GLOBAL FOOD PROJECTIONS TO 2020

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EMERGING TRENDS AND ALTERNATIVE FUTURES

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FOREWORD

Over the years, it has become more and more apparent that any meaningful discussion of policies and priorities for alleviating malnutrition and poverty and achieving economic growth depends on an accurate assessment of where we have been and where we are headed. But forecasting the future of food supply and demand requires more than just an examination of short-term trends in global markets: it is essential to focus on long-term growth in income, population, agricultural technology, and a host of other pressing potential changes.

IFPRI presented the first projections of global food supply and demand based on its IMPACT model in 1995 at its Washington, D.C., conference on a 2020 Vision for Food, Agriculture, and the Environment. The 2020 discussion paper that presented those first projections stressed that the prospects for global food security greatly depend not only on population growth and economic development but also on emerging issues such as trade liberalization, urbanization, environmental degradation, water scarcity, the livestock revolution, and new technologies. Two years later, IFPRI updated its take on the global food situation, extending its baseline scenario forward, and in 1999 further updated it, adding commodities and again extending the baseline. Now, in 2001, on the eve of another 2020 conference—"Sustainable Food Security for All"—to be held September 2001 in Bonn, Germany, IFPRI has once again fine-tuned its IMPACT model.

In this volume, which reports the results of IFPRI's projection work in far more detail than previous publications, the authors give their best assessment of what the future food situation will be in the baseline scenario. Then they examine the effects of changes in policy, technology, and life styles through two sets of alternative scenarios. One set explores changes at the global level; the other is regional, focusing on changes specific to Asia and Sub-Saharan Africa.

These scenarios point to one inescapable conclusion: even rather small changes in agricultural and development policies and investments, made in both developed and developing countries, can have wide-reaching effects on the number of poor and undernourished people around the world. The policy choices we make now will determine to a considerable degree what kind of lives the next generation will lead.

To further share the key findings from this pathbreaking research, IFPRI is publishing a more popular version of this paper as a food policy report titled *2020 Global Food Outlook: Trends, Alternatives, and Choices*.

Per Pinstrup-Andersen
Director General, IFPRI

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1

INTRODUCTION

The world population is expected to grow from 5.8 billion people in 1997 to 7.5 billion people in 2020. Although these latest population projections represent a slowdown from past estimates, such a large absolute increase in population raises serious concerns about whether the world's food production system will be able to feed so many people, especially in the face of a possibly stagnant or even declining stock of natural resources. These concerns escalated sharply in the mid-1990s in the face of dramatic increases in world cereal prices in 1996, declining cereal stocks, and the appearance of several widely read publications starkly depicting a starving twenty-first century world unable to meet growing food demands from a deteriorating natural resource base (Brown 1995; Brown and Kane 1994).

Wheat and maize prices in mid-1996 were 50 percent higher than a year before, while rice prices were 20 percent above 1994 levels. Rising cereal prices were accompanied by declines in cereal stocks between 1993 and 1997, with world stocks dropping from an average of 18 percent of total annual consumption in 1993 to about 13 percent in 1996, the lowest level in recent history. Some observers said that these rising cereal prices and falling stocks were indicators of a new reality for world food markets, with high prices, low stocks, and continuous food shortages. Global cereal production responded to higher prices, hitting record levels in 1997 and 1998, while falling incomes caused by the East Asian economic crisis reduced the demand for food commodities. Prices for wheat and maize fell nearly 50 percent between 1996 and 1999, rice prices dropped by 24 percent, and cereal stocks had risen again to 18 percent of consumption by 1999/2000. The policy focus in much of the world shifted from long-term food supply and demand problems to providing subsidies for financially distressed farmers.

These recent fluctuations in cereal markets show how inappropriate it is to make judgments about long-term food security based on short-term trends in global markets. Indeed, year-to-year variability in prices and production—and the influence that this variability has on the amount and type of attention devoted to the global food situation—may in fact contribute to long-term food problems by encouraging complacency during periods of strong short-run performance. In order to understand the future of food supply and demand and food security, it is essential instead to focus on long-term fundamental drivers, such as income and population growth, and technological changes in agriculture as influenced by investments in agricultural research, irrigation, roads, and other factors. In this volume we explore alternative futures for global food markets, including both a baseline scenario that gives our best estimates of the future and a number of alternative scenarios that assess the flexibility of world food markets and the robustness of baseline results.

We have chosen to examine alternative scenarios because the future world situation is dependent on a number of variables, many of which are the result of policy decisions on investment in agricultural research, irrigation, clean water, and health; population programs; and the general economic policies that drive income growth. Through alternative scenarios, we explore the effects of policy, technology, and lifestyle-driven changes on global food markets and the poor.

The projections of long-term food supply, demand, trade, and prices are based on assessment of the underlying factors driving global food markets, including likely future developments for wheat, maize, rice, other coarse grains, soybeans, roots and tubers, oils, meals, and meats. After a brief review of recent historical trends in the global and regional food situation, we describe the global food projections model called the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), developed by the International Food Policy Research Institute (IFPRI). We then present an overview of the baseline demand and supply projections, including projections of crop area harvested and crop yields, food demand, price and trade projections for these commodities, and the effects of these projections on childhood malnutrition. Next we explore several alternative regional and global scenarios, including optimistic and pessimistic paths for the future world food situation. Finally, we consider the implications of these projections for future global food security and policy. A list of all of the countries and regions and commodities included in the model is presented in Appendix A.

2

RECENT TRENDS IN FOOD SUPPLY AND DEMAND

The world food picture has undergone dramatic changes in the three decades since the mid-1960s, when widespread food shortages in Asia caused predictions of disastrous recurring famines. A Green Revolution, featuring the adoption of high-yielding cereal varieties and rapid increases in irrigated area and fertilizer use, dramatically improved productivity in Asia and other developing regions, easing the fear of endemic famine in Asia. The Green Revolution peaked in much of Asia in the 1970s and early 1980s before slowing in the 1990s. Concurrently with the Green Revolution, many developing countries experienced rising incomes and shifting consumption patterns, which led to striking increases in livestock consumption and production, particularly in Asia. The past few decades have also brought policy shifts—such as economic liberalization—that have improved efficiency in agriculture and eased trade flows. Other shifts, however, including debt crises, structural adjustment programs, the disintegration of the Soviet Union, and the recent East Asian economic crisis, have negatively affected the ability of certain regions to maintain food security. Thus, despite the fact that most regions have made substantial inroads against poverty and averted widespread famine in recent years, malnutrition persists, remaining intransigent in some developing regions and threatening resurgence in others.

Food demand growth caused by expanding populations and shifting consumption patterns will necessitate future food production increases, but unexploited, available arable land is limited, placing the burden for these increases on technologically driven yield improvements. The need for modern agricultural technologies, however, must be balanced against legitimate concerns about environmental sustainability. Empirical evidence has demonstrated that negative effects on the environment from inappropriately applied technologies can translate into productivity losses and threaten human health, although assessing the precise extent of these effects is often difficult. Growing urban and industrial demands on existing water supplies and the need for improved water quality further complicate the situation.

In reviewing recent historical patterns in food security and global food markets, we first look at trends in child malnutrition, followed by a

TABLE 2.1 Number of malnourished children since 1970

Region	1970	1975	1980	1985	1990	1995	1997
				(millions of children under age 5)			
Latin America and the Caribbean	9.5	8.2	6.2	5.7	6.2	5.2	5.1
Sub-Saharan Africa	18.5	18.5	19.9	24.1	25.7	31.4	32.7
West Asia/North Africa	5.9	5.2	5.0	5.0	n.a.	6.3	5.9
South Asia	92.2	90.6	89.9	100.1	95.4	86.0	85.0
East Asia	77.6	45.1	43.3	42.8	42.5	38.2	37.6
All regions	203.8	167.6	164.3	177.7	176.7	167.1	166.3

Source: Smith and Haddad (2000) 1970 through 1995. 1997 data are the IMPACT base-year values extrapolated from 1995 values using the IMPACT model.
Note: n.a. is not available.

broad overview of global commodity trends between the mid-1960s and late-1990s, particularly cereal and livestock production and consumption. Finally, we focus on food supply and demand trends in each of the developing regions: Asia, Latin America, Sub-Saharan Africa, and West Asia and North Africa (WANA). In many cases, we have further subdivided Asia into East Asia, South Asia, and Southeast Asia to capture the diversity of these subregions.

CHILD MALNUTRITION: SPORADIC PROGRESS

Since the 1960s, developing countries have made impressive strides against malnutrition rates among children under five,[1] declining from an aggregate rate of more than 46 percent in 1970 to 31 percent in 1997.[2] Nevertheless, as a result of population growth rates in developing countries averaging 2.1 percent annually between 1967 and 1997 (despite declines in growth throughout the period), the percentage decline in child malnutrition has translated into an absolute decline of 20 million malnourished children since 1967 to approximately 167 million children in 1997.[3]

These aggregate declines mask alarming regional trends (Table 2.1).[4] In South Asia, child malnutrition prevalence rates dropped from 72 percent to just below 50 percent over this 30-year period. Despite these encouraging signs, South Asia's progress against malnutrition has been far from steady: while the region's number of malnourished children declined between 1970 and 1980, it rose sharply in 1985. Improvements between 1990 and 1997, however, offset this backslide, and the number of South Asian malnourished children in 1997 was 7.2 million below 1970 levels.

Sub-Saharan Africa had many more malnourished children in 1997 than it did in the mid-1970s (prevalence rates also rose between 1985 and 1997). While roughly 1 in 10 malnourished children in developing countries resided in Sub-Saharan Africa in 1970, 1 in 5 did by the mid-1990s. Between 1985 and 1997, WANA also experienced a worsening of child malnutrition: the ranks of the malnourished increased by approximately 1 million children, more than erasing gains made in the previous decade and a half.

The overall picture in Latin America has been relatively bright, with child malnutrition prevalence dropping from 21 to 10 percent between 1970 and 1997. Declines in child malnutrition were more impressive (and malnutrition prevalence rates among children lower) in South America than in Central America and the Caribbean (Garrett 1997). In East Asia, the absolute number of malnourished children fell dramatically between 1970 and 1997.

Although a downward trend is evident in the number of malnourished children in developing countries, this trend does not demonstrate a pattern of inevitable, steady progress. The timing and size of gains have been uneven and interspersed with periods of worsening or stagnant malnutrition. The largest declines occurred in Asia during the 1970s. Sub-Saharan Africa was stable between 1970 and 1975, steadily increasing thereafter; improvements in WANA have emerged only recently, and progress in Latin America slowed during the late 1980s. Nevertheless, caloric availability per capita rose in developing countries between the 1960s and the early 1990s by 400 kilocalories, reaching nearly 2,700 kilocalories per day by 1997 (FAO 2000a).

