THE WORLD FOOD SITUATION: RECENT DEVELOPMENTS, EMERGING ISSUES, AND LONG-TERM PROSPECTS

PER PINSTRUP-ANDERSEN • RAJUL PANDYA-LORCH • MARK W. ROSEGRANT

2020 VISION

FOOD POLICY REPORT
THE INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute was established in 1975 to identify and analyze alternative national and international strategies and policies for meeting food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. While the research effort is geared to the precise objective of contributing to the reduction of hunger and malnutrition, the factors involved are many and wide-ranging, requiring analysis of underlying processes and extending beyond a narrowly defined food sector. The Institute's research program reflects worldwide collaboration with governments and private and public institutions interested in increasing food production and improving the equity of its distribution. Research results are disseminated to policymakers, opinion formers, administrators, policy analysts, researchers, and others concerned with national and international food and agricultural policy.

IFPRI is a research center of the Consultative Group on International Agricultural Research and receives support from the Arab Fund for Economic and Social Development, Argentina, the Asian Development Bank, Australia, Belgium, Canada, China, Denmark, the European Commission, the Ford Foundation, France, the German Agency for Technical Cooperation (GTZ), the German Federal Ministry for Economic Cooperation and Development (BMZ), India, the Inter-American Development Bank, the International Development Research Centre (Canada), the International Fund for Agricultural Development, Ireland, Japan, the Land and Agriculture Policy Centre (South Africa), Mozambique, the Netherlands, Norway, the Philippines, the Rockefeller Foundation, the Rural Industries Research and Development Corporation (Australia), South Africa, the Southern African Development Bank, Spain, Sweden, Switzerland, the United Kingdom, the United Nations Children's Fund, the United States, and the World Bank.

"A 2020 Vision for Food, Agriculture, and the Environment" is an initiative of the International Food Policy Research Institute (IFPRI) to develop a shared vision and a consensus for action on how to meet future world food needs while reducing poverty and protecting the environment. It grew out of a concern that the international community is setting priorities for addressing these problems based on incomplete information. Through the 2020 Vision initiative, IFPRI is bringing together divergent schools of thought on these issues, generating research, and identifying recommendations.

The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects

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

2020 VISION

Food Policy Report

International Food Policy Research Institute
Washington, D.C.
December 1997

CONTENTS

Preface 5

Introduction 7

Prospects for Global Food Security 8

Recent Developments and Emerging Issues 14

Implications for Policy and Research 31

Notes 33

PREFACE

During the next quarter century the world will produce enough food to meet the demand of people who can afford to buy it, and real food prices will continue to decline. However, if the global community continues with business as usual, prospects for food security will be bleak for millions of people and degradation of natural resources will continue. IFPRI projections suggest that in developing countries as many as 150 million children—one out of four preschool children—could remain malnourished in 2020. In many developing countries food production is unlikely to keep pace with increases in the demand for food by growing populations. The "food gap"—the difference between production and demand for food—could more than double in the developing world during the next 25 years, increasing dependence on imports from developed countries. For those countries with sufficient foreign currency reserves, including the rapidly growing Asian countries, this should not be cause for alarm. However, many low-income countries, including most of those in Sub-Saharan Africa, will not be able to generate the necessary foreign exchange to purchase needed food on the world market. And many poor people within these countries will not be able to afford the food to fully meet their needs.

Humanity is entering an era of volatility in the world food situation. Several factors have emerged that could lead to larger fluctuations in food availability and access in various regions and countries around the world, making the poor even more vulnerable to hunger. These factors include low grain stocks and declining food aid, which have reduced a key buffer at times of food shortages; growing scarcity of water, which is likely to reduce availability for agricultural uses; weather fluctuations such as those induced by El Niño and global warming, which affect production in hard-to-predict ways; and civil strife and political and social instability, which are both a cause and a result of hunger.

Policymakers, researchers, and others must take proactive steps to minimize uncertainty in the future world food situation in order to achieve food security for all people. In developing countries, policymakers need to ensure that their policies promote broad-based economic growth, especially agricultural growth, so their countries can produce enough food to feed themselves or enough income to buy the necessary food on the world market. Policymakers in developed countries should consider reversing the decline in aid flows and redirecting aid to the most vulnerable developing countries. A world of food-secure people is within our reach, if we take the necessary actions.

This report is taken from a presentation made at the October 1997 International Centers Week meeting of the Consultative Group on International Agricultural Research (CGIAR). Every two years the CGIAR invites the director general of IFPRI to present an assessment of the world food situation to those gathered for International Centers Week. This report comes out of ongoing IFPRI research and activities conducted as part of the 2020 Vision for Food, Agriculture, and the Environment initiative, which aims to generate information to eradicate hunger, prevent poverty, and protect the environment.

The authors would like to thank Raisuddin Ahmed, Christopher Delgado, Peter Hazell, and Sherman Robinson for useful comments and suggestions; Heidi Fritschel for valuable editing assistance; and Vicki Lee for excellent word processing and graphics assistance. Special thanks are due to Mercedita A. Sombilla, who was instrumental in the development of the IMPACT model and was responsible for running alternative scenarios for this report, and Claudia Ringler, whose careful and constructive reviews strengthened the report.

INTRODUCTION

In the past couple of years, developments in global food supply, demand, and trade have raised concerns about the world's future food supply. The prices of wheat and maize rose rapidly during 1995 and the first half of 1996, and at the same time global cereal stocks fell sharply. China's net imports of grain increased substantially in 1995 following two years of net exports. Many of the countries of Eastern Europe and the former Soviet Union failed to make significant advances in economic transition and agricultural development, and flows of food aid and official development finance to developing countries declined. The recent reemergence of El Niño is affecting temperature and rainfall patterns around the world and could have potentially severe implications for food security.

Other developments, however, have offered glimmers of hope. The United Nations (UN) once again revised its population projections downward, thus reducing expected pressures on future food supplies. Although official development finance continued to decline, private capital flows to developing countries increased substantially. Progress was made on international trade liberalization along the lines suggested by the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). The World Food Summit convened by the Food and Agriculture Organization of the United Nations (FAO) in November 1996 raised awareness of world food security problems and stimulated commitments for action.

The outlook for the future world food situation will also be significantly influenced by a number of emerging issues. Dietary patterns are changing rapidly in many countries in response to income increases, urbanization, changing preferences, and government policy. Rapid urbanization in low-income developing countries is placing increasing stress on food marketing and processing systems. Growing scarcity and inappropriate allocation of water, as well as declining soil fertility in many regions of the world, are beginning to constrain food production. Farm yields in parts of Asia are approaching economically optimum levels, and yield growth rates are slowing.

The policy-induced slowdown in grain production and drawdown of cereal stocks in North America and Western Europe, combined with greater variability in agricultural production caused by weather changes, such as those induced by El Niño, are likely to cause greater food price swings in the future. While science, including bioengineering and other modern scientific methods, offers tremendous opportunities for reducing production fluctuations and increasing productivity on small-scale farms in developing countries, little investment is being made in research aimed at these farms. Developments in China and India are of particular interest because policy decisions made, or not made, in these countries are likely to affect not only large populations in these countries themselves, but also the rest of the world. Future food production in Eastern Europe and the former Soviet Union remains uncertain, and Sub-Saharan Africa faces a precarious food security situation. Widespread conflict and instability are further adding to food insecurity in a number of countries.

All of these issues suggest potentially larger fluctuations in food production and prices, and higher associated risks of food insecurity for the world's most vulnerable countries and people. The challenge for policymakers, researchers, and others is how best to minimize these risks to achieve food security for all people.

This report presents the authors' best assessment of prospects for global food security over the next quarter century, drawing upon recently revised and updated infor-

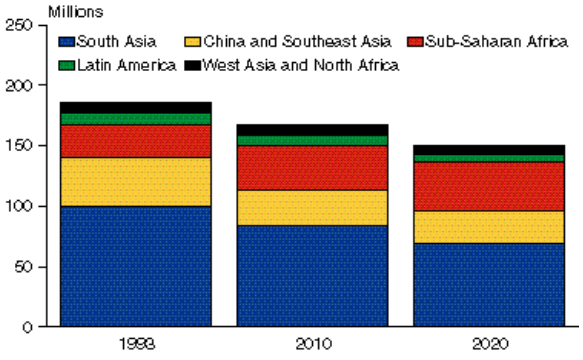
mation from IFPRI's global food model, which projects food demand, supply, and trade to the year 2020. It reviews recent events that have significantly influenced food security as well as key emerging issues that have the potential to significantly affect food security in the coming years. The report also analyzes the implications of these recent events and emerging issues for agricultural research and food policy reform in developing countries.

Prospects for Global Food Security

Projections of food production and consumption to the year 2020 offer some signs of progress, but prospects of a food-secure world—a world in which each and every person is assured of access at all times to the food required to lead a healthy and productive life—remain bleak if the global community continues with business as usual. IFPRI's revised and updated global model, the International Model for Policy Analysis of Commodities and Trade (IMPACT),[1] projects the future world food situation under several scenarios. Under the most likely or baseline scenario, 150 million children under the age of six years will be malnourished in 2020, just 20 percent fewer than in 1993 (Figure 1).[2] One out of every four children will be malnourished in 2020, down from 33 percent in 1993. Child malnutrition is expected to decline in all major developing regions except Sub-Saharan Africa, where the number of malnourished children could increase by 45 percent between 1993 and 2020 to reach 40 million. In South Asia, home to half of the world's malnourished children in 1993, the number of malnourished children is projected to decline by more than 30 million between 1993 and 2020, but the incidence of malnutrition is so high that, even with this reduction, two out of five children could remain malnourished in 2020 (Figure 2). With more than 70 percent of the world's malnourished children, Sub-Saharan Africa and South Asia are expected to remain "hot spots" of child malnutrition in 2020.

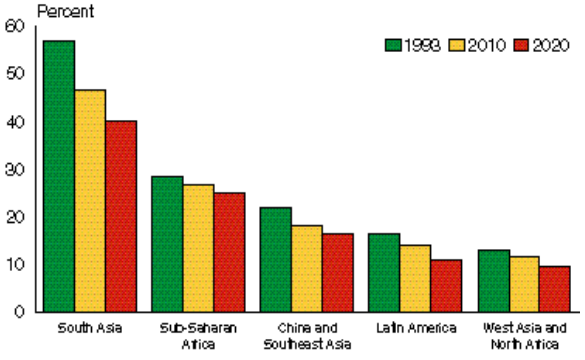
Projections by FAO on the number of food-insecure people paint a similarly mixed picture.[3] FAO projects that 680 million people, 12 percent of the developing world's population, could be food insecure in 2010, down from 840 million in 1990–92 (Figure 3).

Figure 1—Number of malnourished children, 1993, 2010, and 2020



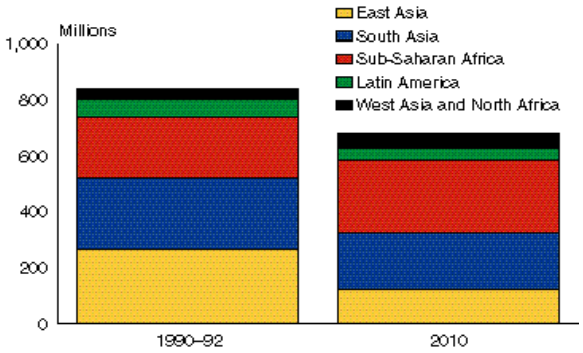
Source: IFPRI IMPACT simulations.

Figure 2—Percentage of malnourished children, 1993, 2010, and 2020



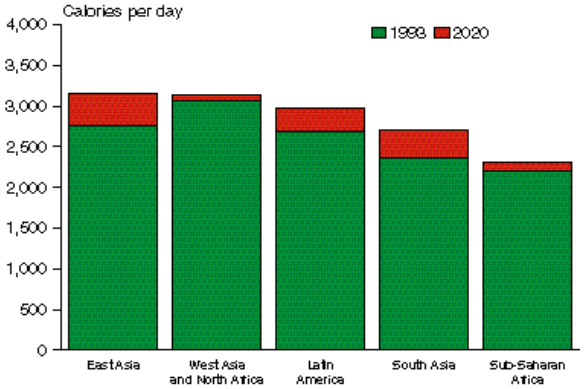
Source: IFPRI IMPACT simulations.

Figure 3—Number of food-insecure people, 1990–92 and 2010



Source: 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, 1996).

Figure 4—Daily per capita calorie availability, 1993 and 2020



Source: IFPRI IMPACT simulations.

