Access to global information systems (GIS), global positioning systems (GPS),

and remote sensing is contributing to increasing application of precision farming in the United States and Europe. Precision farming helps farmers to use inputs such as fertilizers, pesticides, and water more efficiently. It reduces waste, use of chemicals, runoff, and pollution of land and water. Thus, it contributes to lower unit costs of production, more sustainable management of natural resources, and reduced health risks associated with agricultural production.

Precision farming as practiced in the United States and Europe is inappropriate for small farmers in developing countries because it relies on capital-intensive equip-

ment used on large farms, but the principle is highly applicable. In fact, it should be an integral part of sustainable farming practices for small farmers because it increases the efficiency of plant nutrients and other inputs, while protecting the environment and helping to assure sustainable management of natural resources. Like agroecological approaches, it is knowledge and management intensive. If appropriate small-scale and inexpensive equipment were developed, GIS, GPS, and remote sensing could help small farmers get the information they need to apply the principles of precision farming.

CONCLUSIONS

IFPRI projections suggest that, under the most likely scenario, food insecurity and child malnutrition will remain widespread in 2020. Many millions of people will suffer from hunger and its debilitating consequences. This does not have to be so. If we can mobilize the revolutionary developments in information technology and biotechnology for the benefit of the poor and food-insecure in developing countries; if we can renew our investments in the factors essential for agricultural growth, including agricultural research, human resource development, and strengthened agroecological approaches; if we can harness the political will to adopt sound policies for

eradicating poverty, fostering food security, and protecting natural resources; and if we can alter our behaviors and priorities to assure sustainable development, a food-secure world—a world in which every person is assured of access at all times to the food required to lead healthy and productive lives—will be within our reach. This is not an insurmountable task. We have already made great strides in reducing the burden of food insecurity around the world. Building on the progress made and taking the actions described here should enable us to finally realize a food-secure world in the 21st century.

NOTES

1. P. Pinstруп-Andersen, R. Pandya-Lorch, and M. W. Rosegrant, *The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects*, 2020 Vision Food Policy Report (Washington, D.C.: International Food Policy Research Institute, 1997).
2. IMPACT is a global food model covering 37 countries and country groups and 18 major agricultural commodities. The base data used in the current version are averages of the 1994–96 annual data from the statistical database of the Food and Agriculture Organization of the United Nations. Since each of the 37 country groups produces and/or consumes at least some of each commodity, thousands of supply and demand parameters are specified (income, price, and cross-price elasticities of demand; production parameters including crop area and yield growth trends; price response parameters; trade distribution parameters; and so forth). Parameter estimates are drawn from econometric analysis, assessment of past and changing trends, expert judgments, and synthesis of the existing literature. The model has been developed and periodically updated by Mark W. Rosegrant and his colleagues. Model information is available in M. W. Rosegrant, M. Agcaoili-Sombilla, and N. D. Perez, *Global Food Projections to 2020: Implications for Investment*, 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 5 (Washington, D.C.: International Food Policy Research Institute, 1995); M. W. Rosegrant, M. A. Sombilla, R. V. Gerpacio, and C. Ringler, “Global Food Markets and U.S. Exports in the Twenty-First Century,” paper presented at the Illinois World Food and Sustainable Agriculture Program conference “Meeting the Demand for Food in the Twenty-first Century: Challenges and Opportunities for Illinois Agriculture,” Urbana-Champaign, Illinois, U.S.A., May 27, 1997; and M. W. Rosegrant and C. Ringler, “Asian Economic Crisis and the Long-Term Global Food Situation,” paper prepared for the International Agricultural Trade Research Consortium symposium “Policy Reform, Market Stability, and Food Security,” Alexandria, Virginia, U.S.A., June 26–27, 1998. Projections from the July 1999 version of the model are reported in this paper.
3. The authors would like to thank Julie Babinard for her thorough review of this section.
4. The developing world is primarily composed of Africa, Asia (excluding Japan), and Latin America and the Caribbean.
5. United Nations, *World Population Prospects: The 1998 Revision* (New York: UN, 1999).
6. United Nations, *World Urbanization Prospects: The 1996 Revision* (New York: UN, 1996).
7. In the IMPACT simulations, Sub-Saharan Africa does not include South Africa.
8. G. S. Bhalla, P. Hazell, and J. Kerr, “Prospects for Balancing Cereal Needs in India to 2020,” Draft 2020 Vision for Food, Agriculture, and the Environment Discussion Paper (International Food Policy Research Institute, Washington, D.C., photocopy).
9. C. Delgado, M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois, *Livestock to 2020: The Next Food Revolution*, 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 28 (Washington, D.C.: International Food Policy Research Institute, 1999).
10. Malnourished children have a very low weight for their age, below –2 standard deviations of the median value of the National Center for Health Statistics/World Health Organization international growth reference. Subcommittee on Nutrition of the United Nations Administrative Committee on Coordination/International Food Policy Research Institute