WORLD AND DEVELOPED-COUNTRY TRENDS

Cereals

Over the 30-year period 1967–97, per capita cereal production worldwide rose substantially in the context of rapidly increasing cereal yields, slow growth in total harvested area, and declining per capita harvested area. While per capita production in the developed world rose from 565 kilograms in 1967 to 660 kilograms in 1997, per capita cereal production in the developing world rose from 176 kilograms in 1967 to 226 kilograms in 1997, an increase of 28 percent (Table 2.2). (All values throughout this volume are three-year averages centered on the identified year, based on data downloaded from the FAOSTAT database of the Food and Agriculture Organization of the United Nations [FAO 2000a]). Thanks to the Green Revolution, which was sparked by the development of high-yielding varieties of cereals and complemented by expansion of irrigated area and fertilizer use, these production increases in per capita production occurred despite an increase in total

TABLE 2.2 Per capita cereal production and annual growth rates in developing-country regions, 1967–97

	Per capita cereal production				Production growth rates		
Region	*1967*	*1982*	*1990*	*1997*	*1967–82*	*1982–90*	*1990–97*
	(kilograms/capita)				*(percent/year)*		
Latin America	225.3	262.0	222.1	253.4	1.0	−2.0	1.9
Sub-Saharan Africa	127.9	110.8	122.3	124.6	−1.0	1.2	0.3
West Asia/North Africa	255.8	231.5	245.5	245.6	−0.7	0.7	0.0
All Asia	163.6	206.9	224.4	236.4	1.6	1.0	0.7
South Asia	146.0	171.3	182.1	182.6	1.1	0.8	0.0
Southeast Asia	157.8	198.8	210.1	226.3	1.6	0.7	1.1
East Asia	188.7	248.7	276.5	295.8	1.9	1.3	1.0
Developed world	564.6	670.4	680.3	660.1	1.2	0.2	−0.4
Developing world	176.0	206.8	216.0	225.6	1.1	0.5	0.6

Source: Based on FAOSTAT data (FAO 2000a).

harvested cereal area of 26 million hectares worldwide between 1967 and 1997 and a decline in global per capita harvested area from 0.19 hectares in 1967 to 0.12 hectares in 1997. At the Green Revolution's peak, worldwide cereal production moved sharply upward, especially in Asian developing countries, but also more broadly in developing countries, with Sub-Saharan Africa lagging badly.

Cereal Production Trends. Worldwide cereal yield growth has slowed since its peak in the mid-1970s, with cereal production growth in developing countries slowing significantly and cereal production in developed countries practically stagnating until the late 1990s. Recent trends in developing countries will be discussed further on. In those developed countries that produce a large share of cereal exports, dramatic declines in production growth were mostly the result of policy choices that led to area declines averaging 1.2 percent annually between 1982 and 1997. Trends in the developed world are heavily influenced by agricultural subsidy policies in the European Union countries (EU15),[5] the United States, and Canada. As a result of high and increasing producer subsidies in the 1980s, cereal production expanded; stocks rose from an average of 20 percent of production during the late 1970s and early 1980s to 27 percent by 1986–87. Subsidy policies, among other factors, caused international cereal prices to fall by 40 percent between 1981 and 1987. As a result, cereal exporters responded by cutting subsidies and withdrawing land from production (Dyson 1996).

In the United States, producer subsidy equivalents (PSEs) declined from 26 percent to 19 percent of production between 1987 and 1990 but fell little between 1990 and 1997 (see Box 3.1, p. 56). Consumer subsidy equivalents (CSEs) fell even more rapidly between 1987 and 1990, from 8 percent to 3 percent and were actually slightly positive by 1997. Reforms to Canadian agriculture were slower to be implemented, but PSE estimates fell from 32 percent in 1990 to 15 percent in 1997 and CSEs fell from −21 in 1990 to −14 percent in 1997. In the European Union, PSEs fell slightly, from 46 percent of production in 1987 to 39 percent of production in 1997; CSEs in the EU15 fell more—from 42 percent of production in 1987 to 25 percent of production in 1997—with most of this reduction occurring between 1990 and 1997 (OECD 1999). In addition to reducing the magnitude of subsidies, North American and European governments began to decouple subsidies from directly influencing farm production decisions by shifting from farm-price support programs to direct payments to farmers, thus reducing the need to buy and hold large reserves. In 1996, the United States and the European Union together held less than one-half the cereal stocks they held in 1993.

Cereal production grew slowly in the developed countries during 1982–90, reflecting the net effects of rising subsidies early on and some subsidy and area reductions later in the period. Production growth stagnated during 1990–97 except for Australia (Table 2.3), reflecting sharp reductions in the size and changes in the form of farm subsidies, which in turn led to a reduction in cereal area during the period. For the developed countries (other than the Former Soviet Union [FSU] and Eastern Europe), the policy-driven nature of the production slowdown, while yields continue to grow at a positive rate, implies that significant supply remains untapped. It is not surprising that cereal production growth returned to these countries during the mid-1990s, when incentives to increase production—in the form of high international cereal prices—also returned.

Events that took place in the FSU countries in the post-reform period form an important

TABLE 2.3 Growth rates of cereal yields and production in developed countries, 1982–97

Region/Country	Yield 1982–90	Yield 1990–97	Production 1982–90	Production 1990–97
	(percent/year)			
United States	1.5	2.3	0.1	2.2
EU15	2.8	2.1	1.9	1.1
Japan	1.0	0.7	0.1	−1.2
Australia	3.0	2.5	−1.0	6.0
Eastern Europe	1.3	−1.8	0.8	−2.1
Former Soviet Union	3.2	−3.1	1.6	−5.3
Other developed countries	1.0	1.6	0.8	0.0

Source: Based on FAOSTAT data (FAO 2000a).

component of the structure of world cereal demand and production trends during the 1990s, with production, demand, and total imports all falling drastically in the region, while total exports rose (Table 2.4). Cereal production reversals in FSU probably began in 1988 but became apparent only during the period 1990–97, when production fell 5.3 percent annually and yields by 3.1 percent annually.

The reform process in the former Soviet bloc countries had drastically negative effects on agricultural production and yields for both terms-of-trade and institutional reasons. Macours and Swinnen (2000a, 2000b) estimate that price liberalization and subsidy reductions caused a significant decline in the terms of trade for FSU agriculture and have been responsible for 40 to 50 percent of the fall in average crop output during the 1990s. An additional 30 to 60 percent of the agricultural output decline was the result of institutional disruptions to both the agricultural sector and the larger economy, as the absence of contract enforcement mechanisms and information distribution systems severely impeded investment and growth in an increasingly liberalized production environment (Macours and Swinnen 2000a, 2000b). The poor performance of the FSU agricultural sector in the post-reform period, while not as dismal as that of the economy as a whole, became a major political issue; it prompted some retrenchment on agricultural trade liberalization in the mid-1990s in an

TABLE 2.4 Growth rates of cereals, Former Soviet Union, 1982–97

	Production	Yields	Demand	Area per capita
	(percent/year)			
1982–90	1.6	3.2	1.4	−2.4
1990–97	−5.3	−3.0	−8.2	−2.5

Source: Based on FAOSTAT data (FAO 2000a).

TABLE 2.5 Growth rates of population and total cereal demand, 1967–97

Region	Population growth			Total cereal demand		
	1967–82	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*
		(percent/year)			*(percent/year)*	
Latin America	2.4	2.0	1.7	4.0	1.7	3.6
Sub-Saharan Africa	2.8	2.9	2.6	2.8	4.1	4.0
West Asia/North Africa	2.8	3.0	2.2	4.3	4.1	2.4
Asia	2.2	1.9	1.6	3.8	3.2	2.6
South Asia	2.3	2.2	1.9	2.9	3.4	2.6
Southeast Asia	2.4	2.0	1.7	2.8	3.7	3.4
East Asia	2.0	1.5	1.1	4.3	3.0	2.4
Developing world	2.3	2.1	1.7	1.9	0.8	−1.3
Developed world	0.8	0.7	0.5	3.8	3.2	2.7

Source: Based on FAOSTAT data (FAO 2000a).

effort to maintain food self-sufficiency (von Braun et al. 1996).

Cereal Demand. Income and population growth have driven expansion of cereal demand worldwide. The gradual slowing in population growth rates over recent decades has resulted in a corresponding slowdown in the rate of growth in cereal demand (Table 2.5). Cereal demand growth in the developing world declined from 3.8 percent annually in 1967–82 to 3.2 percent in 1982–90, and to 2.7 percent in 1990–97. In reality, however, such aggregate growth rates obscure as much as they reveal; events in Asia have driven the overall demand growth decline, since that region accounts for 54 percent of the world population and dominates trends at the global level. Demand growth has also slowed in other regions for widely divergent reasons; thus, while saturation of consumer demand in most of the developed countries and the collapse of the FSU economies after 1990 helped slow demand growth in the developed world, poverty and a scarcity of foreign exchange restrained demand growth in Sub-Saharan Africa, despite persistently high malnutrition in the region.

Cereal Trade. The dominant trend affecting world cereal markets has been divergence between production and demand growth in a number of regions, thus resulting in a dramatic increase in world cereal trade from about 116 million metric tons in 1967 to 257 million tons in 1997. Most of this increase in cereal trade took place between 1967 and 1982, when total cereal trade expanded at a rate of 5.1 percent annually. Growth slowed between 1982 and 1990 to 0.5 percent annually but picked up to a rate of 1.0 percent between 1990 and 1997. The growth in cereal trade has been influenced by rapid economic growth in developing countries, as well as much improved communication and transport capacities, improving trade and macroeconomic policies, and changing patterns of food demand (Dyson 1996). Total world cereal trade increased from 230.3 million tons in 1982 to 239.9 million tons in 1990. The composition of trade changed substantially during this period, however, as subsidy

TABLE 2.6 Net cereal trade, 1967–97

Region	1967	1982	1990	1997
		(million metric tons)		
Latin America	3.1	−3.5	−11.4	−14.5
Sub-Saharan Africa	−1.5	−8.3	−8.1	−12.0
West Asia/North Africa	−5.9	−28.9	−38.7	−44.3
Asia	−17.4	−28.0	−29.4	−28.0
South Asia	−11.6	−2.9	−3.2	−1.7
Southeast Asia	−0.1	0.8	0.1	−5.5
East Asia	−5.8	−25.9	−26.3	−20.9
Developing world	−21.7	−68.7	−87.6	−98.8
Developed world	24.6	73.8	93.2	105.9

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate exports; negative figures indicate imports.

increases and resulting low cereal prices had varying effects on the major cereal exporting nations. Table 2.6 gives a breakdown of net cereal trade by region.