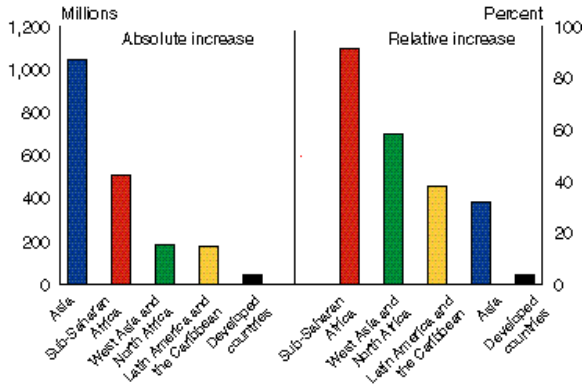
Food insecurity is expected to diminish rapidly in East Asia and, to a lesser extent, in South Asia and Latin America, but it could accelerate substantially in Sub-Saharan Africa and West Asia and North Africa. Sub-Saharan Africa and South Asia, home to a projected 70 percent of the world's food-insecure people in 2010, will be the locus of hunger in the developing world. In fact, Sub-Saharan Africa's share of the world's food-insecure population is projected to almost quadruple between 1969–71 and 2010 from 11 to 39 percent.[4] By 2010, every 3rd person in Sub-Saharan Africa is likely to be food insecure compared with every 8th person in South Asia and every 20th person in East Asia. These disturbing figures reflect widespread poverty and poor health.

Worldwide, per capita availability of food is projected to increase around 7 percent between 1993 and 2020, from about 2,700 calories per person per day in 1993 to about 2,900 calories. Increases in average per capita food availability are expected in all major regions. China and East Asia are projected to experience the largest increase, and West Asia and North Africa the smallest (Figure 4). The projected average availability of about 2,300 calories per person per day in Sub-Saharan Africa is just barely above the minimum required for a healthy and productive life. Since available food is not equally distributed to all, a large proportion of the region's population is likely to have access to less food than needed.

Related to this is an increasing gap between food demand and production in several parts of the world. Demand for food is influenced by a number of forces, including population growth and movements, income levels and economic growth, human resource development, and lifestyles and preferences. In the next several decades, population growth will contribute to increased demand for food. The United Nations recently scaled back its population projections, but even with these reduced estimates, almost 80 million people are likely to be added to the world's population each year during the next quarter century, increasing world population by 35 percent from 5.69 billion in 1995 to 7.67 billion by 2020.[5] More than 95 percent of the population increase is expected in developing countries, whose share of global population is projected to increase from 79 percent in 1995 to 84 percent in 2020. Over this period, the absolute population increase will be highest in Asia, but the relative increase will be greatest in Sub-Saharan Africa, where the population is expected to almost double by 2020 (Figure 5).

At the same time, urbanization will con-

Figure 5—Absolute and relative population increases, 1995–2020



Source: United Nations, *World Population Prospects: The 1996 Revisions* (New York, 1996).

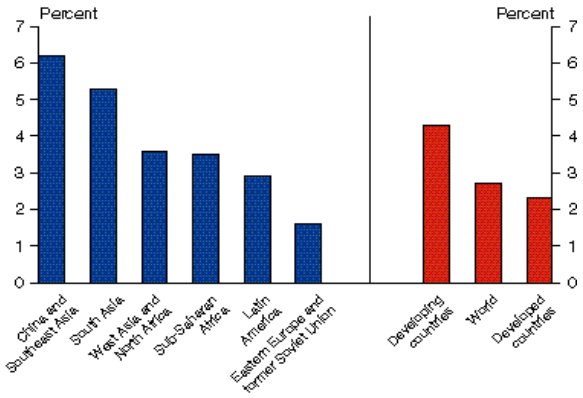
Note: Medium-variant projections.

tribute to changes in the types of food demanded. Much of the population increase in developing countries is expected in the cities; the developing world's urban population is projected to double over the next quarter century to 3.6 billion.[6] Urbanization profoundly affects dietary and food demand patterns: the increasing opportunity cost of women's time, changes in food preferences caused by changing lifestyles, and changes in relative prices associated with rural-urban migration lead to more diversified diets with shifts from basic staples such as sorghum, millet, and maize to other cereals such as rice and wheat that require less preparation and to milk and livestock products, fruits and vegetables, and processed foods.

People's access to food depends on income. Currently, more than 1.3 billion people are absolutely poor, with incomes of a dollar a day or less per person, while another 2 billion people are only marginally better off.[7] Income growth rates have varied considerably between regions in recent years, with Sub-Saharan Africa and West Asia and North Africa struggling with negative growth rates while East Asia was experiencing annual growth rates exceeding 7 percent.[8] Prospects for economic growth during the next quarter century appear favorable, with global income growth projected to average 2.7 percent per year between 1993 and 2020 (Figure 6). The projected income growth rates for developing countries as a group are almost double those for developed countries. Growth rates are projected to be lowest in Eastern Europe and the former Soviet Union. Even Sub-Saharan Africa is expected to experience positive per capita income growth between 1993 and 2020, although it will be quite low. However, unless significant and fundamental changes occur in many developing countries, disparities in income levels and growth rates both between and within countries are likely to persist, and poverty is likely to remain entrenched in South Asia and Latin America and to increase considerably in Sub-Saharan Africa.

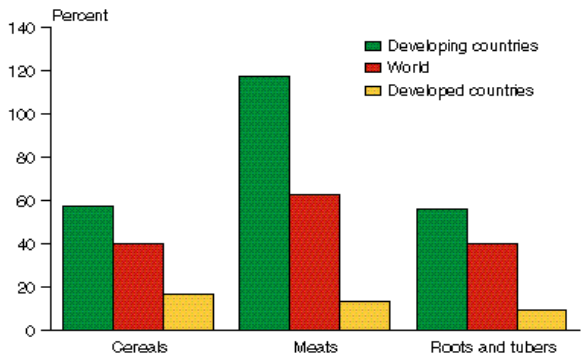
Under the baseline scenario, IMPACT projects global demand for cereals to increase by 41 percent between 1993 and 2020 to reach 2,490 million metric tons, for meat demand to increase by 63 percent to 306 million tons, and for roots and tubers demand to increase by 40 percent to 855 million tons (Figure 7).[9] Most of the increases in demand between 1993 and 2020 are projected to occur in developing countries, which will account for more than 80 percent of the increase in global cereal demand, nearly 90 percent of the increase in meat demand, and more than 90 percent of the increase in demand for roots and tubers.

Figure 6—Projected average annual income growth rates, 1993–2020



Source: IFPRI IMPACT simulations.

Figure 7—Increase in total demand for cereals, meats, and roots and tubers, 1993–2020



Source: IFPRI IMPACT simulations.

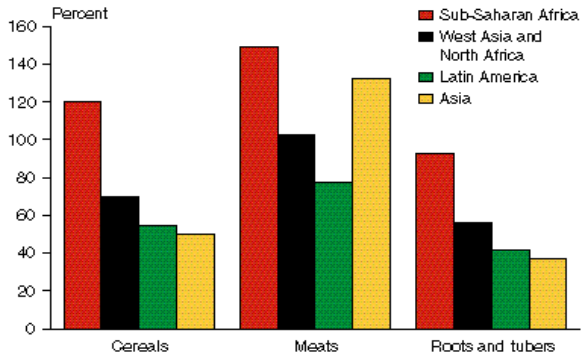
Among the major developing regions, Sub-Saharan Africa is expected to experience the largest percentage increase in demand for all the major food commodities, albeit from low levels (Figure 8).

Demand for cereals for feeding livestock will increase considerably in importance in coming decades, especially in developing countries, in response to strong demand for livestock products. Between 1993 and 2020, developing countries' demand for cereals for animal feed is projected to double while demand for cereals for food for direct human consumption is projected to increase by 47 percent (Figure 9). By 2020, 24 percent of the cereal demand in developing countries will be for feed, compared with 19 percent in 1993. However, in absolute terms, the increase in cereal demand for food will be higher than for feed. In developed countries, the increase in cereal demand for feed will outstrip the increase in cereal demand for food in both absolute and relative terms.

Because of substantial increases in demand for livestock products, especially in developing countries where primarily maize and other coarse grains are used for animal feed, demand for maize is projected to increase faster than for other cereals in both developed and developing countries (Figure 10). Global demand for maize is projected to grow at an annual rate of 1.4 percent between 1993 and 2020, followed by wheat at 1.3 percent and rice at 1.2 percent. In China and India, for instance, demand for maize and other grains for feed is projected to increase by around 3 percent per year between 1993 and 2020.

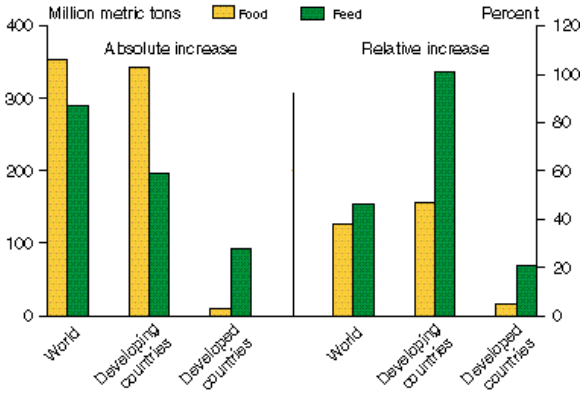
How will the expected increases in cereal demand be met? Not by expansion in cultivated area. IMPACT projections indicate that the area under cereals will increase by only 5.5 percent or 39 million hectares between 1993 and 2020, almost two-thirds of which will be in Sub-Saharan Africa. Since growth

Figure 8—Increase in total demand for cereals, meats, and roots and tubers in major developing regions, 1993–2020



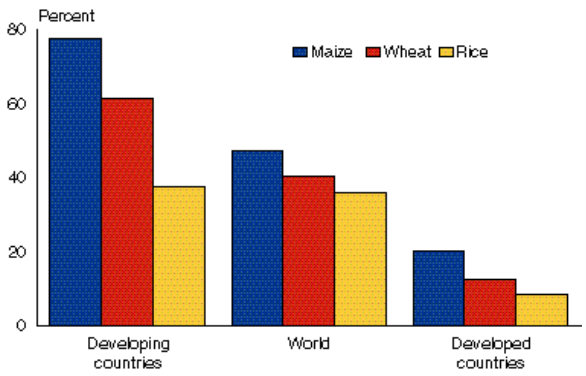
Source: IFPRI IMPACT simulations.

Figure 9—Absolute and relative increase in food and feed demand for cereals, 1993–2020



Source: IFPRI IMPACT simulations.

Figure 10—Increase in total demand for major cereal commodities, 1993–2020



Source: IFPRI IMPACT simulations.

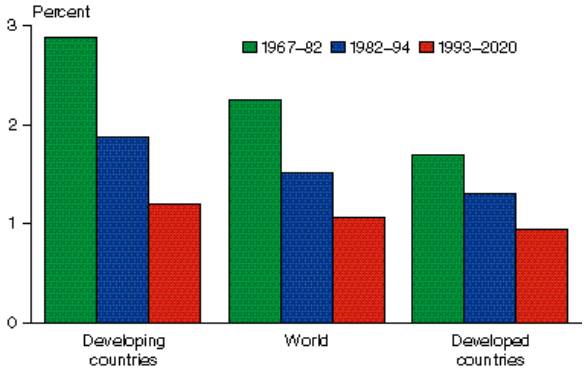
in cultivated area is unlikely to contribute much to future production growth, the burden of meeting increased demand for cereal rests on improvements in crop yields. However, the annual increase in yields of the major cereals is projected to slow down during 1993–2020 in both developed and developing countries (Figure 11). This is worrisome given that yield growth rates were already on the decline. Two of the key reasons for slow cereal yield growth rates are:

1. In regions where input use is high, such as Asia, farmers are approaching economically optimum yield levels, making it more difficult to sustain the same rates of yield gains.
2. Declining world cereal prices are causing farmers to switch from cereals to other, more profitable crops and are causing governments to slow their investment in agricultural research and irrigation and other infrastructure.

With the projected slowdowns in area expansion and yield growth, cereal production in developing countries as a group is also forecast to slow to an annual rate of 1.5 percent during 1993–2020 compared with 2.3 percent during 1982–94. This figure is still higher, however, than the 1.0 percent annual rate of growth projected for developed countries during 1993–2020.