- (SCN/IFPRI), "Fourth Report on the World Nutrition Situation" (SCN/IFPRI, Washington, D.C., 1999, photocopy).
11. Food and Agriculture Organization of the United Nations, *Food, Agriculture, and Food Security: Developments since the World Food Conference and Prospects*, World Food Summit Technical Background Document 1 (Rome, FAO, 1996); FAO, *The State of Food and Agriculture* (Rome, FAO, 1998).
 12. Stunted children have a very low height given their age, below –2 standard deviations of the median value of the National Center for Health Statistics/World Health Organization international growth reference. SCN/IFPRI, "Fourth Report on the World Nutrition Situation."
 13. Ibid.
 14. Ibid.
 15. World Health Organization, *Progress towards the Elimination of Iodine Deficiency Disorders* (IDD) (Geneva: Department of Nutrition for Development and Health, WHO, 1999).
 16. L. Smith and L. Haddad, "Overcoming Child Malnutrition in Developing Countries: Past Performance, Future Possibilities," Draft 2020 Vision for Food, Agriculture, and the Environment Discussion Paper (Washington, D.C.: International Food Policy Research Institute, photocopy).
 17. SCN/IFPRI, "Fourth Report on the World Nutrition Situation."
 18. E. Messer, M. J. Cohen, and J. D'Costa, *Food from Peace: Breaking the Links between Conflict and Hunger*, 2020 Vision for Food, Agriculture, and the Environment Discussion Paper 24 (Washington, D.C.: International Food Policy Research Institute, 1998).
 19. U.S. Department of Agriculture, *Agricultural Outlook, September* (Washington, D.C.: Economic Research Service, USDA, 1999).
 20. P. Pinstrip-Andersen and J. L. Garrett, "Rising Food Prices and Falling Grain Stocks: Short-Run Blips or New Trends?" 2020 Vision Brief 30 (Washington, D.C.: International Food Policy Research Institute, 1996).
 21. E. Díaz-Bonilla and S. Robinson, "Essay: Globalization, Trade Reform, and the Developing Countries," *IFPRI 1998* (Washington, D.C.: International Food Policy Research Institute, 1999); and E. Díaz-Bonilla and S. Robinson, eds., *Getting Ready for the Millennium Round Trade Negotiations*, 2020 Vision Focus 1 (Washington, D.C.: International Food Policy Research Institute, 1999).
 22. Food and Agriculture Organization of the United Nations, "Report on Technical Assistance Related to the Uruguay Round," Committee on Commodity Problems, 62nd session, January 12–15, 1999 (Rome: FAO, 1999).
 23. N. Mukherjee and R. L. Harris, "Getting Ready for the Millennium Round Trade Negotiations: African Perspective," 2020 Vision Focus 1, Brief 4 (Washington, D.C.: International Food Policy Research Institute, 1999).
 24. J. Henao and C. Baanante, "Nutrient Depletion in the Agricultural Soils of Africa," 2020 Vision Brief 62 (Washington, D.C.: International Food Policy Research Institute, 1999).
 25. These were identified and discussed at a recent conference on "Sustainable Agriculture: Evaluation of New Paradigms and Old Practices," sponsored by the Cornell International Institute for Food, Agriculture, and Development, Bellagio, Italy, April 26–30, 1999.

26. G. J. Persley, ed., *Biotechnology for Developing-Country Agriculture: Problems and Opportunities*, 2020 Vision Focus 2 (Washington, D.C.: International Food Policy Research Institute, 1999).
27. E. A. Chaparro, "Investigating the Digital World," in *Information and Communication Technology and Development*, RAWOO Lectures and Seminar Publication No. 18 (The Hague: Netherlands Development Assistance Research Council, 1998).
28. J. van Till, "Information and Communication Technology: How Does It Help?" in *Information and Communication Technology and Development*, RAWOO Lectures and Seminar Publication No. 18 (The Hague: Netherlands Development Assistance Research Council, 1998).
29. Chaparro, "Investigating the Digital World."
30. M. Jensen, "Internet Opens New Markets for Africa: Many Practical Benefits for Business, Farming, Health, and Education," *Africa Recovery* 12 (3, December 1998): 6–7.

Per Pinstруп-Andersen is director general of IFPRI. Rajul Pandya-Lorch is head of IFPRI's 2020 Vision for Food, Agriculture, and the Environment initiative. Mark W. Rosegrant is leader of the IMPACT project and a research fellow in IFPRI's Environment and Production Technology Division.