The EU15 countries benefited from the subsidy war, rapid technological progress in agriculture, and the saturation of domestic consumption, shifting from net cereal imports of 1.8 million tons in 1982 to net exports of 29.1 million tons in 1990, as production growth significantly exceeded consumption growth (Koester and Tangermann 1990) (Table 2.7). The emergence of the European Union as a major exporter certainly played an important role in keeping international cereal prices low during the early to mid-1980s, although a number of other factors were at play as well, including the adoption of deflationary monetary policy by many industrialized countries following the second oil crisis, worldwide economic recession between 1981 and 1983, and macroeconomic crises in a number of developing countries during the early 1980s. Cereal prices began recovering after 1986.

Despite the declining international price environment, Viet Nam and India also managed to become net cereal exporters between 1982 and 1990 (Table 2.7). Domestic policies in both Asian nations limited cereal imports and favored the expansion of cereal exports, in part as a result of policies that depressed consumer demand for food (Rosegrant and Hazell 2000). Meanwhile, the United States—partly due to EU15 competition and partly due to its own subsidy reductions—experienced a decline in net exports (Sanderson and Mehra 1990).

Argentina also had a difficult decade, with net cereal exports falling by 48 percent between 1982 and 1990, partly because the economic decline of the Soviet Union in the late 1980s softened demand for Argentina's agricultural commodities, while economic crises throughout Latin America weakened regional demand. Moreover, in a high-subsidy environment, Argentina—in the throes of economic crisis—simply could not afford to compete with developed world producers. Poor domestic macroeconomic and sectoral policies and deficiencies in transport and

TABLE 2.7 Net cereal trade by individual cereal exporters, 1967–97

Region/Country	*1967*	*1982*	*1990*	*1997*
		(million metric tons)		
United States	43.5	104.1	93.6	76.8
EU15	−24.2	−1.8	29.1	20.0
Australia	7.3	13.1	14.9	21.7
Other developed countries	2.6	4.5	4.7	6.2
Argentina	8.1	18.5	9.7	19.4
India	−9.1	−1.3	0.4	1.8
Thailand	2.7	6.2	5.8	4.5
Viet Nam	−1.5	−0.6	1.2	2.8

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

marketing hurt Argentina more than other countries in the low-price environment of the late 1980s (Diaz-Bonilla 1999).

The 1990s saw a recovery of world cereal prices and the general erosion of the dominance established by the United States and the EU15 in world cereal markets during the 1980s. Total world cereal trade rose by 20 million tons between 1990 and 1997, while net cereal exports from the United States declined from 94 million tons in 1990 to 78 million tons in 1997, and significant reforms to the Common Agricultural Policy (CAP) in the EU15 helped reduce exports there. Other traditional exporters gained at the expense of the two leaders. Argentina, benefiting from the overall economic recovery of Latin America and from expanded regional markets as the result of MERCOSUR—a common market agreement between Argentina, Brazil, Paraguay, and Uruguay—saw an increase in 1997 of 103 percent above 1990 levels. Australia also increased its net exports 32 percent.

Table 2.8 shows net cereal import trends for selected developing countries in more detail. Between 1967 and 1982, Japan, the other WANA countries (excluding Egypt), and China all emerged as major players in world cereal markets. However, this trend of rapidly increasing cereal imports had slowed by the end of the 1980s. Chinese net cereal imports actually declined by 3.5 million tons in 1990. Most other major importing regions and countries have not shown such dramatic fluctuations: their levels of net imports increased slowly but steadily throughout the 1980s and 1990s.

Growing wheat and maize import demand by developing countries has clearly been the major source of growth for overall cereal trade (see Appendix B, Tables B.1 and B.2). Worldwide wheat trade rose from 63 million tons in 1967 to 122 million tons in 1997, and worldwide maize trade rose from 27 million tons in 1967 to 75 million tons in 1997. While some countries—including Argentina, China, India, and Pakistan—matched their high growth in wheat demand with rapid production growth, most developing countries experienced growing import dependence (FAO 2000b). Feed uses were the dominant factor behind rising demand for maize and other grains (including barley, millet, oats, rye, and sorghum), although the growing importance of compet-

TABLE 2.8 Net cereal trade by major importing countries, 1967–97

Region/Country	1967	1982	1990	1997
		(million metric tons)		
Asia	–18.9	–27.5	–30.2	–31.0
China	−4.6	−19.1	−15.6	−7.6
Indonesia	−0.6	−2.3	−2.1	−5.7
Japan	−11.8	−24.7	−27.9	−27.8
Korea, Republic of	−0.9	−6.4	−9.8	−12.0
Malaysia	−0.9	−1.8	−2.8	−3.8
Philippines	−0.8	−1.3	−2.2	−4.0
Latin America	2.7	–3.2	–10.6	–15.3
Brazil	−1.8	−4.7	−4.4	−9.3
Colombia	−0.3	−0.8	−0.8	−3.4
Mexico	1.3	−6.4	−6.6	−9.5
Other Latin American countries, excluding Argentina	−4.2	−10.1	−9.3	−12.0
West Asian/North African	–6.3	–29.2	–39.7	–45.1
Egypt	−2.0	−7.1	−7.9	−9.4
Other West Asian/North African countries, excluding Turkey	−3.8	−22.6	−30.3	−33.8

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

ing feed sources such as oil crops, meals, and cassava, and the overall shift of meat production toward poultry, which has higher feeding efficiencies than other livestock, slowed demand for these crops. The consumption of other coarse grains increasingly shifted away from food to feed uses, although some are still important food crops in a number of poor developing countries in Sub-Saharan Africa and Latin America.

World Cereal Prices. Between 1982 and 1997, real world wheat prices declined by 28 percent, rice prices by 29 percent, and maize prices by 30 percent. These trends combined to mitigate the effects of higher cereal import demand on world cereal prices in many developing countries. India, a significant net cereal importer always on the verge of a food crisis during the 1960s and 1970s, actually became a net exporter of cereals by the 1990s. And China, consistently defying predictions of impending disaster, experienced only modest increases in cereal imports, with net imports standing at only 7.6 million tons in 1997 (Table 2.8). Important questions remain as to the sustainability of these two trends, however. The high persistence of poverty in India has dampened cereal demand growth there. And highly publicized degradation of the natural resource base in both countries may have serious implications for future production growth. Nevertheless, it is undeniable that the two most populous countries in the world have had remarkable success in maintaining a high level of cereal self-sufficiency under very difficult circumstances. Another important development that helped to keep prices low during the 1980s is the subsidization of Western European agriculture, which led to the emergence of that region as a major net cereal exporter. Without Western Europe's remarkable turnaround from large net importer to significant net exporter, the strain on traditional cereal exporters of supplying the growing import demands of the developing world might have put strong upward pressure on cereal prices (McDowell 1991).

Livestock

Demand: A Livestock Revolution? Some debate has emerged over whether the term "revolution" applies legitimately to the tremendous growth in livestock consumption that has occurred worldwide in recent decades (Delgado et al. 1999; FAO 2000b). The analysis is somewhat complicated by the fact that meat consumption has historically been concentrated disproportionately in industrialized countries, where per capita consumption growth tends to be slow because meat consumption is already at such a high level. This slow growth in developed countries has served to counteract the effects of rapid growth in developing countries, led by Brazil and China. While developed countries accounted for 30 percent of the world's population and 71 percent of its meat consumption in 1967, they accounted for only 22 percent of population and 47 percent of meat consumption in 1997. Thus world per capita meat consumption appears at first glance to have risen more slowly than the term "revolution" would imply, with the fastest growth rates achieved during 1982–90 at 1.5 percent annually, slowing to 1.4 percent during 1990–97 (Table 2.9).

Despite this apparent slowdown, several trends appear to justify the notion of a "revolution." First, the magnitude of changes occurring in the developing world undoubtedly indicates an extraordinary change in the diet of the emerging middle class in developing countries

TABLE 2.9 Growth rates of per capita meat demand, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Former Soviet Union	1.8	2.2	−8.5
Eastern Europe	2.1	1.3	−2.4
United States	0.5	0.8	0.9
EU15	1.9	0.9	0.2
Latin America	1.4	0.9	3.5
Sub-Saharan Africa	0.2	−0.8	0.2
West Asia/North Africa	3.4	0.0	0.9
Developing Asia	2.4	6.0	7.1
Developing world	2.0	3.4	5.2
Developed world	1.5	1.2	−1.1
World	1.1	1.5	1.4

Source: Based on FAOSTAT data (FAO 2000a).

(Delgado et al. 1999). While per capita meat consumption in the developed world rose from 60 kilograms in 1967 to 76 kilograms in 1997, per capita consumption in the developing world more than doubled from 11 kilograms in 1967 to 24 kilograms per capita in 1997 (Table 2.10). Between 1990 and 1997, per capita meat demand in the developing world actually grew faster than in any other period at 5.2 percent annually, representing a substantial increase above the 3.4 percent annual growth rate achieved between 1982 and 1990 (Table 2.9). Total demand increased at a rather remarkable 7.1 percent annually during 1990–97, substantially above increases during the earlier periods. Therefore, the slowdown in global per capita meat demand growth can be squarely laid at the door of declines in per capita demand in the developed world.

There are two reasons for believing that this slowdown will be far less important in the long term than its effect on overall statistics during 1990–97 would indicate. First, given that demand in the developed world has fallen from 71 to 47 percent of total demand over the 30-year period, and is likely to continue to fall, the developed world's demand will have less effect on overall demand trends. Second, the other major factor behind the sharp fall in meat demand growth in the developed world—the economic collapse of the transition economies—was a one-time event. Total demand in the transition economies fell at an annual rate of 8.5 percent between 1990 and 1997, declining from about 20 million tons in 1990 to 12 million tons in 1997, representing a significant portion of the developed world's total demand of 98 million tons.

The evidence that demand growth will progress rapidly in the developing world is strong. First, while 53 kilograms of per capita meat consumption in Latin America (with much higher consumption in Argentina and Brazil) is fairly close to the developed world average of 76 kilograms per capita, most of the developing regions are still significantly below consumption levels in the developed world. Following Latin America, at 43 kilograms per capita, China's unsatisfied demand for meat will continue to rise as its population becomes increasingly wealthy and urbanized. If China's meat consumption and production figures are overstated, which seems highly plausible given the almost impossibly high growth in the region during 1990–97, the divide between per capita consumption in the developed and developing worlds is even wider than it appears.[6]

TABLE 2.10 Per capita meat demand, 1967 and 1997

Region	*1967*	*1997*
	(kilograms/capita)	
Latin America	33.1	53.0
Sub-Saharan Africa	10.0	9.9
West Asia/North Africa	12.0	21.0
Asia	7.3	23.6
South Asia	3.9	5.6
Southeast Asia	8.5	18.1
East Asia	9.5	42.1
Developing world	11.0	24.0
Developed world	59.5	75.8
World	25.5	36.0

Source: Based on FAOSTAT data (FAO 2000a).