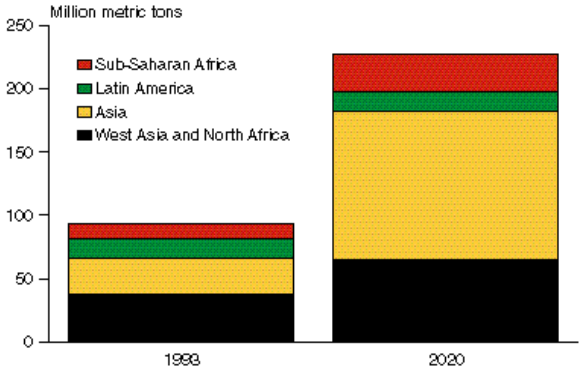
Cereal production in developing countries will be insufficient to meet the expected increase in demand. As a group, developing countries are projected to more than double their net imports of cereals (the difference between demand and production) between 1993 and 2020 (Figure 12). With the exception of Latin America, all major developing regions are projected to increase their net cereal imports: the quadrupling of Asia's net imports will be driven primarily by rapid income growth, while the 150 percent increase forecast for Sub-Saharan Africa will be driven primarily by its continued poor performance in food production. While wheat is

Figure 11—Annual growth in cereal yields, 1967–82, 1982–94, and 1993–2020



Source: 1967–82 and 1982–94: Food and Agriculture Organization of the United Nations, FAOSTAT Database <http://faostat.fao.org>, accessed March 1997; 1993–2020: IFPRI IMPACT simulations.

Figure 12—Net cereal imports of major developing regions, 1993 and 2020

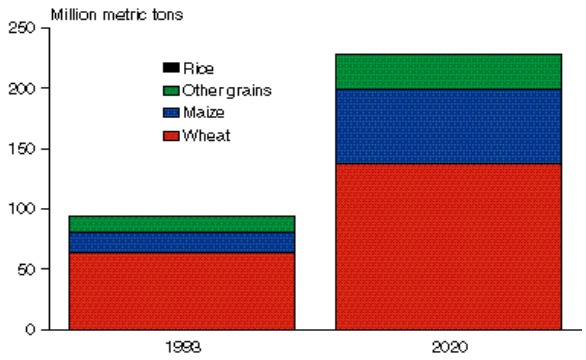


Source: IFPRI IMPACT simulations.

expected to constitute the bulk of the developing world's net cereal imports in 2020, the share of maize is forecast to sharply increase from 19 percent in 1993 to 27 percent primarily because of the rapid increase in demand for meat (Figure 13). Trade in rice is forecast to remain negligible. With an almost 60 percent projected increase in net cereal exports between 1993 and 2020, the United States is expected to capture a large share of the increased export market for cereals (Figure 14). Australia is forecast to almost double its net cereal exports during this period. It is also noteworthy that under the baseline scenario, Eastern Europe and the former Soviet Union are expected to shift from being significant net cereal importers to significant net exporters by 2020.

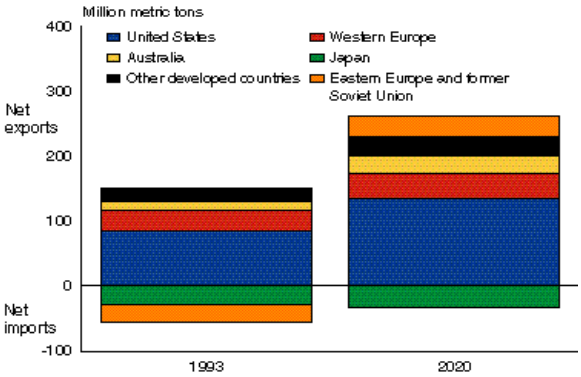
With continued population growth, rapid income growth, and changes in lifestyles, demand for meat is expected to rise rapidly in developing countries. IMPACT projections indicate that total demand for meat will increase by 2.9 percent per year during 1993–2020 in developing countries and by 0.5 percent per year in developed countries. Worldwide, demand for meat is projected to increase by

Figure 13—Composition of net cereal imports by developing countries, 1993 and 2020



Source: IFPRI IMPACT simulations.

Figure 14—Net cereal trade of developed countries, 1993 and 2020

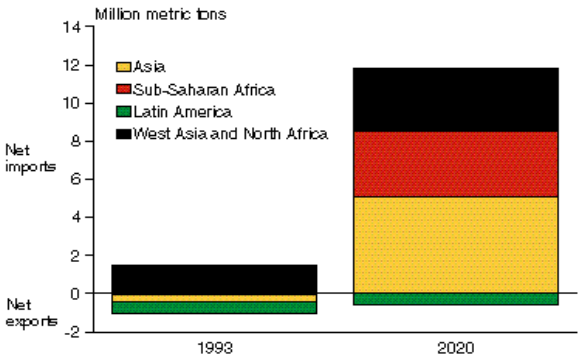


Source: IFPRI IMPACT simulations.

almost 50 percent in developing countries to 31 kilograms in 2020, and by 4 percent in developed countries to 81 kilograms. In 1993, developing countries accounted for 47 percent of world meat demand; by 2020, they are projected to account for 63 percent. Meat production is expected to grow by 2.7 percent per year in developing countries during 1993–2020 (compared with 5.9 percent during 1982–94) and by 0.8 percent in developed countries (compared with 0.9 percent during 1982–94). Despite high rates of production growth, developing countries as a group are projected to increase their net meat imports 20-fold, reaching 11.5 million tons in 2020 (Figure 15). Latin America will continue to be a net exporter of meat, but Asia will switch from being a small net exporter to a large net importer. Beef is expected to constitute 46 percent of the developing world's net meat imports in 2020, poultry 30 percent, pigmeat 13 percent, and sheep and goatmeat 11 percent.

Projections of future fish consumption are scarce. IMPACT does not include fish because of data limitations. FAO projections suggest that direct human consumption of fish will increase from 75–80 million tons in 1994/95 to 110–120 million tons in 2010.[10] Much of the increase in fish consumption is projected to occur in East Asia and, to a lesser extent, in North America and Australia.

Figure 15—Net trade in meat by major developing regions, 1993 and 2020



Source: IFPRI IMPACT simulations.

China's per capita consumption of fish is predicted to double from 9.8 kilograms in 1990 to 20 kilograms in 2010, driven primarily by income increases, and will be met increasingly from aquaculture production.

With sustainable production from the world's natural fish stock at its limit, supplies from capture fisheries have stabilized at around 90 million tons after nearly three decades of steady growth. Aquaculture, however, has become the fastest-growing food production system in the world, with global production increasing on average by more than 11 percent annually between 1990 and 1995.[11] The share of global fish production contributed by aquaculture rose from 13 percent to 19 percent in the period 1990–95.[12]

Real fish prices have remained relatively stable since 1970, while real beef prices have declined substantially and are now less than one-third of the 1970 price. Some researchers report an emerging consensus that real fish prices are likely to rise by about 10 percent by 2020,[13] while IMPACT projections suggest that beef prices will decline by about 5 percent between 1993 and 2020, implying a long-run increase in the relative fish-beef price and therefore major adjustments in the world markets for both fish and beef.

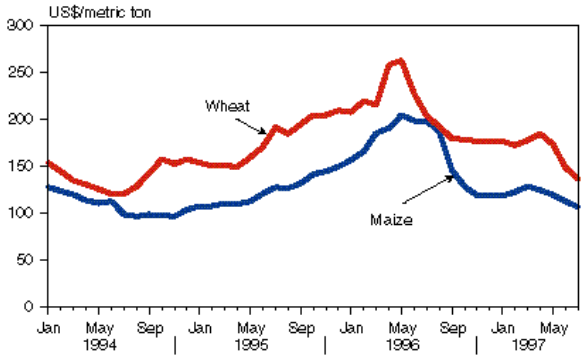
Net imports are a reflection of the gap between production and market demand. For many of the poor, the gap between food production and human needs is likely to be even wider than that between production and demand, because many of these people are priced out of the market, even at low food prices, and are unable to exercise their demand for needed food. The higher-income developing countries, notably those of East Asia, will be able to fill the gap between production and demand through commercial imports, but the poorer countries may be forced to allocate foreign exchange to other uses and thus might not be able to import food in needed quantities. It is the latter group of countries, including most of those in Sub-Saharan Africa and some in Asia, that will remain a challenge and require special assistance to avert widespread hunger and malnutrition.

Recent Developments and Emerging Issues

Rising Cereal Prices and Falling Cereal Stocks

Sharp increases in international wheat and maize prices, along with significant reductions in global cereal stocks, have received wide publicity and greatly excited concerns about food security during the past two to three years. Most of 1995 and the first half of 1996 were characterized by rising international prices of wheat and maize (Figure 16). The price of wheat peaked in May 1996 at around US$260 per ton, 65 percent higher than the price one year earlier and more

Figure 16—Average monthly wheat and maize prices, 1994–97



Source: World Bank, "Commodity Price Data Monthly Series" (Washington, D.C.: World Bank, Commodity Policy and Analysis Unit, various years).

than double the price in May 1994. The price of maize also peaked in May 1996 at around US$200 per ton, almost twice the price prevailing in May 1995 and May 1994. The run-up in prices resulted from an unusual combination of factors, including poor weather in some major cereal-producing countries such as Australia, Canada, and the United States; policy-induced reductions in price subsidies in Western Europe and North America that diminished production and stock-holding incentives; substantial drawdowns in cereal stocks to compensate for production shortfalls; significant declines in food production in the former Soviet Union; and adverse policies and weather combined with accelerating demand for meat and feedgrain in China.[14] Between 1994/95 and 1995/96, global cereal production declined by 3.0 percent to 1,728 million tons, driven by a 9.6 percent reduction in production in developed countries that was only partly offset by a slight increase in production in developing countries (Table 1). At the same time, global consumption of cereals outstripped production for the third year in a row, considerably depleting stocks and contributing to a rapid increase in prices.

If fully transmitted to domestic markets, these sharp increases in international cereal prices could have boosted producer incomes but hurt poor consumers in developing countries, given that many of them spend more than half of their income on food.[15] However, many governments took measures to offset price increases, usually trade-related measures, including tariff reductions and substitution with cheaper, lower-quality cereal imports. An FAO study of 30 developing countries found very low price transmission between international and domestic prices for cereals and noted that domestic price increases were less than world market price increases in the majority of countries.[16] An IFPRI study reported that in 13 out of the 22 import-dependent developing countries studied, import bills rose less than they would have if imports had continued through 1996 at their 1991–93 levels, suggesting that many countries reduced their cereal imports significantly in response to higher international prices. Some major cereal importers such as India and Pakistan even became temporary net exporters. Moreover, the cereal price increases of 1995–96 were relatively mild compared with those experienced during the crisis of the early 1970s; at its peak, the 1996 wheat price was, in real terms, only one-third of the peak price in 1974, while the maize price was less than half of the 1974 peak price.[17]

Closely associated with the cereal price increases of 1995–96 were substantial reductions in global cereal stocks, which reached a 20-year low of 258 million tons in 1995/96 (Figure 17). As a share of consumption, global cereal stocks slipped to 14 percent in 1995/96, well below the 17 percent considered by FAO to provide the necessary margin of safety for world food security. Much of the drawdown in stocks occurred in the traditional exporting or stock-holding countries (Table 1). Since then, stocks have been gradually built up, but the ratio of stocks to consumption remains below the 17 percent minimum safe level. Additional analysis is needed to explore whether 17 percent is still necessary given the current market conditions.

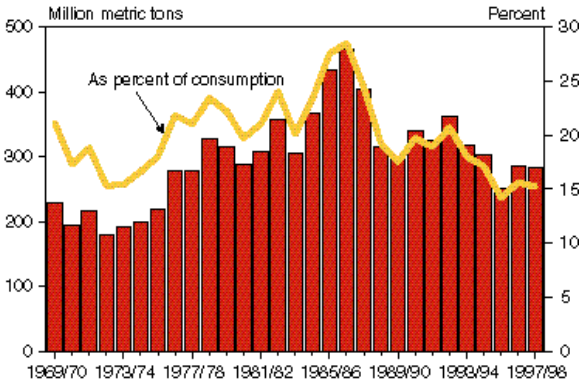
Table 1—Cereal production, utilization, and stocks, 1993/94–1997/98

Source	1993/94	1994/95	1995/96	1996/97	1997/98[a]
			(million tons)		
Production					
Developing countries	932	931	959	1,008	1,003
Developed countries	797	851	769	868	865
World	1,729	1,782	1,728	1,877	1,869
Utilization					
Developing countries	1,017	1,049	1,080	1,106	1,117
Developed countries	747	752	716	741	750
World	1,764	1,801	1,796	1,847	1,867
Stocks					
Developing countries	169	158	153	155	147
Developed countries	176	161	105	127	133
World	345	318	258	282	280
Stocks as % of world cereal consumption	19.1	17.7	14.0	15.1	14.9

Source: Food and Agriculture Organization of the United Nations, *Food Outlook* no. 7/8/9 (July/August/September 1997).
[a] Forecast.