Second, high latent demand in income-constrained regions should keep meat demand growth rates in developing countries quite high over the foreseeable future if these countries realize sustained income growth. Estimates of income elasticities indicate that in countries with low but rising per capita incomes, meat demand grows faster than per capita income (Bhalla, Hazell, and Kerr 1999;

Delgado et al. 1999). While the issue of cultural constraints on meat consumption in Islamic countries is certainly an issue, there is little doubt that the major restraining factor on meat demand growth in Sub-Saharan Africa, WANA (after 1982), and much of South Asia has been income related rather than cultural. Increasing urbanization and the greater exposure of developing-country populations to developed-world lifestyles has played a continuing role in driving meat demand growth (Bhalla, Hazell, and Kerr 1999).

In addition to rapidly rising consumption, the major meat demand trend over the 30-year period in developing countries has been the growing role of poultry in total meat consumption, particularly at the expense of beef. Growth of the poultry sector has driven increases in meat demand, with poultry raising its share of total meat production in the developing world from 12 percent in 1967 to 26 percent in 1997 and in the developed world from 15 percent in 1967 to 30 percent in 1997 (Table 2.11). The most radical shifts in poultry meat consumption occurred in regions that are traditionally large producers of beef or sheep and goat meat, including Latin America, where poultry's share of total meat consumption rose from 10 percent in 1967 to 35 percent in 1997, and WANA, where poultry's share went from 20 percent in 1967 to 50 percent in 1997. Per capita poultry demand rose accordingly, increasing from 1 kilogram in 1967 to 6 kilograms in 1997 in the developing world and from 9 to 23 kilograms in the developed world. Beef consumption increased relative to other meats in some individual countries, including Chile, Japan, Malaysia, and South Korea. Although overall consumption of beef worldwide increased from 85 million tons in 1967 to 206 million tons in 1997, beef's share of total meat consumption declined from 41 percent in 1967 to 27 percent in 1997 (FAO 2000b).

TABLE 2.11 Poultry's share of total meat consumption, 1967 and 1997

Region	*1967*	*1997*
	(percent)	
Latin America	10.0	35.2
Sub-Saharan Africa	10.8	17.7
West Asia/North Africa	19.7	49.5
Asia	12.6	21.4
South Asia	5.9	15.0
Southeast Asia	23.2	40.1
East Asia	11.6	19.3
Developing world	11.8	26.2
Developed world	14.7	29.7

Source: Based on FAOSTAT data (FAO 2000a).

Livestock Trade. A rapid expansion of trade accompanied the large increase in meat consumption between 1967 and 1997, rising from 5 million tons in 1967 to 21 million tons in 1997 (Appendix Table B.3). Much of this trade occurred between countries in the developed world, where Japan and FSU were the top two importers of meat products in 1997, with net imports of 2.4 million tons each (Table 2.12). The United States, which was a net importer at 0.7 million tons in 1967, led exporters at 2.5 million tons in 1997. This marked shift was the result of rising poultry exports. The developing world tended to be less involved in the meat trade, with total net imports of 0.6 million tons in 1997, although both Latin America and South Asia were net exporters of meat products in that year.

Feed Demand. Worldwide use of cereals for livestock feed increased from 369 million tons in 1967 to 659 million tons in 1997, representing 36 percent of total cereal consumption in that year. Feed demand grew much faster than

TABLE 2.12 Net meat trade, 1967–97

Region/Country	1967	1982	1990	1997
		(million metric tons)		
United States	–0.7	–0.7	–0.3	2.5
Japan	–0.1	–0.5	–1.3	–2.4
Former Soviet Union	0.1	–1.0	–1.1	–2.4
Australia	0.5	0.9	1.0	1.3
Latin America	0.8	1.2	0.9	0.6
Sub-Saharan Africa	0.1	–0.1	–0.2	–0.1
West Asia/North Africa	–0.1	–1.3	–0.9	–0.9
Asia				
South Asia	0.0	0.1	0.1	0.2
Southeast Asia	0.0	0.0	0.1	0.0
East Asia	0.1	0.1	0.2	–0.2
Developing countries	0.9	–0.1	0.1	–0.6
Developed countries	–0.7	0.8	0.9	2.5

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

food demand in the developing world, with the growth of feed demand reaching 6.4 percent annually during 1990–97, a period when food demand grew only 1.8 percent annually (Table 2.13). The situation was far different in the developed world, where feed demand growth actually turned negative between 1990 and 1997 at –1.5 percent annual growth. Feed use declined from 462 million tons in 1990 to 425 million tons in 1997. This phenomenon again owes much to events in the FSU, where cereal feed demand collapsed more than demand for any other commodity, falling 12.3 percent annually from 123 million tons in 1990 to 56 million tons in 1997. Considering that demand in Eastern Europe alone declined from 56 million tons in 1990 to 48 million tons in 1997, it is clear that demand growth in the rest of the developed world, while slow, was certainly positive during this period.

Feed Demand and Meat Production. It is rather difficult to generalize about the relationship between feed demand and meat production because so many different factors around the globe have been at work over the last 30 years. Feed demand and meat production tracked together between 1967 and 1982, at 2.4 percent annually in the developed world, but the two have since diverged, with feed demand growth lagging meat production growth almost across the board (Table 2.13). This apparent trend may be somewhat misleading, however, because of the extraordinary circumstances of the decline in feed demand in the transition economies. Several factors may help to explain this phenomenon. Although demand for noncereal feed crops such as cassava and meals grew rapidly between 1982 and 1990, the overall demand for feed lagged almost certainly because of improvements in livestock feeding efficiency resulting from advances in management, genet-

TABLE 2.13 Growth rates of meat production and feed demand, 1967–97

Region/Country	1967–82 Meat production	1967–82 Feed demand	1982–90 Meat production	1982–90 Feed demand	1990–97 Meat production	1990–97 Feed demand
			(percent/year)			
United States	1.5	0.8	1.9	0.9	2.9	2.0
EU15	2.9	1.7	1.4	−2.1	1.0	2.6
Former Soviet Union	2.2	4.5	2.8	1.3	−9.5	−12.3
Australia	2.7	2.4	1.7	5.3	1.5	4.5
Eastern Europe	2.9	3.9	1.2	−0.3	−2.4	−2.7
Latin America	3.7	5.3	2.3	1.2	4.5	5.0
Sub-Saharan Africa	2.7	2.1	2.1	6.8	2.9	3.8
West Asia/North Africa	4.6	5.5	4.9	3.9	3.6	3.9
Asia	4.6	7.6	7.2	5.6	7.4	7.9
South Asia	2.9	5.2	4.4	−0.6	3.9	3.2
Southeast Asia	3.7	6.8	5.6	9.3	5.9	6.1
East Asia	5.3	7.8	8.1	5.3	8.2	8.3
Developed world	2.4	2.4	1.7	0.2	−0.5	−1.5
Developing world	4.1	6.3	5.1	4.0	6.2	6.4

Source: Based on FAOSTAT data (FAO 2000a).

ics, and hormone use (Rosegrant et al. 1997). Smil (2000) reports that between the early 1960s and 1998, ratios for feed per kilogram of meat produced in the United States improved 25 percent. A factor in this improvement in efficiency was the growing shift from beef to poultry production, since poultry requires less feed than other livestock, and the poultry sector has seen rapid efficiency gains (Smil 2000). Genetic improvements and better management practices account for most of these gains (FAO 2000b). In the United States, poultry production growth significantly exceeded other meat production growth in every period.

Between 1990 and 1997, however, the trend of lagging cereal feed demand growth slightly reversed itself, with cereal feed demand growing faster than meat production in every developed region except the transition economies and the United States. Overall trends in the EU15 seem to have been dominated by domestic price distortions. When price ceilings on cereals used as feed were lowered under the 1992 McSharry reform of the CAP, feed use recovered from the negative growth rates of the period 1982–90. In general, rapid cereal feed demand growth in the developed world in the 1990s may represent the effects of reduced distortions in cereal markets as a result of agricultural trade liberalization (FAO 2000b).

Cereal feed demand in the developing world grew 6.4 percent annually during 1990–97. Negative growth in South Asia and very slow growth in Latin America between 1982 and 1990 gave way to relatively strong performances during 1990–97. Feed demand increased most rapidly in Asia due to expanding livestock production and low per capita land ratios (Delgado et al. 1999). At 8.3 percent annually, feed demand growth was particularly strong in East Asia in the 1990s, especially in contrast to food demand for cereals, which did not grow at all during the period. Between 1990 and 1997, feed demand also grew rapidly in Southeast Asia and Latin America.

Between 1967 and 1997, annual feed demand growth outpaced meat production growth in East Asia, Southeast Asia, and Sub-Saharan Africa, indicating the growing intensification of feed use per unit of meat output. In all regions of the developing world, grazing areas, mixed-farming systems, and small-scale backyard operations are diminishing in importance in the face of land shortages, low returns to labor, and heightened competition from large-scale producers (Delgado et al. 1999). Industrial production of pork, poultry, feedlot beef, and mutton has been the fastest growing form of animal production in recent years worldwide; it supplied 43 percent of global meat production (over half of pork and poultry production) in 1996, compared with 37 percent of total production in 1992. While industrial systems concentrated in the developed world accounted for 52 percent of global industrial pork production and 58 percent of industrial poultry production in 1996, Asia is the region with the fastest growing industrialized livestock sector. It is already responsible for 31 percent of all industrialized pork production worldwide. Industrial systems depend on outside feed, energy, and other inputs, and are able to achieve large economies of scale and high production efficiencies in terms of output per unit of feed (de Haan, Steinfeld, and Blackburn 1996). Despite their greater efficiency, however, large operations may underuse certain crop residue and household food waste feed sources that have been traditionally important for small-scale producers (Delgado et al. 1999). Industrialized livestock production also poses significant environmental threats: very large flocks or herds lead to high waste volumes and significant animal health risks (de Haan, Steinfeld, and Blackburn 1996).

Roots and Tubers

While cereals and livestock are the most important staple foods at the global level, roots and tubers form an essential component of food security for many of the poor and undernourished in the developing world, contributing a significant amount to overall caloric consumption. Worldwide demand for roots and tubers for food stood at 359 million tons in 1997, and demand for feed consumed an additional 148 million tons (Appendix B, Table B.4). The developing world accounted for 72 percent of worldwide food demand and 65 percent of feed demand, although trends for these categories are moving in opposite directions; food demand growth accelerated to an annual rate of 3.3 percent between 1990 and 1997, after stagnating at 0.3 percent a year during the previous period; at the same time feed demand growth declined from a torrid rate of 7.0 percent a year during 1982–90 to 3.6 percent a year during 1990–97 (Table 2.14). While roots and tubers are most important in Sub-Saharan Africa, supplying 20 percent of all caloric consumption in the region, they also serve as an important supplemental source of carbohydrates, vitamins, and amino acids in Asia and Latin America. Within developing countries, roots and tubers are generally consumed in poorer regions, such as Sichuan, China, and Northern Brazil (Scott, Rosegrant, and Ringler 2000).

Not much research has been done to develop yield-enhancing technologies for roots and tubers. Developing world yields grew at a rate of only 1.0 percent annually during

TABLE 2.14 Growth rates of roots and tubers demand, 1967–97

	1967–82		*1982–90*		*1990–97*	
Region	**Food**	**Feed**	**Food**	**Feed**	**Food**	**Feed**
			(percent/year)			
Latin America	−0.9	−2.0	−0.8	−2.3	0.9	−3.8
Sub-Saharan Africa	1.9	3.1	3.8	3.9	4.0	3.7
West Asia/North Africa	6.9	6.3	5.6	31.5	3.9	−15.5
Asia	0.8	4.4	−2.0	5.5	3.1	3.8
South Asia	3.8	3.8	2.8	−6.3	4.0	−6.4
Southeast Asia	1.7	2.9	−1.1	10.5	2.0	1.0
East Asia	0.2	4.5	−3.3	5.4	3.1	3.9
Developing world	1.8	4.3	0.3	7.0	3.3	3.6
Developed world	−0.4	−1.2	0.2	−0.8	1.4	−4.7

Source: Based on FAOSTAT data (FAO 2000a).

1967–97, with this rate slowing slightly in recent years (Scott, Rosegrant, and Ringler 2000). Area expansion in the developing world has also not been particularly rapid, averaging 0.9 percent annually between 1967 and 1997. One caveat to these general trends is that developing world potato production, yields, and area have all expanded much more rapidly than those of other root and tuber crops; potato production grew at a rate of 3.9 percent annually during 1967–97, with yields rising 1.9 percent and area expanding 2.0 percent annually over the same period. Potato production and demand have expanded rapidly in Asia, which increased its percentage of global consumption from 8.2 percent in 1967 to 27.8 percent in 1997.

Soybeans, Meals, and Oils

Production and consumption of edible oils, meals for livestock feed, and soybeans expanded rapidly between 1967 and 1997. In the developing world, total demand for soybeans rose 6.9 percent a year, demand for meals rose 6.4 percent, and demand for oils rose 5.1 percent (Table 2.15). Feed demand has been the most dynamic source of growth. Feed demand for meals stood at 67 million tons in 1997, with growth averaging 6.7 percent annually over the period as a whole, with growth accelerating to 8.3 percent annually during 1990–97 (FAO 2000b). Processed uses, such as oils for human consumption and meals for feed, have dominated growth in soybean demand, which averaged a torrid 9.1 percent annually between 1967 and 1997 to reach 59.4 million tons in 1997 (from only a few million in 1967), although demand growth was most rapid between 1967 and 1982. Nonfood or feed uses for oilseeds—averaging growth of 8.1 percent annually between 1990 and 1997—have also increased in importance, especially in China and the European Union, where oilseeds serve as inputs for a large number of industrial products with rapidly growing demand (FAO 2000b).

Oil crops are also essential components of food security. According to FAO (2000b), they have accounted for one out of every five calories added to developing-world diets since 1976. Consumption of edible oilseeds reached 44.9 million tons in 1997, with growth averaging 4.8 percent annually between 1967 and 1997; direct

TABLE 2.15 Growth rates of soybeans and meals demand, 1967–97

	Soybeans								
	1967–82			*1982–90*			*1990–97*		
Region	**Food**	**Feed**	**Other uses**	**Food**	**Feed**	**Other uses**	**Food**	**Feed**	**Other uses**
					(percent/year)				
Latin America	0.4	6.8	24.3	6.8	12.8	4.6	7.8	10.7	6.4
Sub-Saharan Africa	4.5	n.a.	12.2	13.4	n.a.	8.9	6.8	n.a.	2.8
West Asia/North Africa	26.7	14.5	24.9	12.3	11.7	1.0	1.3	8.9	11.3
Asia	1.1	0.5	4.9	2.3	−3.0	5.6	7.1	14.2	7.5
South Asia	27.9	41.7	25.7	−4.3	−10.4	27.4	30.3	−17.9	13.6
Southeast Asia	6.0	n.a.	8.7	7.8	n.a.	17.6	2.2	n.a.	2.8
East Asia	0.2	0.4	4.4	1.1	−3.0	2.1	7.6	14.2	6.0
Developing world	1.1	3.3	12.5	2.6	7.9	4.9	7.2	6.7	6.8
Developed world	1.1	6.5	5.3	2.3	16.0	0.1	0.4	0.4	3.1

	Meals								
	1967–82			*1982–90*			*1990–97*		
Region	**Food**	**Feed**	**Other uses**	**Food**	**Feed**	**Other uses**	**Food**	**Feed**	**Other uses**
					(percent/year)				
Latin America	n.a.	9.5	−2.5	n.a.	2.5	56.8	n.a.	8.4	−44.3
Sub-Saharan Africa	–2.2	7.8	12.9	8.4	4.3	−1.1	10.8	5.3	−166.7
West Asia/North Africa	n.a.	10.5	−1.2	n.a.	5.3	14.8	n.a.	6.8	0.5
Asia	n.a.	6.1	2.7	n.a.	5.0	−0.8	n.a.	8.7	7.2
South Asia	n.a.	4.3	13.1	n.a.	7.5	0.3	n.a.	3.9	−1.5
Southeast Asia	n.a.	8.7	9.5	n.a.	10.5	2.8	n.a.	7.3	53.7
East Asia	n.a.	6.9	2.6	n.a.	1.8	− 0.9	n.a.	12.6	6.7
Developing world	–2.2	7.2	2.8	8.5	4.4	–0.7	10.7	8.3	6.9
Developed world	n.a.	4.7	0.8	n.a.	1.8	−13.3	n.a.	0.6	31.0

Source: Based on FAOSTAT data (FAO 2000a).

Note: n.a. indicates that data were not available.

soybean food consumption grew at a slower rate of 2.9 percent annually during the period, reaching 11.8 million tons by 1997. Per capita food demand for oils is relatively high in Latin America at 15 kilograms per capita, East Asia at 9 kilograms per capita, and South Asia at 9 kilograms per capita. Per capita food demand growth has been particularly fast in East Asia at 4.6 percent annually and in Latin America at 4.1 percent annually, although China, India, and a few other countries are effectively driving overall oil crop food demand trends in the developing world.

As demand for oil crops has grown over recent years, trade has expanded significantly. Total worldwide trade in meals rose from 9.7 million tons in 1967 to 49.0 million tons in

1997, trade in edible oilseeds rose from 8.5 million tons in 1967 to 41.4 million tons in 1997, and soybean trade rose from 8.1 million tons in 1967 to 37.1 million tons in 1997. The United States and the EU15 are the two main developed-country players in world oil crop markets, with the United States exporting 24 million tons of soybeans and almost 6 million tons of meals, and the EU15 importing 14 million tons of soybeans and 15 million tons of meals in 1997 (Table 2.16).

The developing countries remained net exporters of meals and edible oilseeds between 1967 and 1997—with net exports of meals a substantial 12.7 million tons in 1997—but they have become net importers of soybeans in recent years, importing 2.7 million tons in 1997. Among developing countries, a few countries dominate oil crop exports: Brazil is a net exporter of meals and soybeans, Argentina of all three oil crops, Malaysia and Indonesia of edible oilseeds, and India of meals. A significant number of developing countries are also net importers of these crops, led by China, with 4.7 million tons of net soybean imports, 3.3 million tons of net edible oilseed imports, and 2.9 million tons of net meals imports. Other big importers include Mexico, with 3.3 million tons of net soybean imports; India, with 1.8 million tons of net edible oilseed imports; and Pakistan, with 1.3 million tons of net edible oilseed imports. As developing country demand for oil crops increases, the net export status of the developing world will continue to erode.

In the remaining sections of this historical assessment chapter, we focus on the major developing regions. Tables summarizing basic indicators for food supply and demand and

TABLE 2.16 Net trade in meals, oils, and soybeans, 1967 and 1997

	Meals		Oils		Soybeans	
Region/Country	*1967*	*1997*	*1967*	*1997*	*1967*	*1997*
			(million metric tons)			
United States	3.0	5.9	1.5	2.3	7.3	24.0
EU15	−6.3	−14.6	−2.7	−1.1	−4.5	−14.4
Former Soviet Union	0.3	−0.1	0.8	−1.1	0.0	0.0
Australia	0.0	0.0	0.2	0.3	0.0	−0.1
Eastern Europe	−0.9	−2.2	−0.1	−0.2	−0.1	−0.2
Latin America	1.6	19.6	0.2	2.4	0.1	5.4
Sub-Saharan Africa	0.9	0.5	0.5	−0.9	0.0	0.0
West Asia/North Africa	0.9	−3.2	−0.6	−4.5	0.0	−0.6
Asia	1.4	−2.1	0.3	4.8	0.2	−7.5
South Asia	0.9	4.2	−0.2	−4.1	0.0	0.0
Southeast Asia	0.4	−1.3	0.6	12.7	0.0	−1.2
East Asia	0.0	−5.1	0.0	−3.9	0.2	−6.2
Developing world	4.3	12.7	0.3	1.9	0.4	−2.7
Developed world	−4.1	−12.0	−0.8	−0.4	−0.3	3.9

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

annual growth rates for each region are given in Appendix C. For Asia, see Tables C.1 to C.6.

ASIA

Cereals

Slow Cereal Production Growth. The Green Revolution had a dramatic effect on food security in Asia. It enabled the two most populous countries in the region, China and India, to escape rising import dependence and periodic food shortages. In the last decade, however, concerns have arisen about the health of cereal production systems in Asia. Recent signs indicate that phenomenal Green Revolution growth in wheat and rice productivity is slowing, especially in the intensively cultivated lowlands. Since the early 1990s, rising unit production costs have led to a decline in farmer profits in both India and China. Slackening of investments in infrastructure and research and reduced policy support partly explain the sluggish growth. Degradation of the lowland resource base from long-term, intensive use also has contributed to declining productivity growth rates.

Rice yield growth rates declined steadily in China throughout 1967–97, falling from 2.8 percent annually between 1967 and 1982 to 2.1 percent between 1982 and 1990, and to 1.6 percent annually between 1990 and 1997 (Table 2.17). Rice yields took off in India later than in China, with annual growth rates rising from 2.0 percent annually in 1967–82 to 3.4 percent in 1982–90, declining to 1.3 percent in 1990–97. The precipitous drop must be a cause for concern for a country that still has a massive amount of food insecurity despite overall cereal self-sufficiency. Southeast Asia followed a similar trajectory to China. Its rice yield growth in 1990–97 was the lowest of the three regions.