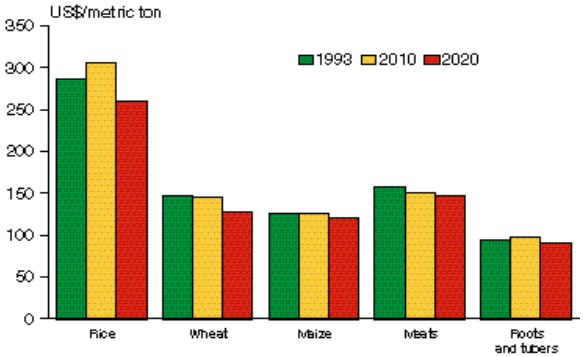
The rising cereal prices of 1995–96 were a short-run phenomenon and not the beginning of a permanent upswing in prices or the forerunner to another world food crisis as feared by some. With the rebound in cereal production in 1996/97 and forecasts of further increases in 1997/98, international prices have started to decline once again. The long-term trend is for cereal prices to continue to decline, although at slower rates than in the past. Real wheat prices will decrease only slightly until 2010, maize prices are expected to stagnate, and rice prices are projected to increase (Figure 18). After 2010, the continued fall in the rate of population growth and the declining propensity to consume cereals as incomes rise (that is, declining income elasticity of demand for cereals) will combine to reduce demand growth, and cereal prices are projected to

Figure 17—World cereal stocks, 1969/70–1997/98



Source: U.S. Department of Agriculture, "Grain: World Markets and Trade," Foreign Agricultural Service Circular Series (Washington, D.C., various years).

Figure 18—Real world prices for cereals, meats, and roots and tubers, 1993, 2010, and 2020

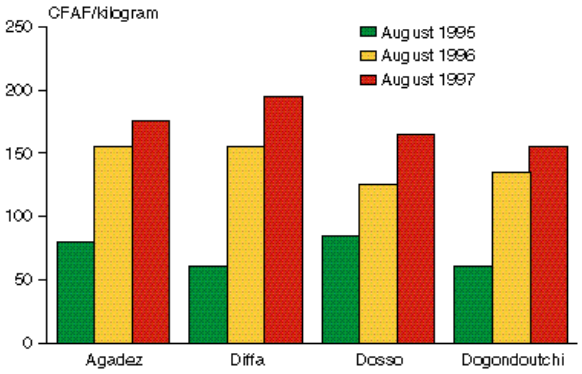


Source: IFPRI IMPACT simulations.

drop by 11 percent between 2010 and 2020. Meat prices are projected to decline by only 5 percent between 1993 and 2010, and thereafter by another 1 percent to 2020. Prices for roots and tubers are expected to increase by 3 percent between 1993 and 2010 before declining by 7 percent to 2020.

Concerns are growing that cereal prices may be more volatile than in the past.[18] Reduced stocks and uncertainties associated with developments in China and the former Soviet Union, among other factors, could increase price instability. On the other hand, market liberalization in developing countries, policy reform in developed countries, and more consistent and transparent stock-holding and trade policies will make producers more responsive to price changes and could reduce price instability. How these factors play out will determine whether cereal prices will be more volatile in coming years. In addition to price fluctuations in the international market, many low-income food-insecure developing countries suffer from large domestic price fluctuations owing to inadequate markets, poor roads and other infrastructure, and inappropriate policies and institutions. Even small changes in production resulting from better or poorer growing conditions may cause large fluctuations in food prices. In Niger, for example, the price of millet during August 1997 was significantly higher than in August 1996 and almost double the price in August 1995 (Figure 19).

Figure 19—Millet prices in selected markets in Niger



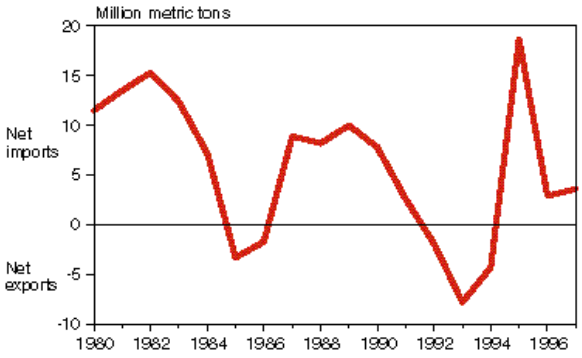
Source: *FEWS Bulletin* (published for the U.S. Agency for International Development), AFR/97-09, September 26, 1997.

Concerns about Feeding China

With one-fifth of the world's population and one of the fastest-growing and most rapidly transforming economies in the world, China has the potential to significantly affect global food security depending on the extent of its future demand for cereals, its capacity to meet its needs through production, and the degree to which it enters world markets to satisfy its unmet needs.[19] Concerns about how China will meet its food requirements escalated recently when China shifted from being a minor net exporter of cereals in 1992–94 to a substantial net importer in 1995 (Figure 20). China has since returned to past levels of virtual self-sufficiency in grain, with small net cereal imports of 2–4 million tons annually. In any case, the concerns arising from China's shift to being a net cereal importer in 1995 seem misplaced given that China has been a net importer in 13 of the 18 years since 1980.

Views on the size and dominance of China's food economy in the 21st century

Figure 20—China's net trade in cereals, 1980–97



Source: State Statistical Bureau of China, *China's Statistics Yearbook* (Beijing: China Statistical Press, various years); U.S. Department of Agriculture, "Grain: World Markets and Trade," Foreign Agricultural Service Circular Series (Washington, D.C., various years).

vary widely, with some forecasting that China will be a major cereal exporter[20] and others cautioning that China might become a major cereal importer, if not the world's largest importer.[21] IMPACT projections indicate that, in the baseline scenario, total cereal demand in China will increase by 42 percent, to 490 million tons, between 1993 and 2020, and cereal production by 31 percent, to 449 million tons. At 41 million tons, China's net cereal imports in 2020 would represent 18 percent of the developing world's projected net cereal imports. While sizable, China's projected imports are unlikely to pose an intolerable burden on the global food situation. For meat, China's production is projected to almost keep up with increases in demand. A predicted increase in demand of 132 percent between 1993 and 2020 would result in net imports of only 0.3 million tons—3 percent of the developing world's projected net imports in 2020.

Alternative simulations suggest that only with extraordinarily rapid income growth, severe resource degradation, and failure to invest in agriculture would China's net cereal imports increase substantially and have a significant effect on world cereal prices.[22] For instance, should there be no increase in government investment in the agriculture sector in China, cereal production could be 19 percent lower in 2020 relative to the

Table 2—China's projected production, demand, and net trade of cereals and meat, 1993 and 2020, various scenarios

	Cereals				Meat			
Year/scenario	Production	Demand	Net trade[a]	World price	Production	Demand	Net trade[a]	World price
	(million metric tons)			(US$/ metric ton)	(million metric tons)			(US$/ metric ton)
1993	343.3	344.3	–0.9	164	39.4	38.6	0.9	1,576
2020								
Baseline scenario	448.9	490.1	–41.1	147	89.0	89.4	–0.4	1,480
Zero increase in government investment in agriculture	362.9	448.2	–85.2	162	89.0	89.2	–0.2	1,486
5% annual increase in government investment in agriculture	572.8	541.6	31.2	131	90.4	91.1	–0.8	1,465
100% self-sufficiency in cereals	469.5	469.5	0.0	138	89.3	89.9	–0.5	1,461
95% self-sufficiency in cereals	457.2	481.8	–24.5	152	89.1	89.5	–0.4	1,476
Structural change in livestock sector without technical change[b]	488.1	557.1	–69.0	162	100.4	125.0	–24.6	1,735
Structural change in livestock sector with technical change[b]	447.8	474.1	–26.3	154	89.3	89.5	–0.2	1,718

Source: S. Fan and M. A. Sombilla, "China's Food Supply and Demand in the 21st Century: Baseline Projections and Policy Simulations," paper prepared for the postconference workshop on "China's Food Economy in the 21st Century" at the American Agricultural Economics Association Annual Meeting, Toronto, Canada, July 31, 1997.

[a] Negative sign denotes net imports; positive sign denotes net exports.

[b] Structural change refers to the shift from backyard to commercial livestock production. Technical change refers to more efficient feed use.

baseline scenario (Table 2). This could lead to net cereal imports of 85 million tons in 2020, more than double the volume forecast in the baseline scenario, which would cause world cereal prices to increase by 10 percent relative to the baseline scenario. However, should China increase its government investment in agriculture by 5 percent annually in real terms, domestic production is forecast to increase to 573 million tons in 2020, 28 percent higher than production levels in the baseline scenario. In this scenario, China would become a net exporter of as much as 31 million tons of cereals in 2020, easing pressure on world markets and causing prices to decline by 11 percent.

If the Chinese government adopts policies to promote the attainment of 100 percent self-sufficiency in cereals, world cereal prices are forecast to be 6 percent lower in 2020 relative to the baseline scenario. China's cereal production would be higher relative to the baseline scenario, while demand would be lower (Table 2). By definition, there would be no net trade in cereals under this scenario. And should the Chinese government pursue a policy of 95 percent self-sufficiency in cereals, world cereal prices would only be slightly higher relative to the baseline scenario.[23]

Expanded livestock production in China will rely more on grain-based feed and less on backyard foraging. If China were to employ the same proportion of feed originating from cereals as that employed in commercial farms in the United States, it is projected that cereal demand would increase by 14 percent in 2020 relative to the baseline scenario. Net cereal imports would increase to 69 million tons, almost 70 percent higher than in the baseline scenario (Table 2), causing world cereal prices to increase by 10 percent relative to the baseline scenario. More notably, China's net meat imports are projected to jump to 24.6 million tons in 2020, an extraordinarily high level compared with the baseline scenario. Consequently, world meat prices are projected to be 17 percent higher relative to the baseline. However, should the structural transformation in the Chinese livestock sector be accompanied by technical changes that promote efficiencies in animal feed use, total cereal demand in 2020 is projected to be about 4 percent lower than in the baseline scenario, while net cereal imports would be 36 percent lower. Net meat imports would be half the volume forecast in the baseline scenario.

China is already a significant player in world food markets and is likely to become increasingly important. However, it does not represent a major threat to world food markets.

Rapid Growth and Structural Changes in Indian Diets

With a population of 930 million in 1995, India is the second most populous country in the world after China.[24] Like China more than a decade ago, India is in the midst of major economic reform. If it succeeds, incomes in India will rise much faster than they have in recent decades, with profound effects on food demand and food security. In the baseline scenario, India is projected to have an average annual economic growth rate of 5.5 percent during 1993–2020. With this growth rate, the number of malnourished children is projected to decline from 76 million in 1993 to 49 million in 2020, while the proportion of children who are malnourished is projected to decline from 60 percent to 43 percent. Daily per capita calorie availability is projected to increase from around 2,400 calories to 2,780 calories.

As incomes increase, will Indians greatly increase their consumption of livestock products, or will they remain more or less vegetarian, as India's history and cultural traditions would suggest? Views are mixed. In the baseline scenario, demand for livestock products is projected to increase by 4.6 million tons between 1993 and 2020 to 8.5 million tons (the corresponding increase in meat demand in China is 51 million tons to 89 million tons in 2020). Given the extremely

low initial levels of livestock consumption in India, rapid growth in absolute demand for livestock would require a dramatic change in eating patterns. In a scenario modeling the effects of such a change in Indian diets, India's demand for meat products is forecast to increase almost 10-fold from 3.8 million tons in 1993 to 36.4 million tons in 2020. This increase in demand would have to be met through trade, as meat production is not projected to increase beyond the 8.5 million tons shown in the baseline scenario for 2020. India's projected net meat imports of 28 million tons under this scenario are a far cry from the less than 0.5 million tons forecast in the baseline scenario. This increase in Indian net imports would increase world meat prices by 21 percent in 2020 relative to the baseline scenario and by 13 percent relative to 1993. If India attempts to meet potentially large increases in livestock demand through domestic livestock production rather than imports, thereby raising demand for feed grain, implications for global livestock and cereal trade and prices would be dramatically different from those predicted by the scenario that relies primarily on livestock imports to meet demand.

The Transition in Eastern Europe and the Former Soviet Union

The fall of the Berlin Wall and the associated political changes in Eastern Europe and the former Soviet Union brought great promise for rapid economic growth in that part of the world. Many projected that food production in a number of countries affected, including Ukraine and the Russian Federation, would expand rapidly and significantly, causing Eastern Europe and the former Soviet Union to switch quickly from being net importers of grain to being significant net exporters.[25] Although net grain imports by the former Soviet Union have fallen dramatically, this optimistic scenario has not materialized.[26] There is still a great deal of uncertainty regarding future food production and demand in those countries.

Many of the countries of Eastern Europe and the former Soviet Union have tremendous agricultural potential that is as yet underutilized. Appropriate changes in institutions and policies (including property rights), increased market and trade liberalization, and investment in rural infrastructure could result in rapid production increases, but such changes have been extremely slow. For example, grain production in Ukraine has decreased sharply since the beginning of the transition process from an annual average of 47.4 million tons during 1986–90 to 36.4 million tons during 1991–96.[27] The decline continues, and grain production fell to about 27 million tons in 1996. Appropriate institutions and policies could turn Ukraine's large grain production potential into major exportable surpluses. European Union (EU) membership by some of the countries of Eastern Europe could accelerate agricultural transformation in these countries with resulting expansions in food production.

IMPACT's baseline scenario projects that Eastern Europe and the former Soviet Union will become major net exporters of cereal by 2020, on the order of about 33 million tons. Cereal production is projected to increase by almost 40 percent between 1993 and 2020 to 341 million tons, while demand is projected to increase by 12 percent to 308 million tons. However, if incomes in Eastern Europe and the former Soviet Union grow faster than the baseline projection and crop productivity increases at a slower pace than forecast, these regions would remain net importers. For example, with an increase in income growth of 30 percent and a drop in production growth of two-thirds, crop production would increase by only 12 percent between 1993 and 2020 to 278 million tons while demand would increase to 304 million tons, resulting in net cereal imports of 26 million tons in 2020—a very different outcome. Slow crop production in Eastern Europe and the former Soviet Union could cause world cereal prices to be higher in 2020 relative to the baseline scenario. Changes in cereal production and demand in Eastern Europe

and the former Soviet Union can have significant effects on the world food situation, but it would take very large declines in productivity growth in this region to dramatically drive up cereal prices.

Malthus's Shadow Waning in Sub-Saharan Africa

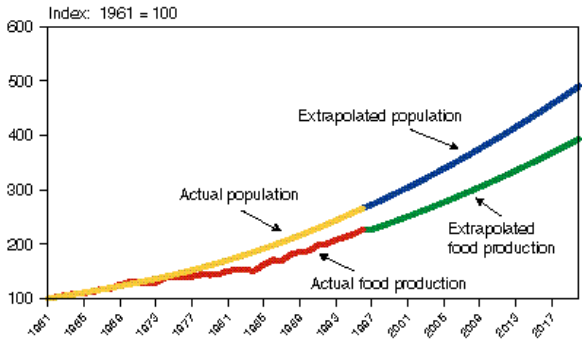
Thomas Malthus's basic argument was that the world's natural resources could not assure expansions in food supply that would match population growth. Region after region has disproved his prediction, but in Sub-Saharan Africa the population growth rate has exceeded the rate of growth in food production since the early 1970s and the gap is widening, resulting in declining per capita food production (Figure 21). Simple extrapolations of the trends in population and food production growth since 1961 show a further increase in the gap between population and food production. This is exactly the gap predicted by Malthus.[28] However, several recent developments suggest that Malthus's shadow over Sub-Saharan Africa could finally be waning.

First, Malthus's predictions grossly underestimated the potential of productivity-increasing technology. Where such technology has been effectively developed and utilized, such as in Asia, food production has expanded much faster than population. In Sub-Saharan Africa, the potential of appropriate productivity-increasing technology has yet to be realized. Maize yields for Africa and Asia were virtually the same in 1961, but since then they have tripled in Asia and quintupled in China while they have remained stagnant at around 1 ton per hectare in Africa.[29] However, there are encouraging signs that productivity-increasing technology is beginning to accelerate yield growth of African food crops. For example, the introduction of improved maize varieties has resulted in productivity increases in West and Central Africa at rates as high as 4 percent per year during the period 1983–92.[30] Some countries have experienced particularly high rates of growth in maize production during this period, including Burkina Faso (17.1 percent), Ghana (8.3 percent), and Mali (7.5 percent), albeit starting from low levels.

Second, Sub-Saharan Africa is experiencing economic recovery. After a number of years of low or negative growth, gross domestic product (GDP) increased by 4.2 percent in 1995 and 4.8 percent in 1996 and is forecast to increase by 4.8 percent in 1997 (Figure 22). With population growing by about 3 percent per year, GDP per capita will have increased for three consecutive years for the first time in many years. The economic recovery is widely shared, with 20 countries achieving a GDP growth rate of 5 percent or higher in 1996. Spurred partially by favorable weather, agricultural growth is a key contributor to the overall economic recovery. Cereal production in Southern Africa, for instance, is estimated to have increased by 68 percent in 1996.[31]

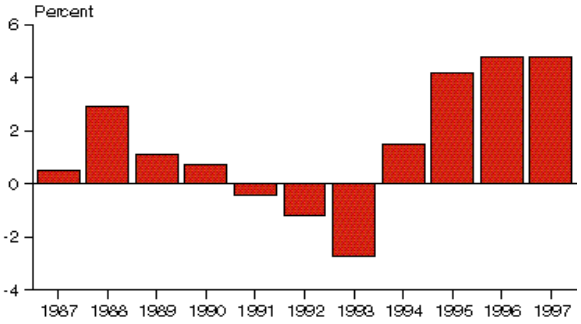
However, the economic recovery in Sub-Saharan Africa is fragile. Some of the factors that contributed to the recovery are short term in nature and cannot be expected to persist; these include the higher commodity

Figure 21—Actual and extrapolated population and food production indexes for Sub-Saharan Africa, 1961–2020



Source: Data for 1961–96: Food and Agriculture Organization of the United Nations, FAOSTAT database, <http://faostat.fao.org> (accessed August and September 1997); extrapolations for 1997–2020: authors' estimates.

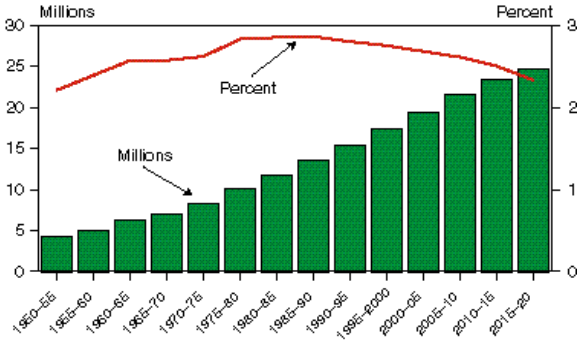
Figure 22—Annual growth rate of real gross domestic product in Sub-Saharan Africa, 1987–97



Source: United Nations, *World Economic and Social Survey 1997* (New York, 1997).

Note: 1996 = preliminary, 1997 = forecast. Data do not include Nigeria or South Africa.

Figure 23—Annual population change and growth in Sub-Saharan Africa, 1950–2020



Source: United Nations, *World Population Prospects: The 1996 Revisions* (New York, 1996).

Note: Medium-variant projections for 1995–2020.

prices during 1994 and 1995 and the favorable weather conditions in 1996 that enabled recovery from the effects of drought in 1994. Other factors, such as policy reforms, an improved macroeconomic environment, and social and political stability, can have a more lasting effect on economic growth, if properly nurtured. Moreover, economic growth rates will have to be substantially higher if they are to make a dent in Sub-Saharan Africa's poverty; per capita incomes have fallen so much that even if economic growth were to continue at the current pace (about 5 percent per year), it would still take at least a decade to recover to the levels prevailing in 1980.[32]

If Malthus is to be proven wrong in Sub-Saharan Africa, a much greater effort must be made to ensure that farmers have access to appropriate production technology and that policies are conducive to expanded productivity in staple food crops. Besides new initiatives and expanded support for agricultural development, more must also be done to reduce population growth. Sub-Saharan Africa's annual population growth rate is projected to decline between 1993 and 2020 (Figure 23). Yet the number of people added to the region's population every year is projected to increase until at least 2020, a consequence of the past high rates of population increase. Moreover, Sub-Saharan Africa's projected annual population growth rate of 2.33 percent during 2015–2020 will be more than double the growth rates in other regions.[33] Population growth of this magnitude will severely constrain efforts to increase income and improve welfare, while at the same time it will greatly increase the need for food.

Weather Fluctuations and Climate Change

With the resurgence of El Niño, a large-scale abnormal warming of the sea surface off the South American coast, major weather fluctuations are under way or imminent in many parts of the world. These weather fluctuations could lead to sizable food production shortfalls and deterioration in food security in many parts of the world. Many expect the current El Niño to approach, if not surpass, the last two major El Niños of 1982–83 and 1991–92 in severity. The 1982–83 El Niño caused severe flooding in Latin America, droughts in parts of Asia, declines in fish stocks, and other weather-related damage estimated at over US$10 billion.[34] The 1991–92 El Niño resulted in severe drought in Southern Africa that caused cereal production to drop by 60 percent or more in several

countries, and imports and food aid had to increase to meet more than half of the cereal consumption in at least five countries.[35]

The current El Niño has caused a warmer and earlier dry period in Central America, hindering the development of crops already in the ground and reducing the area planted. El Niño's effects are expected to intensify between December 1997 and March 1998 and could affect Central America's premier foreign exchange earner, coffee, which will be in a critical flowering stage at that time. In the Andean countries of South America, floods in the north and excessively dry conditions in the south may affect the planting of the 1998 main season cereal crops.[36] Rainfall may be significantly below normal during the main rainy season in South Africa, southern Mozambique, Lesotho, and Swaziland.[37] Indonesia, Papua New Guinea, the Philippines, and Thailand are currently gripped by their most severe drought in several decades, which exacerbated recent forest fires in Indonesia and cast a smoky haze over the entire region.[38] Two-thirds of China is suffering from prolonged dry spells. Australia is in the midst of a severe drought that could cut its wheat harvest by more than 30 percent.[39] Of course, in other parts of the world, El Niño could have positive effects on weather patterns and correspondingly perhaps on agricultural production. Nevertheless, El Niño adds a major element of uncertainty to agricultural production and livelihoods around the world. And concerns are growing that El Niños may become more frequent and more severe in the future as a result of climate changes.

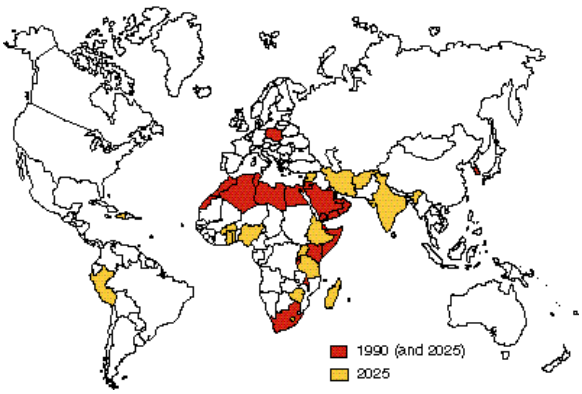
Although the trend of global warming is becoming increasingly clear, its effects on food production are still uncertain. Some research suggests that growing conditions will deteriorate in current tropical areas (where many of the developing countries are located) and improve in current temperate areas (where many of the developed countries are located).[40] However, effects on productivity and production will occur over a long period of time and will be very small in any given year. Therefore, it is reasonable to believe that policies and technologies can be developed to effectively prevent or counter the negative productivity effects of global warming. Failure by the public sector to act, and failure by the market and the private sector to respond, could result in significant long-terms effects on food supply. Such a scenario might include reduced food production in tropical and subtropical countries and increased production in temperate countries. Whether these opposing effects will cancel each other out through expanded international trade, with little or no effect on total world food supply, is yet to be determined.

Growing Water Scarcity

Unless properly managed, fresh water may well emerge as the key constraint to global food production. While supplies of water are adequate in the aggregate to meet demand for the foreseeable future, water is poorly distributed across countries, within countries, and between seasons. And with a fixed amount of renewable water resources to meet the needs of a continually increasing population, per capita water availability is declining steadily. Today, 28 countries with a total population exceeding 300 million people face water stress;[41] by 2025, their number could increase to about 50 countries with a total population of about 3 billion people (Figure 24).[42]

Demand for water will continue to grow rapidly. Since 1970, global demand for water has grown by 2.4 percent per year.[43] Projections of water demand[44] to 2020, consistent with the food supply and demand projections to 2020 from IMPACT, indicate that global water withdrawals will increase by 35 percent between 1995 and 2020 to reach 5,060 billion cubic meters. Developed countries are projected to increase their water withdrawals by 22 percent, more than 80 percent of the increase being for industrial uses (Figure 25). Developing countries are projected to increase their withdrawals

Figure 24—Countries experiencing water stress, 1990 and 2025



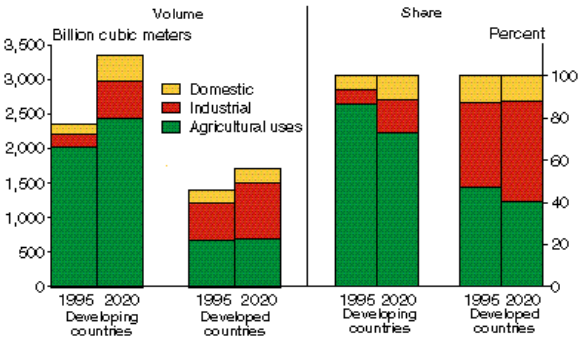
Source: Population Action International, *Sustaining Water: An Update* (Washington, D.C., 1995).

by 43 percent over the same period and to experience a significant structural change in their demand for water. The share of domestic and industrial uses in their total water demand is projected to double from 13 percent in 1995 to 27 percent in 2020, reducing the share for agricultural uses.