Wheat yield growth throughout Asia declined from 4.7 percent annually in 1967–82 to 2.9 percent in 1982–90, with a further decline to 2.5 percent annual growth in 1990–97 (Table 2.17). Wheat yield growth in East Asia slowed from an annual rate of 5.5 percent in 1967–82 to 3 percent thereafter. The slowdown in maize yield growth has been less dramatic, since maize in Asia has not been subject to Green Revolution–type yield growth. For Asia as a whole, maize yield growth dropped from 3.4 percent a year during 1967–82 to 2.3 percent a year during 1990–97. Although maize yield growth expanded significantly in Southeast Asia in the latter period, with the increased adoption of hybrid varieties, it slowed dramatically in China and East Asia.

At the same time that cereal yield growth rates were declining in Asia, the contribution of area expansion to cereal production growth also declined dramatically, as countries in the region ran up against limits to remaining land suitable for cultivation. For Asia as a whole, total growth in cereal area virtually stagnated after 1990, dropping from an already slow rate of 0.1 percent annually between 1982 and 1990. Only maize area showed significant expansion after 1990, growing at a rate of nearly 1 percent annually. Wheat and rice area continued to expand after 1982, but at much slower rates, and area planted to other grains declined sharply. Wheat area grew at a rate of only 0.4 percent annually between 1990 and 1997, while rice area expansion declined from 0.7 percent per year to 0.4 percent over the period (Table 2.18). Area growth varied considerably across regions within Asia. East Asia and South Asia showed declines in area planted to cereals after 1982, with declines in rice and coarse grain area offsetting expansion in maize area (East Asia) and wheat area (South Asia). Cereal area continued to expand slowly in Southeast Asia, mainly because rice area con-

TABLE 2.17 Growth of rice, wheat, and maize production and yields, Asia, 1967–97

	Production growth			Yield growth			Yields			
Region/Country	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967*	*1982*	*1990*	*1997*
		(percent/year)			*(percent/year)*			*(metric tons/hectare)*		
Rice										
China	3.4	1.8	1.0	2.8	2.1	1.6	2.1	3.2	3.7	4.2
India	2.7	4.2	1.7	2.0	3.4	1.3	1.0	1.3	1.7	1.9
East Asia	3.4	1.8	0.8	2.8	2.0	1.5	2.1	3.3	3.8	4.2
South Asia	2.6	3.7	1.6	1.9	3.1	1.3	1.1	1.3	1.7	1.9
Southeast Asia	3.9	2.5	2.7	3.1	1.8	1.2	1.1	1.8	2.0	2.2
All Asia	3.2	2.5	1.5	2.5	2.1	1.1	1.4	2.0	2.4	2.6
Wheat										
China	6.5	3.9	2.7	5.5	3.0	3.0	1.1	2.5	3.1	3.8
India	7.7	4.0	3.2	4.1	3.3	2.0	0.9	1.7	2.2	2.6
East Asia	6.5	3.9	2.6	5.5	3.0	3.1	1.1	2.4	3.1	3.8
South Asia	7.4	3.6	3.2	4.1	2.8	2.0	0.9	1.7	2.0	2.4
Southeast Asia	3.7	0.3	–5.3	5.3	–2.9	–0.7	0.6	1.2	1.0	0.9
All Asia	6.8	3.8	2.9	4.7	2.9	2.5	1.0	2.0	2.6	3.1
Maize										
China	5.1	4.9	4.1	4.1	3.4	1.9	1.8	3.3	4.3	5.0
India	1.6	2.8	2.2	1.1	2.7	1.6	1.0	1.2	1.5	1.7
East Asia	5.1	4.8	3.6	4.1	3.4	1.6	1.8	3.3	4.4	4.9
South Asia	1.5	3.1	2.0	0.9	2.4	1.4	1.1	1.2	1.5	1.7
Southeast Asia	4.1	4.1	3.2	2.6	2.7	4.0	1.0	1.5	1.8	2.4
All Asia	4.5	4.6	3.4	3.4	3.3	2.3	1.5	2.5	3.2	3.8

Source: Based on FAOSTAT data (FAO 2000a).

Note: n.a. indicates that data were not available.

TABLE 2.18 Growth rates of cereal area, Asia, 1967–97

	East Asia			South Asia			Southeast Asia			All Asia		
Cereal	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*
					(percent/year)							
Wheat	0.9	0.9	−0.4	3.2	0.8	1.1	−1.4	3.3	−4.6	2.0	0.9	0.4
Maize	1.0	1.3	2.0	0.6	0.7	0.6	1.5	1.4	−0.8	1.0	1.2	1.1
Rice	0.6	−0.2	−0.7	0.7	0.6	0.3	0.8	0.7	1.4	0.7	0.4	0.4
Other coarse grains	−4.4	−4.5	−3.5	−0.9	−2.1	−2.5	5.4	−2.1	−0.3	−1.8	−2.6	−2.6

Source: Based on FAOSTAT data (FAO 2000a).

tinued to grow. One trend that will exacerbate the problem of Asian land shortages in the future is the ongoing removal of land from agricultural use to satisfy the needs of expanding urban and periurban areas. Since 1979, China's annual farmland losses have averaged 500,000 hectares per year, with rice field losses alone averaging 100,000 hectares per year (enough to feed half the country's annual population increase) (Smil 1998).[7]

Declining world cereal prices and factors related to the increasing intensification of cereal production have caused cereal production growth to slow in developing Asian countries since the early 1980s. Declining cereal prices caused a direct shift of land out of cereals into more profitable cropping alternatives and slowed growth in input use, thus hurting yields. More important over the long run, declining world prices have also slowed investment in crop research and irrigation infrastructure, with consequent effects on yield growth (Rosegrant and Pingali 1994; Rosegrant and Svendsen 1993). Green Revolution growth in cereal crop productivity resulted from an increase in land productivity; it occurred through strong policy support and good market infrastructure in areas of growing land scarcity or high land values or both. High investment in research and infrastructure—especially in irrigation infrastructure—resulted in the rapid intensification of agriculture in the lowlands, with the result that both irrigated and high-rainfall lowland environments became the primary source of food supply for Asia's escalating population.

The use of high levels of inputs and achievement of relatively high wheat and rice yields in parts of Asia have made it more difficult to sustain the same rate of yield gains, as family farm yields in these regions approach economically optimum yields. By 1990, modern varieties of rice occupied 74 percent of rice area in Asia, accounting for all irrigated area plus about one-third of the rainfed lowlands. Opportunities for further expansion of modern variety use are essentially exhausted in existing irrigated areas, and the risk of drought or flooding is severely constraining dissemination in rainfed environments (Pingali, Hossain, and Gerpacio 1997). The decline in the potential for yield growth has been particularly evident in India, where both the full diffusion of modern technologies in the northwest and the stagnation of agricultural productivity in the rest of the country contribute to the decline (Hopper 1999). More generally, both China and India have undergone significant shocks to their cereal production systems and major reforms to institutions affecting agricultural performance. It seems likely that very high yield growth in China between 1970 and 1974 at least partially reflected recovery from the famine of 1959–64, and major reforms undertaken in response to periodically recurring food crises spurred rapid yield growth in India during the 1980s (Dyson 1996). Gains from structural changes in response to crises are one-off effects, although room remains for more economic reform throughout the region.

Environmental and resource constraints have also contributed significantly to the slowdown in yield growth evident over the last two decades. Increased intensity of land use has led to increasing input requirements in order to sustain current yield gains. Moreover, Pingali, Hossain, and Gerpacio (1997) argue that the practice of intensive rice monoculture itself contributes to the degradation of the paddy resource base and hence declining productivities. Declining yield growth trends can be directly associated with the ecological consequences of intensive rice monoculture, including buildup of salinity and waterlogging, use of poor quality groundwater, nutrient depletion and mining, increased soil toxicities, and increased pest buildup, especially soil pests. Salinization affects an estimated 4.5 million hectares in India, and waterlogging affects a further 6 million hectares (Abrol 1987; Chambers 1988; and Dogra 1986 as cited in Pingali, Hossain, and Gerpacio 1997. Many of these degradation problems are also prevalent in the irrigated lowlands, where farmers grow wheat in rotation after rice (Hobbs and Morris 1996). Experimental evidence from India shows that constant application of too low a level of inputs over an extended period has led to declining yields in rice-wheat systems (Paroda 1998).

However, intensification per se is not the root cause of lowland resource base degradation; rather, a policy environment that encourages monoculture systems and excessive or unbalanced input use is to blame. Trade policies, output price policies, and input subsidies—particularly for water and fertilizer—have all contributed to the unsustainable use of the land base. The dual goals of food self-sufficiency and sustainable resource management are often mutually incompatible. Policies designed for achieving food self-sufficiency tend to undervalue goods not traded internationally, especially land, water, and labor resources. As a result, food self-sufficiency in countries with an exhausted land frontier came at a high ecological and environmental cost. Appropriate policy reform—at both macro and sectoral levels—will go a long way toward arresting and possibly reversing the current degradation trends, but the degree of degradation in many regions will pose severe policy challenges (Pingali and Rosegrant 1998). But even if environmental degradation in intensive Asian cropping systems were stabilized, it is unlikely that previous crop yield growth rates will be restored, as long as research and infrastructure investments continue to decline.

Cereal Demand: Slowing Growth. The extent to which all these potentially worrisome declines may represent a demand phenomenon more than a supply shock is dependent on the region under discussion. China's total per capita cereal demand is shared fairly equitably among rice, maize, and wheat, all of which had per capita total consumption of approximately 100 kilograms in 1997 (Table 2.19). Nevertheless, maize dominated growth in cereal demand between 1990 and 1997 to an extent not seen in prior periods. Maize accounted for 22 kilograms of the total 24-kilogram increase in per capita cereal demand in China between 1990 and 1997, whereas maize and wheat each accounted for 13 kilograms of the 23 kilograms increase in per capita cereal demand between 1982 and 1990.[8] This increase in maize demand is an entirely feed-driven phenomenon, with the demand for maize for animal feed actually increasing a remarkable 33 kilograms per capita between 1990 and 1997 as food demand declined. The rising demand for maize as a feed crop is due not only to the rapid expansion of the Chinese livestock sector during this period, but also to structural changes within the livestock sector leading to replacement of traditional feeds with cereals (Steinfeld and Kamakawa 1999). Despite this massive increase in per capita maize demand, however, Chinese maize imports rose only 1.6 million tons between 1990 and 1997, although they reached a peak of 5.0 million tons in 1995. Meanwhile, rice demand has essentially leveled off.