Growth in irrigated area is projected to slow significantly. Worldwide, irrigated area is projected to grow at an average annual rate of 0.6 percent per year during 1995–2020, less than half the annual growth rate of 1.5 percent during 1982–93. In developed countries, irrigated area is projected to increase by only 3 million hectares (Figure 26), at an annual rate of only 0.2 percent, compared with 0.8 percent during 1982–93. Irrigated area in developing countries is projected to increase by 37 million hectares to 227 million hectares in 2020, at an average annual rate of 0.7 percent, far below the growth rate of 1.7 percent during 1982–93. The largest increase in irrigated area is expected in India (17 million hectares); public investment in irrigation has remained relatively strong and private investment in tubewells has been rapid. Acreage under irrigation will remain very low in Sub-Saharan Africa, despite a 50 percent increase to 7.4 million hectares in 2020. Simulations suggest that increased investment in irrigation can make a significant contribution to food production growth in Sub-Saharan Africa, although the amount of land under irrigation and the potential area exploitable relative to total crop area may not be large enough to generate revolutionary increases in crop production.[45]

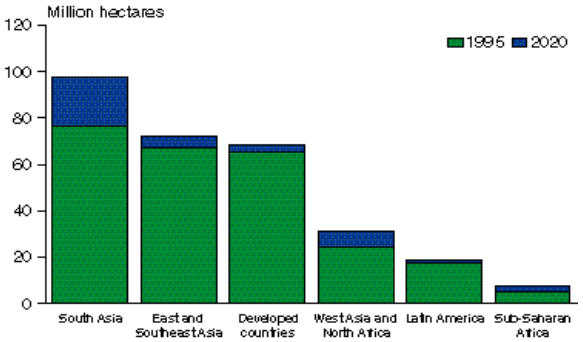
The costs of developing new sources of water are high and rising, and nontraditional sources such as desalination, reuse of wastewater, and water harvesting are unlike-

Figure 25—Water withdrawals for domestic, industrial, and agricultural uses, 1995 and 2020



Source: M.W. Rosegrant, C. Ringler, and R.V. Gerpacio, "Water and Land Resources and Global Food Supply," paper prepared for the 23rd International Conference of Agricultural Economists, Sacramento, Calif., August 10–16, 1997.

Figure 26—Irrigated area in major regions, 1995 and 2020



Source: M.W. Rosegrant, C. Ringler, and R.V. Gerpacio, "Water and Land Resources and Global Food Supply," paper prepared for the 23rd International Conference of Agricultural Economists, Sacramento, Calif., August 10–16, 1997.

ly to add much to global water availability, although they may be important in some local or regional ecosystems. So how can the rapid increases in water demand be met? The rapidly growing domestic and industrial demand for water will have to be met from reduced use in the agriculture sector, which is by far the largest water user, accounting for 72 percent of global water withdrawals and 87 percent of withdrawals in developing countries in 1995.[46] Reforming policies that have contributed to the wasteful use of water offers considerable opportunity to save water, improve efficiency of water use, and boost crop output per unit of water. Required policy reforms include establishing secure water rights for users; decentralizing and privatizing water management functions; and setting incentives for water conservation, including markets in tradable water rights, pricing reform and reduction in subsidies, and effluent or pollution charges.[47] Failure to address the gap between tightening supplies and increasing demand for water could significantly slow growth in food production.

Declining Soil Fertility

Improved soil fertility is a critical component of low-income countries' drive to increase sustainable agricultural production. Past and current failures to replenish soil nutrients in many countries must be rectified through the balanced and efficient use of organic and inorganic plant nutrients and through improved soil management practices.

Although some of the plant nutrient requirements can be met through the application of organic materials available on the farm, or in the community, such materials are insufficient to replenish the plant nutrients removed from the soils and thus to further expand crop yields. But the use of chemical fertilizers has decreased worldwide during the last few years, particularly in the developed countries and in parts of Asia. Although reduced use of fertilizers is warranted in some locations because of negative environmental effects, it is critical that fertilizer use be expanded in countries where soil fertility is low and a large share of the population is food insecure. Fertilizer consumption in these countries is generally low because of high prices, insecure supplies, and the greater risk associated with food production in marginal areas. For example, on average, fertilizer consumption in Sub-Saharan Africa is about 14 kilograms per hectare compared with about 200 kilograms per hectare in East Asia.[48] Expanded use of fertilizers in Sub-Saharan Africa will help alleviate current production shortfalls as well as serious land degradation.

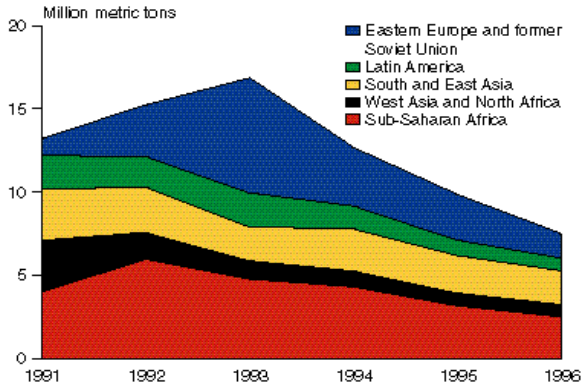
Between 1990 and 2020, global fertilizer demand is forecast to grow by 1.2 percent per year, a significantly lower rate than the 2.8 percent of the 1980s. Average annual growth rates are projected to be about 1.8–2.4 percent in Africa, Asia, and Latin America. These rates will be inadequate to meet nutrient requirements for food production and resource conservation.[49]

In view of the size and seriousness of the soil fertility problem in many low-income countries, a cost-effective fertilizer sector and policies providing incentives for farmers and communities to implement soil fertility programs are needed. Such policies should focus on supporting agricultural research to generate appropriate technology; clear long-term property rights to land; access to credit, improved crop varieties, water, and information about effective and efficient fertilizer use in various production systems; efficient and effective markets for plant nutrients; and investments in roads and rural transportation systems. Of particular importance to maintaining and enhancing soil fertility is the adoption of integrated plant nutrient management (IPNM) practices. The goal of IPNM is to integrate the use of natural and human-made sources of plant nutrients to increase agricultural productivity in an efficient and environmentally benign manner without diminishing the productive capacity of soil for present and future generations.

Diminishing Food Aid

At 7.5 million tons, global food aid deliveries in 1996 were less than half the 16.8 million tons distributed just three years earlier and the smallest volume delivered in more than a decade. Preliminary indications are that food aid deliveries during 1997 are likely to be the same or even slightly lower than in 1996. Changes in agricultural policies in North America and the European Union, the implementation of the Uruguay Round trade agreements, and changing geopolitical and domestic concerns within donor countries have contributed to diminished interest in and support for food aid among donors, especially the United States, which reduced its food aid deliveries from over 10 million tons in 1993 to less than 4 million tons in 1996. As Figure 27 shows, all regions, most notably Eastern Europe and the former Soviet Union, have experienced reductions in food aid deliveries. In Sub-Saharan Africa, food aid deliveries in 1996 reached their lowest level since 1983. An increasingly higher proportion of the reduced food aid is being channeled through targeted relief operations and development projects—60 percent in 1996 compared with 40 percent in 1990—rather than through untargeted program assistance, which does not target specific beneficiaries but provides broad-based economic support.[50]

Figure 27—Food aid deliveries to major regions, 1991–96

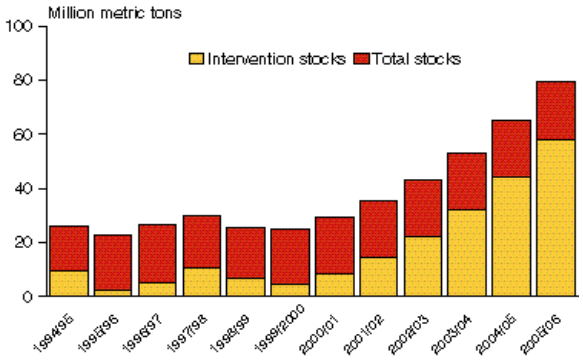


Source: World Food Programme, *1996 Food Aid Flows* (Rome, 1997).

The substantial reduction in food aid deliveries, combined with the growing tendency to channel food aid through relief operations and development projects, has disturbing implications for food security unless other development assistance increases. The need for aid to combat food insecurity has not diminished. For instance, 29 countries are currently facing food emergencies due to man-made or natural disasters; of these, 17 are in Sub-Saharan Africa.[51] Moreover, if the resurgence of El Niño has consequences similar to those experienced earlier, large volumes of food aid may be required to meet the needs of drought-stricken countries in parts of Africa, especially in Southern Africa, which was hit hard on the last few occasions. Food aid will have an important role for some years, not only in addressing humanitarian emergencies but also in directing resources to many of the world's most vulnerable food-insecure people to help them permanently escape poverty and assure food security.[52]

Food aid has traditionally been driven primarily by the availability of excess food stocks in the United States, Western Europe, and other countries with quantity-related farm subsidies. As such stocks are reduced, however, an increasing amount of food aid will need to be purchased in the market. Given the high transaction costs usually associated with food aid, consideration should be given to gradually replacing program food aid with increasing cash assistance for commercial food import. It is, of course, not certain that surplus stocks will continue to be low. According to a recent European Commission study, continuation of current farm policies could result in the rebuilding of large grain stocks during the next 10 years (Figure 28).[53] Should the European Union be enlarged by inclusion of Eastern European countries and should these new members be permitted to obtain the benefits of existing common agricultural policies, grain stocks may increase even faster.

Figure 28—Total cereal stocks in the EU-15 (actual and projected), 1994/95–2005/06



Source: European Commission, "Long-Term Prospects: Grains, Milk, and Meat Markets," CAP 2000 Working Document (Brussels, 1997).

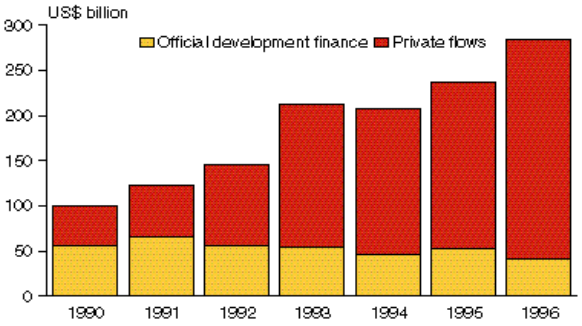
Declining Official Development Finance

Paralleling the rapid decline in food aid to developing countries has been a notable reduction in official development finance to developing countries (Figure 29). In nominal terms, official development finance has fallen almost 40 percent between 1991 and 1996 to US$41 billion. Between 1995 and 1996 alone, official development finance declined by almost 25 percent. Of course, in real terms the reduction is even sharper. While official development finance has been falling, net private capital flows to developing countries have been growing extraordinarily fast, increasing more than fivefold between 1990 and 1996, from US$44 billion to US$244 billion. However, most of the private capital flows have been directed to a handful of countries in East Asia and Latin America. Sub-Saharan Africa and South Asia are all but bypassed by these private flows—together they received less than 10 percent of the net private capital flows to the developing world in 1996—and remain dependent on shrinking flows of international assistance. This has significant implications for their capacity to engage in broad-based and sustained economic growth and thereby to improve their prospects for food security. Agriculture has been one of the sectors to suffer most from the decline in international assistance to developing countries. In real terms, external assistance to developing-country agriculture almost halved from a peak of US$19 billion in 1986 to US$10 billion in 1994 (Figure 30).

Trade Liberalization Issues

In response to the recent GATT agreement and structural adjustment programs, a large number of developing countries have liberalized foreign trade in food and agricultural

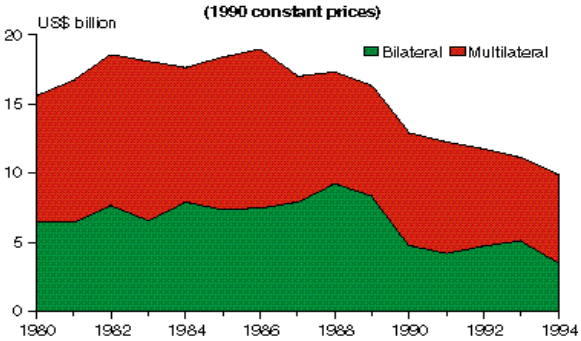
Figure 29—Aggregate net long-term resource flows to developing countries, 1990–96



Source: World Bank, *Global Development Finance,* vol. 1, *Analysis and Summary Tables* (Washington, D.C., 1997).

Note: 1996 = preliminary.

Figure 30—External assistance to agriculture, 1980–94



Source: Food and Agriculture Organization of the United Nations, *Investment in Agriculture: Evolution and Prospects*, World Food Summit Technical Background Document 10 (Rome, 1996).

commodities. Unfortunately, the opening up of markets in developing countries has not been matched by market openings in the countries of the Organization for Economic Cooperation and Development (OECD). This asymmetry in trade liberalization reduces benefits to developing countries and may make continued market liberalization under these conditions unviable for them. While preferential treatments are still in place for specific quantities of certain commodities, OECD countries have been reluctant to open up their domestic markets for imports from developing countries of high-value commodities such as beef, sugar, groundnuts, and dairy products. At the same time, developing countries are being encouraged through structural adjustment to emphasize production of these same high-value agricultural commodities for export. From the point of view of food security and poverty alleviation in developing countries, the next round of World Trade Organization (WTO) negotiations should emphasize the opening up of domestic markets in OECD countries for commodities from developing countries.

To fully benefit from trade liberalization, developing countries must invest in domestic infrastructure, effective and efficient agricultural input and output markets, research and technology, and a more equitable distribution of land and other productive resources. Furthermore, while most poor and food-insecure people are expected to benefit from trade liberalization, the distribution of benefits will be determined largely by the distribution of productive assets. Countries with very skewed distribution of assets may experience an amplification of this pattern as a result of trade liberalization. Therefore, emphasis on trade liberalization should be matched with similar or stronger emphasis on rectifying domestic policies, including improved access by the poor to productive assets and employment.

Recent estimates indicate that the impact of the Uruguay Round of GATT on international food and agricultural prices will be very limited indeed.[54] It is estimated that the Uruguay Round will result in price increases for grains and livestock products between 2 and 5 percent by the year 2005. These small increases will not offset the long-term declining trend in food prices.

Population Growth Slower Than Projected

Recently, the United Nations again concluded that its earlier projections had overestimated population growth. The actual annual population growth rate between 1990 and 1995 was 1.48 percent rather than the 1.68 percent estimated in 1992 or the 1.57 percent estimated in 1994.[55] In light of this development, the United Nations revised its projections for population growth in the next century. The annual rate of change in world population during 2015–20 is now estimated at 1.03 percent instead of 1.13 percent as projected in 1992. Under the current medium-variant estimates, the world's population is projected to reach 7.67 billion by 2020, about 300 million less than had been projected in 1992 and 200 million less than had been projected in 1994. Clearly, should these revised projections hold, pressure on the world's food supplies will be reduced. Nevertheless, there are no grounds for complacency since even under the revised medium-variant projections, the world's population is projected to increase by about 2 billion people between 1995 and 2020.[56]

Escalating Concerns about Food Safety and Genetic Engineering

The movement toward increasing food safety and consumption of organic foods produced without the use of chemical inputs such as fertilizers, pesticides, and herbicides is strong in the developed countries. Related to this movement is the possibility of rapid increases in the desire for purely vegetarian diets. IMPACT projections do not effectively take into account an accelerated movement toward organic food. In the short run, such a

movement would result in sharp reductions in agricultural productivity and food production. In the longer run, some of the negative productivity effects could be dealt with through accelerated agricultural research aimed at such issues as host-plant resistance to pests, nitrogen fixation from the air, and plants that are more efficient in extracting and utilizing nutrients. An accelerated movement toward vegetarian diets would, on the other hand, reduce the demand for feedgrain and thereby reduce pressure on future grain supplies.

The current rate of increase in the demand for organic food in Western Europe and North America is likely to slow down in response to higher relative prices for such foods, and, while total demand will increase, organic food is unlikely to be a major part of total food consumed in these regions within the next 25 years. However, public pressure in Western Europe is likely to move governments to introduce legislation that will constrain or prohibit full use of the opportunities offered by genetic engineering and other tools of modern science for food production and processing. There is a trend in several European societies toward seeing the application of science to agriculture as part of the problem rather than part of the solution. Combined with this view is a failure to appreciate the need for productivity increases in food production. While the application of modern science, including genetic engineering and other biotechnology research, to solving human health problems is applauded and encouraged, there is an increasing suspicion that the application of such scientific methods to food production and processing will compromise agricultural production systems, food safety, and the health of current and future generations.

In fact, modern scientific methods, including molecular biology–based methods, offer tremendous opportunities for expanding food production, reducing risks in food production, improving environmental protection, and strengthening food marketing in developing countries.[57] Tolerance to drought in selected staple foods as well as resistance to other adverse conditions such as insects, diseases, and other pests could greatly increase and stabilize food production and incomes among small farmers in developing countries. Should legislation constraining modern agricultural science spread within the developed countries, the consequences for long-term food supplies in developing countries could be severe, partly because of reduced exports by developed countries and partly because similar policies might be adopted in developing countries as well.

Environmental and biosafety policies may pose similar threats to food security. Several countries have already implemented legislation that will curb the use of chemicals in agriculture, including chemical fertilizers and pesticides. Environmental protection legislation is also being introduced to regulate and curb animal production to avoid or reduce air pollution, carbon dioxide buildup in the atmosphere, and pollution of groundwater and streams due to excessive or inappropriate use of animal manure on the land. While some of this legislation can be justified on environmental grounds, the short-run effect is likely to be reduced food production. In the longer run, the negative productivity effects could be partially or totally eliminated through agricultural research on pest-resistant plants, use of animal manure for biogas, and other opportunities. Several developing countries are currently reviewing their biosafety legislation as well as legislation related to the use of biotechnology in food production and processing, and the outcome of these deliberations is far from clear. Developed countries may also use food safety and biosafety policies to maintain barriers to imports from developing countries.

Misinformation and lack of information on the potential environmental effects of the use of chemicals in agriculture and on the health effects of the use of genetically engineered foods could significantly affect food supply, demand, and therefore food security for many millions of people in developing countries. For example, failure to assist

African farmers in getting access to economically viable plant nutrients, including organic materials and inorganic fertilizers, because of the perceived negative environmental effects of fertilizers would make it almost impossible for them to expand productivity on the lands currently in production to the level needed to assure food security in the region. On the other hand, with the right policies for plant nutrients, agricultural research, rural infrastructure, and agricultural markets, African agriculture could accelerate its annual growth rate from the current 2 percent to at least 4 percent, while assuring sustainability in the management of natural resources.

Although it is critical that society establish ethics and social norms for the use of results from scientific endeavor, it is important that governments not be pushed by vocal minorities and widespread misinformation to take the easy way out and simply outlaw all research results with unknown side effects. A more enlightened approach involves assessing the risks and opportunities and establishing sound biosafety rules based on the best available scientific knowledge. As part of such an enlightened biosafety policy, societies should decide on the extent to which consumers should be permitted to make their own judgments based on the best available information. Genetically modified maize, soybeans, and tomatoes as well as livestock products produced with the use of synthetic growth hormones are cases in which society must determine whether it wants the state to judge for all or consumers to judge for themselves. The issues are far from resolved. For example, the EU recently appealed the WTO's conclusion that livestock products produced with the use of synthetic growth hormones in the United States could not be excluded from the EU market on health grounds.

Conflicts and Food Security

Widespread local, national, and regional instability and armed conflicts contribute to the persistence of poverty, food insecurity, and natural resource degradation. While relief agencies around the world are fully aware of the disastrous effects of conflicts on peoples' capacity to assure their food security, opportunities for preventing or resolving conflict through improvements in food security and more sustainable use of natural resources have received little attention until recently. It is becoming increasingly clear that poverty, food insecurity, and natural resource degradation contribute to the initiation or prolongation of instability or conflicts. Poor, food-insecure people may, in desperate circumstances, perceive no option but to engage in conflict to secure their access to resources that will assure future well-being. Of course, not all poor, food-insecure people engage in conflict, but the probability of instability or conflict rises in circumstances where people are pushed to the limit to meet even their most fundamental needs. The complex, mutually reinforcing relationship between poverty, food insecurity, and natural resource degradation on the one hand, and social and political instability and conflict on the other hand, has not been fully recognized or acknowledged.

Yet, 57 percent of the countries considered by the United Nations to have low human development (low life expectancies at birth, low levels of education, and low incomes) were gripped by conflict during 1990–95, compared with 14 percent of the countries considered to have high human development (high life expectancies at birth, high levels of education, and high incomes).[58] And more than half of the 17 Sub-Saharan African countries currently suffering from food emergencies also suffer from civil strife or armed conflict.[59] Conflicts in countries such as Burundi and Rwanda are frequently characterized as resulting from tribal or political issues when, in fact, the underlying or catalytic causes are natural resource degradation, extreme poverty, and widespread food insecurity. Such conflicts in turn breed further food insecurity, poverty, and natural resource degradation, continuing

a vicious circle of hunger and instability. Rural populations are frequently forced to flee for their safety, leaving agricultural lands uncultivated and crops and livestock untended. Animal herds are raided, crops are burned, and productive assets are stolen.[60] Conflicts disrupt traditional agricultural and pastoral practices, thus exacerbating the effects of weather fluctuations. Cattle herds that frequently are a significant buffer or safety net against the negative food security effects of droughts are often reduced or eliminated during conflicts. The widespread use of land mines prohibits the use of much agricultural land in a large number of low-income countries.[61] Conflicts also tend to undermine trade between regions.

Degradation of natural resources, food insecurity, and conflict interact to cause rapid increases in the number of refugees and displaced persons, thereby aggravating both the consumption and production sides of food security. The number of international refugees has increased 10-fold since 1974, from about 2.4 million to 23 million in 1995. In addition, an estimated 27 million people are displaced within their home countries.[62] Large-scale movements of refugees and displaced persons interfere with production activities, disrupt food markets, and place severe pressures on local food supplies, which, in turn, may further amplify tensions and civil strife. Large inflows of refugees and displaced persons also increase pressure on natural resources, often accelerating local deforestation, soil erosion, and water contamination and depletion.

The extent to which agricultural research and improved technologies can alleviate poverty, improve food security, and encourage sustainable use of natural resources will depend greatly on the extent to which conflicts are avoided. At the same time, the extent to which conflicts are avoided will depend greatly on the extent to which poverty is alleviated, food security is improved, and sustainable use of natural resources is encouraged. Technologies and policies capable of improving food security will decrease the probability of conflict. The interaction between conflict and the impact of agricultural research deserves more attention from the research community.

Implications for Policy and Research

During the next 25 years, food production will not keep pace with increases in food demand in developing countries, and an increasing share of their demand for cereals and meat will have to be met through imports from developed countries. For those countries with the necessary foreign exchange, including the fast-growing East Asian countries, this should not be cause for alarm. However, many of the low-income developing countries, including most of those in Sub-Saharan Africa, may not be able to generate the necessary foreign exchange to fill the gap between food demand and production through commercial imports. These low-income, slower-growth countries will also face a widening gap between food needs and economic demand because many poor people will lack the purchasing power to fully meet their needs. Greater risks and larger fluctuations in food availability and prices will exacerbate the precarious food security situation for poorer people in low-income countries. Unless new action is taken, the gap between food needs and availability in many low-income coun-

tries will widen, resulting in increasing food insecurity, hunger, and malnutrition.

The actions needed are comprehensively described in action plans from the World Food Summit and IFPRI's 2020 Vision initiative.[63] Although increasing price fluctuations are expected in the world market, the most recent projections confirm that the long-run trend for world cereal and meat prices is downward in real terms. However, real price decreases will be limited over the next 10–15 years. Various factors described in this report—unexpected cuts in public investments in agricultural research, environmentally or food safety motivated production restraints in developed and middle-income countries, adverse developments in China, Eastern Europe, or the former Soviet Union—could prove the price projections wrong.

The focus of agricultural research and policy aimed at reduced poverty and food insecurity should be on low-income developing countries, and particularly small-scale farmers in those countries. Continued low productivity in agriculture not only contributes to food gaps in these countries, but also prevents attainment of the broad-based income growth and lower unit costs in food production needed to help fill the gap and improve food security. While efforts to improve long-term productivity on small-scale farms must be accelerated, more emphasis must also be placed on research and policy that will help farmers, communities, and governments better cope with expected increases in risks resulting from poor market integration, dysfunctional or poorly functioning markets, climatic fluctuations, and a host of other factors. All appropriate scientific tools, including bioengineering, should be mobilized to help solve the problems facing small-scale farmers in developing countries. Current investments are extremely low and must be expanded.