These changes in Chinese diets are largely a function of increasing urbanization. Huang and Bouis (1996) show that diets change as populations move from rural to urban areas. Urban markets offer a wider choice of foods, and urban dwellers are exposed to the dietary

TABLE 2.19 Per capita cereal demand, Asia, 1967–97

	China				India				Southeast Asia				East Asia				South Asia			
Cereal	*1967*	*1982*	*1990*	*1997*	*1967*	*1982*	*1990*	*1997*	*1967*	*1982*	*1990*	*1997*	*1967*	*1982*	*1990*	*1997*	*1967*	*1982*	*1990*	*1997*
									(kilograms/capita)											
Wheat	42	81	94	96	36	54	62	69	6	10	11	16	41	79	93	94	39	57	65	71
Maize	38	65	78	100	11	10	10	11	20	27	38	47	37	67	93	94	39	57	65	71
Rice	80	102	105	106	66	74	85	85	129	154	161	166	82	103	106	105	73	78	85	85
Other coarse grains	29	19	13	12	42	33	26	22	1	1	2	2	31	20	13	12	34	27	20	18

Source: Based on FAOSTAT data (FAO 2000a).

patterns of foreign cultures. Urban lifestyles also place a premium on foods that require less time to prepare (inducing, for example, a shift from rice to wheat bread) as employment opportunities for women improve and the opportunity cost of their time increases. Urban occupations tend to be more sedentary than rural ones. People engaged in more sedentary occupations require fewer calories to maintain a given body weight. In addition, urban residents typically do not grow their own food. Thus, their consumption choices are not constrained by the potentially high cost of selling one food item at farmgate prices (say, rice) to buy another food item (say, bread) at retail prices (a choice faced by semi-subsistence producers). And while changes in food demand patterns that cannot be attributed to increases in household incomes and changes in food prices may first be noticed in urban areas, as structural transformation proceeds to a more advanced level, these same changes in food demand patterns may eventually move to rural areas (Huang and Bouis 1996).

The demand trends have been slightly different in India, however. Per capita cereal demand has slowed significantly in the 1990s, only rising 4 kilograms per capita during 1990–97 to 187 kilograms per capita, compared with gains in per capita consumption of 12 kilograms during 1982–90. Increases in per capita cereal consumption in India over the last 30 years have been unimpressive, especially considering the low initial level of consumption. Both wheat and rice contributed to the increase in cereal consumption between 1982 and 1990, with rice consumption rising 11 kilograms per capita and wheat consumption rising 8 kilograms per capita (Table 2.19). Consumption of other coarse grains declined significantly during this period, from 33 kilograms per capita to 26 kilograms per capita. Between 1990 and 1997, however, rice consumption remained constant, while wheat consumption continued its modest increases. In contrast to China, maize consumption in India has risen a bare 1 kilogram per capita between 1982 and 1997, indicating that it has not yet become an important feedgrain in that country.

Rice—at 166 kilograms per capita of consumption in 1997—dominates Southeast Asian diets far more than it dominates Indian and Chinese diets. Wheat only accounted for 16 kilograms per capita of consumption in Southeast Asia in 1997. Southeast Asian rice demand has increased steadily since 1982, while wheat seems to be emerging as an increasingly important crop, with demand rising 45 percent between 1990 and 1997.

These trends indicate that while the slowdown in Chinese rice production probably has a significant demand component associated with it—mainly the shift to maize production in response to rising demand for animal feed—the trend of slowing yields and production in India is more of a supply phenomenon and thus more of a cause for concern. Per capita rice and wheat consumption in India are still well below Chinese levels, despite some growth in per capita wheat consumption between 1990 and 1997. Hopper (1999) calculates that energy and protein supplies in India only grew at a rate of 1 percent per year between 1980 and 1995, and that the developing world as a whole has increased per capita energy supplies twice as fast as India since 1960. Thus, despite overall food self-sufficiency, Hopper (1999) concludes that "average supplies of energy and protein in India are insufficient to meet average needs." Protein in particular fell 21 percent below existing per capita needs, and several million people did not receive the energy intake necessary to escape wasting and stunting.

Livestock: Structural Changes Affect Both Demand and Supply

A phenomenon oft noted in the literature concerns the dietary shift away from cereals and roots and tubers to meat products as incomes rise and populations in developing countries become increasingly urbanized (Bhalla, Hazell, and Kerr 1999). China's per capita gross domestic product (GDP) in purchasing power parity terms rose from $509 in 1982 to $2,963 in 1997,[9] while the percentage of the population in urban areas rose from 21 to 31 percent over the same period. India's per capita GDP in purchasing power parity terms rose from $736 in 1982 to $2,036 in 1997, while the percentage of the population in urban areas only rose from 24 to 27 percent (World Bank 2000b). Rapid change in the Chinese society and economy brought about a steep rise in per capita meat consumption (Table 2.20) from 15.2 kilograms per capita in 1982 to 42.3 kilograms in 1997. Southeast Asian meat consumption also rose substantially during this period. Indian meat consumption, however, only rose from 3.7 kilograms to 4.5 kilograms. Thus, while meat consumption in China has clearly risen in tandem with the significant shifts occurring in the Chinese society and economy, India, with slower growth and levels of urbanization and significant cultural constraints against meat consumption, has barely seen meat consumption rise at all.

TABLE 2.20 Per capita meat demand, Asia, 1982–97

Region/Country	*1982*	*1990*	*1997*
		(kilograms/capita)	
India	3.7	4.2	4.5
China	15.2	25.5	42.3
Southeast Asia	10.3	13.6	18.1
East Asia	15.6	25.5	42.8
South Asia	4.2	4.9	5.6

Source: Based on FAOSTAT data (FAO 2000a).

Rising livestock demand in Asia has led to surging livestock production accompanied by structural changes to the sector. According to Steinfeld and Kamakawa (1999), the three main changes sweeping the Asian livestock sector in recent years are the concentration of production near large cities favored by cheap input supplies and good output markets, the gradual shift in production away from land-based systems toward large-scale industrial operations, and the vertical integration of primary production, processing, and marketing that has generated large economies of scale. These changes to the livestock sector, while supplanting the traditional functions of livestock as assets, insurance, and objects of sociocultural importance, have permitted a rapid expansion of livestock production that simply would not have been possible under low-intensity production (Steinfeld and Kamakawa 1999). Between 1967 and 1997 livestock production increased at an annual rate of 6.7 percent in East Asia, 4.7 percent in Southeast Asia, and 3.5 percent in South Asia. Production grew fastest in both East and Southeast Asia during the period 1990–97, rising 8.3 percent annually in East Asia and 5.9 percent annually in Southeast Asia. Within the livestock sector, production has increasingly shifted toward pigs and poultry, which offer better feed conversion than ruminants, require less space, and provide for flexible production (Steinfeld and Kamakawa 1999). In East Asia, poultry production increased at an overall rate of 8.5 percent annually during 1967–97, but from 1990 to 1997 the pace of growth was a torrid 14.4 percent annually, as production became increasingly industrialized (Table 2.21). The trend of rapidly expanding poultry production during the 1990s was similar in South and Southeast Asia. Egg

TABLE 2.21 Poultry production growth rates, Asia, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
India	3.8	12.5	6.6
China	5.0	9.9	15.1
East Asia	5.2	10.0	14.4
Southeast Asia	6.5	6.2	7.5
South Asia	4.1	10.3	8.9

Source: Based on FAOSTAT data (FAO 2000a).

production rose more slowly than poultry production in all Asian regions during the 1990s, but it actually grew faster between 1982 and 1990 in both South and Southeast Asia. This was not the case in East Asia, where egg production grew fastest between 1990 and 1997 at 12.7 percent annually.

Modern, demand-driven, and capital-intensive production is thus dominating growth in Asian livestock production—particularly poultry, eggs, pork, and occasionally milk—at the expense of a more traditional, resource-driven, and labor-intensive sector. While this change has brought with it rapidly expanding production, it has had its costs as well. Industrial livestock production generates relatively little employment, poses severe environmental hazards due to its tendency to cluster near large urban areas, and increases the potential severity of animal health problems (Steinfeld and Kamakawa 1999). Nevertheless, as long as rising incomes and urbanization continue to generate high demand for livestock products, structural change in the Asian livestock sector will be sure to follow.

Roots and Tubers: The Rise of the Potato

Demand for roots and tubers as a food source expanded at a rate of only 0.6 percent annually between 1967 and 1997 in Asia, but this slow overall increase masks sharp differences among regions, especially the growing importance of potatoes throughout East and South Asia. Potato demand grew at a modest 3.7 percent annually in East Asia during the period as a whole, but growth exploded to 11.2 percent annually during 1990–97, reaching 28.6 million tons of food demand in 1997. South Asian demand grew from 3.5 million tons in 1967 to 17.7 million tons in 1997, a 5.6 percent annual rate of growth. Rapid economic development and rising incomes have driven potato demand in Asia, where consumers desire to diversify their diets and where potatoes are viewed as a preferred luxury good, in contrast to their inferior status in the developed world. In addition, potato demand has often increased at the expense of less preferred, alternative commodities such as sweet potatoes. And an increasingly urban population desires processed foods generally associated with Western diets. Finally, expanding Asian production and resulting low prices have further stimulated demand (Scott, Rosegrant, and Ringler 2000). Along with other roots and tuber crops, sweet potatoes are an important feed crop in China, with demand rising at an overall rate of 4.4 percent annually to 56.9 million tons in 1997. Sweet potatoes are used mainly as feed for pigs, and more than 80 percent of pig production in China takes place at the village and household level, much of it in Sichuan Province, a geographically isolated area without easy access to feed imports (Scott, Rosegrant, and Ringler 2000). Recent shifts in the livestock sector toward industrialized production of pigs and poultry slowed growth in sweet potato feed demand in China to 2.7 percent annually between 1990 and 1997.

Conclusion

Asian agricultural production systems have undergone dramatic changes over the last 30 years, but much work remains if the gains already achieved are to be extended to the vast numbers who remain food insecure. In China, the two main problems confronting policymakers over the next several decades will be preservation of the natural resource base—with sustainable use of water resources and conflict over competing land uses the big issues—and demand-driven structural change in the livestock sector as intensive, industrial production gradually replaces extensive, small-scale traditional production. More generally, political change in China remains the wild card in any assessment of future agriculture performance. Indian policymakers currently face the difficult challenge of dismantling a heavily state-centered food production system that has historically involved heavy input and consumption subsidies as well as import and export controls. Beyond the wastefulness and inefficiencies associated with such policies, a record of slow per capita consumption growth and persistent food insecurity on a massive scale speaks for itself. Given the realities of local production capacity, Indian policymakers must acknowledge the fact that food self-sufficiency is not a viable option if the nation wishes to achieve true food security in the foreseeable future (Hopper 1999). Democratic accountability renders the process of gradual liberalization inevitable over the long run, but the resistance of those who benefit from wasteful and expensive policies, as well as the reluctance among much of the leadership to return to high levels of cereal imports, has rendered reform difficult over the short run.

LATIN AMERICA

Basic indicators for food supply and demand and annual growth rates for Latin America are presented in Appendix C, Tables C7 and C8.