The agricultural productivity increases needed to lift the populations of low-income developing countries out of poverty and food insecurity without doing irreparable damage to natural resources will be possible only if appropriate government policies are pursued and investments in the rural areas are expanded. While the specific policy measures must be designed within each country, low-income developing countries should review their trade and macroeconomic policies as well as policies on water management and allocation, property rights to land and other natural resources, agricultural input and output markets, income-earning opportunities and social safety nets for low-income families, rural infrastructure, rural financial markets, and various other incentives for small farmers, including those needed to adjust to and benefit from further trade liberalization. Governments should also review their current allocation of public sector resources to primary education, health care, agricultural research and extension, rural infrastructure, and other public goods needed to accelerate broad-based growth within and outside agriculture. Developed countries should consider reversing the downward trend of official development finance, particularly to the most vulnerable developing countries. Failure to do the right thing will result in continued low economic growth and rapidly increasing food insecurity and malnutrition in many low-income developing countries, forgone opportunities for expanded international trade, widespread conflict and civil strife, and an unstable world for all.

NOTES

1. IMPACT covers 37 countries and regions (which account for virtually all of the world's food production and consumption) and 17 commodities (including all cereals, soybeans, roots and tubers, meats, and dairy products). The basic methodology of IMPACT is described in M. W. Rosegrant, M. Agcaoili-Sombilla, and N. D. Perez, *Global Food Projections to 2020: Implications for Investment,* Food, Agriculture, and the Environment Discussion Paper 5 (Washington, D.C.: International Food Policy Research Institute, 1995). Revisions and updates to IMPACT are described in 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, May 27, 1997.
2. Malnourished children are those whose weight-for-age is more than two standard deviations below the weight-for-age standard set by the U.S. National Center for Health Statistics and adopted by many United Nations agencies in assessing the nutritional status of persons in developing countries.
3. FAO classifies these people as chronically undernourished; that is, their access to per capita food supplies is less than 1.55 times the basal metabolic rate.
4. Food and Agriculture Organization of the United Nations, *Investment in Agriculture: Evolution and Prospects,* World Food Summit Technical Background Document 10 (Rome, 1996).
5. United Nations, *World Population Prospects: The 1996 Revisions* (New York, 1996).
6. United Nations, *World Urbanization Prospects: The 1994 Revisions* (New York, 1995).
7. World Bank, *1997 World Development Indicators* (Washington, D.C., 1997).
8. World Bank, *World Development Report 1997* (New York: Oxford University Press for the World Bank, 1997).
9. All tons in this report are metric tons.
10. C. L. Delgado and C. Courbois, "Changing Fish Trade and Demand Patterns in Developing Countries and Their Significance for Policy Research," Markets and Structural Studies Division Paper 18 (Washington, D.C.: International Food Policy Research Institute, 1997).
11. M. Ahmed, "Policy Issues Deriving from the Scope, Determinants of Growth, and Changing Structure of Supply of Fish and Fishery Products in Developing Countries," paper presented at the International Consultation on Fisheries Policy Research in Developing Countries: Issues, Priorities, and Needs, Hirtshals, Denmark, June 2–5, 1997.
12. Food and Agriculture Organization of the United Nations, FAOSTAT Database, <http://faostat.fao.org>, accessed August and September 1997.
13. Delgado and Courbois, "Changing Fish Trade and Demand Patterns in Developing Countries."
14. P. Pinstrup-Andersen and J. L. Garrett, "Rising Food Prices and Falling Grain Stocks: Short-Run Blips or New Trends?" 2020 Brief 30 (Washington, D.C.: International Food Policy Research Institute, 1996); Food and Agriculture Organization of the United Nations, *Review of the Cereal Price Situation in Selected Developing Countries in 1995–96 and Policy*

Measures to Offset the Price Rise (Rome, 1996); M. Friedberg and M. Thomas, "The 1990s Global Grain Situation and Its Impact on the Food Security of Selected Developing Countries," Trade and Macroeconomics Division Discussion Paper 16 (Washington, D.C.: International Food Policy Research Institute, 1997); Rosegrant, Sombilla, Gerpacio, and Ringler, "Global Food Markets and U.S. Exports in the Twenty-First Century."

15. Pinstrup-Andersen and Garrett, "Rising Food Prices and Falling Grain Stocks."
16. Food and Agriculture Organization of the United Nations, *Report of a Meeting of Experts on Agricultural Price Stability* (Rome, 1996).
17. Friedberg and Thomas, "The 1990s Global Grain Situation and Its Impact on the Food Security of Selected Developing Countries."
18. Food and Agriculture Organization of the United Nations, *Rome Declaration on World Food Security and World Food Summit Plan of Action* (Rome, 1996).
19. S. Rozelle and M. W. Rosegrant, "China's Past, Present, and Future Food Economy: Can China Continue to Meet the Challenges?" *Food Policy* 22, no. 3 (1997): 191–200.
20. L. Y. Chen and A. Buckwell, *Chinese Grain Economy and Policy* (Wallingford, U.K.: CAB International, 1991); F. Mei, "China Can Feed Its Population," *China Daily,* April 29, 1995.
21. R. Garnaut and G. Ma, *Grain in China: A Report* (Canberra, Australia: Department of Foreign Affairs and Trade, East Asian Analytical Unit, 1992); C. Carter and Z. Funing, "China's Past and Future Role in the Grain Trade," *Economic Development and Cultural Change* 39 (1991): 791–814; L. Brown, *Who Will Feed China?* (New York: W. W. Norton, 1995).
22. Rozelle and Rosegrant, "China's Past, Present, and Future Food Economy."
23. S. Fan and M. A. Sombilla, "China's Food Supply and Demand in the 21st Century: Baseline Projections and Policy Simulations," paper prepared for the postconference workshop on "China's Food Economy in the 21st Century" at the American Agricultural Economics Association Annual Meeting, Toronto, Canada, July 31, 1997.
24. United Nations, *World Population Prospects: The 1996 Revisions.*
25. R. Tyers, *Economic Reform in Europe and the Former Soviet Union: Implications for International Food Markets*, Research Report 99 (Washington, D.C.: International Food Policy Research Institute, 1994).
26. Food and Agriculture Organization of the United Nations, *Food Outlook,* various years.
27. S. von Cramon-Taubadel, "Grain Production in Ukraine: Missed Opportunities and the Need for Immediate Action," *Ukrainian Economic Monitor* 5, no. 24 (May 1997): 17–22.
28. While Malthus argued that the population would grow geometrically and food production would grow arithmetically, the extrapolations shown in Figure 21 are based on a nonlinear regression. Such a function showed a better fit than linear functions for either of the two variables. Extrapolations based on Malthus's argument would result in a larger gap.
29. Food and Agriculture Organization of the United Nations, FAOSTAT database; D. Byerlee and C. K. Eicher, eds., *Africa's Emerging Maize Revolution* (Boulder, Colo., U.S.A.: Lynne Rienner, 1997).
30. Consultative Group on International Agricultural Research, "Phenomenal Increase in Maize Production in West and Central Africa," *CGIAR News* 4, no. 2 (1997): 1, 14, 15.
31. United Nations, *World Economic and Social Survey 1997* (New York, 1997).

32. Ibid.
33. United Nations, *World Population Prospects: The 1996 Revisions.*
34. Food and Agriculture Organization of the United Nations, *Special Report: El Niño's Impact on Crop Production in Latin America* (Rome, 1997), and *Special Report: The Impact of El Niño and Other Weather Anomalies on Crop Production in Asia* (Rome, 1997).
35. P. Pinstrup-Andersen, R. Pandya-Lorch, and S. Babu, "A 2020 Vision for Food, Agriculture, and the Environment in Southern Africa," in *Achieving Food Security in Southern Africa: New Challenges, New Opportunities*, ed. Lawrence Haddad (Washington, D.C.: International Food Policy Research Institute, 1997).
36. Food and Agriculture Organization of the United Nations, *Special Report: El Niño's Impact on Crop Production in Latin America.*
37. *FEWS Bulletin* (published for the U.S. Agency for International Development), AFR/97-09 (September 26, 1997).
38. Food and Agriculture Organization of the United Nations, *Special Report: The Impact of El Niño and Other Weather Anomalies on Crop Production in Asia.*
39. Food and Agriculture Organization of the United Nations, *Food Outlook,* no. 7/8/9 (July/August/September 1997).
40. C. Rosenzweig and M. L. Parry, "Potential Impact of Climate Change on World Food Supply," *Nature* 367 (January 13, 1994): 133–138; G. Fischer, K. Frohberg, M. L. Parry, and C. Rosenzweig, "Impacts of Potential Climate Change on Global and Regional Food Production and Vulnerability," in *Climate Change and World Food Security*, ed. T. E. Downing, NATO ASI Series, Vol. 37 (Berlin: Springer Verlag, 1996).
41. Their annual internal renewable water resources are less than 1,600 cubic meters per person per year.
42. M. W. Rosegrant, C. Ringler, and R. V. Gerpacio, "Water and Land Resources and Global Food Supply," paper prepared for the 23rd International Conference of Agricultural Economists, Sacramento, California, August 10–16, 1997; Population Action International, *Sustaining Water: An Update* (Washington, D.C., 1995).
43. Rosegrant, Ringler, and Gerpacio, "Water and Land Resources and Global Food Supply."
44. Approximated by water withdrawals because of a lack of consistent data on consumptive use of water at national or regional levels.
45. M. W. Rosegrant and N. D. Perez, "Water Resources Development in Africa: A Review and Synthesis of Issues, Potentials, and Strategies for the Future," Environment and Production Technology Division Paper 28 (Washington, D.C.: International Food Policy Research Institute, 1997).
46. Rosegrant, Ringler, and Gerpacio, "Water and Land Resources and Global Food Supply."
47. M. W. Rosegrant, *Water Resources in the Twenty-First Century: Challenges and Implications for Action,* Food, Agriculture, and the Environment Discussion Paper 20 (Washington, D.C.: International Food Policy Research Institute, 1997).
48. World Bank, *1997 World Development Indicators.*
49. B. L. Bumb and C. A. Baanante, *The Role of Fertilizer in Sustaining Food Security and Protecting the Environment to 2020,* Food, Agriculture, and the Environment Discussion Paper 17 (Washington, D.C.: International Food Policy Research Institute, 1996).

50. World Food Programme, *1996 Food Aid Flows* (Rome, 1997).

51. Food and Agriculture Organization of the United Nations, *Food Outlook,* no. 7/8/9.

52. P. Webb, *A Time of Plenty, a World of Need: The Role of Food Aid in 2020,* 2020 Brief 10 (Washington, D.C.: International Food Policy Research Institute, 1995).

53. European Commission, *Agricultural Situation and Prospects in the Central and Eastern European Countries* (Brussels, 1997).

54. K. Anderson, B. Dimaranam, T. Hertel, and W. Martin, "Asia-Pacific Food Markets and Trade in 2005: A Global, Economy-Wide Perspective," *Australian Journal of Agricultural and Resource Economics* 41, no. 1 (1997): 19–44.

55. United Nations, *World Population Prospects: The 1992 Revisions* (New York, 1993); *World Population Prospects: The 1994 Revisions* (New York, 1995)*; World Population Prospects: The 1996 Revisions.*

56. United Nations, *World Population Prospects: The 1996 Revisions.*

57. P. Pinstrup-Andersen and R. Pandya-Lorch, "Using Modern Science to Assure Food Security," *IFPRI Report* (October 1996).

58. D. Smith, *The State of War and Peace Atlas,* new rev. 3rd ed. (London: Penguin, 1997).

59. Food and Agriculture Organization of the United Nations, *Food Supply Situation and Crop Prospects in Sub-Saharan Africa*, no. 3 (August 1997).

60. *FEWS Bulletin*.

61. Bread for the World Institute, *Hunger 1996: Countries in Crisis* (Silver Spring, Md., U.S.A., 1995).

62. Ibid.

63. Food and Agriculture Organization of the United Nations, *Rome Declaration on World Food Security and World Food Summit Plan of Action;* International Food Policy Research Institute, *A 2020 Vision for Food, Agriculture, and the Environment: The Vision, Challenge, and Recommended Action* (Washington, D.C., 1995)*.*

Per Pinstrup-Andersen is director general of IFPRI. Rajul Pandya-Lorch is coordinator 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.

IFPRI

1200 SEVENTEENTH STREET, N.W. • WASHINGTON, D.C. 20036-3006 • U.S.A. • 1-202/862-5600
FAX 1-202/467-4439 • E-MAIL ifpri@cgnet.com • WEB www.cgiar.org/ifpri