Macroeconomic Cycling and Recovery

The overarching story of the agricultural sector in Latin America over the last 30 years has been that of a policy-induced macroeconomic cycle, which led to expansion of the agricultural sector during the 1960s and 1970s, retrenchment during the 1980s, and subsequent rapid growth in a low-inflation, liberalizing environment during the 1990s. During the 1960s and 1970s, Latin American countries benefited from the overall strength of the world economy and were able to weather the first oil shock through a combination of high commodity prices and accessible financing. Agricultural production accelerated rapidly during the 1970s, with high worldwide and income-driven domestic demand fueling the expansion of exports and supporting high prices. Nevertheless, the agricultural sector grew slightly slower than the overall economy, reflecting the region's policy emphasis on import-substituting industrialization and basic structural shifts in economies undergoing rapid development.

In the early 1980s, Latin America's unsustainable macroeconomic policies finally brought the region to crisis, as the second oil shock caused declining terms of trade, falling export volumes, and skyrocketing interest rates. The region suffered another major trade shock in 1986, when prices for a number of its major export commodities collapsed worldwide. The macroeconomic crisis affected both private investment and the banking sectors, with inflation rising from 45 percent during the 1970s to 190 percent during the 1980s, and per capita GDP falling 10 percent between 1980 and 1990 (Reca and Díaz-Bonilla 1997; Garrett 1997). The crisis hit the agricultural sector hard throughout the region, particularly through reduced domestic demand. Governments across the region were forced to terminate support programs to heavily subsidized import-substituting sectors of agriculture. Fiscal crisis also reduced governmental capacity to invest in agricultural research and infrastructure development (Díaz-Bonilla 1990). As a result, strong cereal production growth of 3.5 percent between 1967 and 1982 actually turned negative, with −0.1 percent annual growth in cereal production between 1982 and 1990. Per capita cereal production declined from about 262 kilograms per capita in 1982 to 222 kilograms per capita in 1990, then rose to 253 kilograms per capita in 1997.

While the 1980s is often called "the lost decade" for Latin America, crisis did force regional governments to undertake major reforms during the mid- and late 1980s, beginning with initial efforts at economic stabilization through devaluation and cuts in government expenditures and eventually shifting into structural reforms that included liberalization of markets and reduction of trade barriers (Garrett 1997). Reforms led to improvement of external indicators and strong prospects for long-term recovery despite the fact that internal economic and social indicators still reflected the difficulties faced by the region. The agricultural sector benefited tremendously from the reform efforts of the late 1980s, with devaluation of the exchange rate and the advance of trade liberalization removing the policy bias against agriculture and mitigating the negative effects of the overall deterioration of the region's infrastructure and the widespread scarcity of inputs and credit (Díaz-Bonilla 1999). Ultimately, the reforms of the late 1980s and early 1990s—combined with strong investment inflows, rising world prices, and a rapidly liberalizing regional trade system—led to a tremendous rebound in the region's agricultural sector (Díaz-Bonilla 1999).

Agricultural Production

Agricultural production growth was extremely rapid throughout the region during the 1990s, with cereal production growth averaging 3.7 percent annually—the fastest in the world—and meat production growth averaging 4.5 percent annually between 1990 and 1997 (Table 2.22). Latin America's growth in per capita cereal production also led all other developing regions during 1990–97 at a rate of 1.9 percent annually. Maize—the region's dominant crop, representing 59 percent of total cereal production in 1997—led the overall production increase with 5.3 percent annual growth, recovering from production growth of only 0.4 percent annually between 1982 and 1990. In the meat sector, poultry production grew rapidly at 8.6 percent annually, although this growth rate was still slower than the 9.4 percent annual growth achieved in the sector between 1967 and 1982.

While overall agricultural production performance was strong between 1990 and 1997, this period was also one of accelerating diver-

TABLE 2.22 Growth rates of meat production, Latin America, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Argentina	0.6	−0.1	1.0
Brazil	5.4	4.2	6.4
Colombia	3.6	4.5	2.2
Mexico	6.0	−0.3	4.7
Other Latin America	3.5	2.2	3.9
All Latin America	3.7	2.3	4.5

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

gence between major agricultural producing countries and the rest of the countries in the region. Concentration of agricultural production in Latin America within a few economies increased substantially between 1965, when agriculture in the three largest economies accounted for 58 percent of value added in the sector, and 1995, when the corresponding figure was 77 percent (Díaz-Bonilla 1997). On the trade side, trade liberalization, appreciation of the real exchange rate, low world prices during the early 1990s, and the termination of internal support measures led to larger imports in many sectors, while fundamental supply-side restructuring led to a significant increase in exports from other sectors.

Agricultural Demand

On the demand side, Latin American cereal consumption exhibited strong growth in 1967–82 and 1990–97. The economic downturn during the 1980s, however, reduced cereal demand growth to 1.7 percent annually, by far the lowest in the developing world during that period. As shown in Table 2.23, per capita cereal demand also rose significantly. The increasing importance of feed demand as a component of total cereal demand has been a major trend (Table 2.24). All countries in the region except Argentina experienced rapid rises in the feed component of total cereal demand, with the most dramatic increases occurring in Colombia, where the share of total demand accounted for by feed demand rose from 9.2 to 27.5 percent. The anemic performance of Argentina's livestock sector explains its declining share of the feed component.

Regional meat demand has expanded particularly rapidly in the 1990s, rising at a rate of 5.6 percent annually. Dairy demand rose 3.9 percent annually. During 1967–97, per capita meat demand rose from 33 to 53 kilograms per capita, while per capita dairy demand rose from 96 to 125 kilograms per capita. Brazil had a particularly large increase in per capita meat demand, rising from 28 to 69 kilograms per capita; meat demand in Argentina, on the other hand, declined from 103 kilograms per capita in 1967 to 91 kilograms per capita in 1997 (Table 2.25).

TABLE 2.23 Per capita cereal demand, Latin America, 1967 and 1997

	1967		*1997*	
Region/Country	**Total**	**Food**	**Total**	**Food**
		(kilograms/capita)		
Argentina	427.4	133.2	372.4	130.5
Brazil	215.4	97.1	316.2	106.6
Colombia	88.9	71.1	146.3	96.4
Mexico	256.4	165.7	394.6	173.5
Other Latin America	155.4	108.3	189.8	112.7
All Latin America	212.5	113.8	280.9	122.3

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

TABLE 2.24 Share of feed in total cereal demand, Latin America, 1967 and 1997

Region/Country	*1967*	*1997*
	(percent)	
Argentina	49.9	38.1
Brazil	41.3	53.7
Colombia	9.2	27.5
Mexico	22.4	38.9
Other Latin America	20.3	29.4
All Latin America	32.9	41.8

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

Brazil Emerges

Perhaps the biggest story in Latin America over the 30-year period has been Brazil's emergence as the dominant agricultural force on the continent. While Brazil expanded its share of production of cereals from 30 percent in 1967 to 33 percent in 1997 (Table 2.26), it expanded its share of total regional meat production from 27 to 46 percent, mainly through rapid growth in poultry production of 9.8 percent annually and beef production of 4.6 percent annually. Major government subsidy campaigns from the late 1960s to early 1970s and during the crisis period of the mid-1980s helped achieve these gains (Díaz-Bonilla 1999). Brazil's agricultural surge came at the expense of Argentina, whose share of total regional meat production declined from 32 percent in 1967 to 13 percent in 1997. Argentina's beef sector, in particular, grew slowly in 1967–97, with production expanding only 0.3 percent annually, with no growth at all between 1990 and 1997.

TABLE 2.25 Per capita meat demand, Latin America, 1967–97

Region/Country	*1967*	*1982*	*1990*	*1997*
		(kilograms/capita)		
Argentina	103	99	92	91
Brazil	28	39	51	69
Colombia	23	27	33	38
Mexico	25	40	36	46
Other Latin America	26	31	30	36
All Latin America	33	41	43	53

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

Agricultural Trade

Latin America's emergence as a major cereal importer over the last several decades has been a major development in world cereal markets. The region exported 3.1 million tons of cereals in 1967, but by 1982, it was importing 3.5 million tons, and by 1997, a substantial 14.5 million tons. These figures actually disguise the extent to which most countries in the region had become heavily dependent on cereal imports by 1997, since Argentina was a net exporter of 19.7 million tons by that year, much of it to other countries in the region. Argentina's dependence on regional export markets has increased significantly as it has lost market share in the rest of the world, particularly the FSU. For instance, while total wheat exports to Brazil represented less than 10 percent of Argentina's total exports in 1985, that percentage jumped to between 60 and 79 percent from 1993 to 1996. Other important Argentine cereal markets are Chile, Colombia, and Peru, all of which have grown in importance since the mid-1980s (Díaz-Bonilla 1999).

Both Brazil and Mexico had emerged as heavy importers on world cereal markets by 1997, with Brazil importing 9.3 million tons and Mexico 9.5 million tons. Imports into Latin

TABLE 2.26 Share of country's cereals, meat, and roots and tuber production in total Latin America production, 1967 and 1997

Region/Country	Cereals 1967	Cereals 1997	Meat 1967	Meat 1997	Roots and tubers 1967	Roots and tubers 1997
			(percent)			
Argentina	30	27	32	13	5	7
Brazil	30	33	27	46	69	54
Colombia	3	2	5	5	4	10
Mexico	23	23	12	14	1	3
Other Latin America	15	14	23	22	20	27

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

America, excluding Argentina, represented 38 percent of total regional production in 1997. These figures represent a sharp increase in import dependence over a short period of time—a trend spurred in part by low world cereal prices in the second half of the 1980s, acceleration of economic growth and consumption, the liberalization of the region's trade regime, and the appreciation of domestic currencies as capital flows returned to the region (Díaz-Bonilla 1997). Perhaps the most important factor in this rising import dependence, however, has been the growing role of maize as a feed crop (Table 2.27). Overall, the region imported only 1.9 million tons of maize in 1997 because Argentina is a net exporter of 9.9 million tons. Both Mexico and the countries in the Other Latin America category have

TABLE 2.27 Maize production, demand, and net trade, Latin America, 1967 and 1997

Region/Country	Production 1967	Production 1997	Demand 1967	Demand 1997	Feed demand as percent of total 1967	Feed demand as percent of total 1997	Net trade 1967	Net trade 1997
	(million metric tons)				(percent)		(million metric tons)	
Argentina	7.4	15.1	3.4	4.5	87.2	55.9	3.7	9.9
Brazil	12.3	32.1	11.4	33.7	69.1	79.5	0.7	−0.6
Colombia	0.9	0.9	0.9	2.7	10.0	40.3	0.0	−1.8
Mexico	9.0	18.0	7.8	21.5	12.8	21.9	1.0	−4.4
Other Latin America	4.2	7.9	4.6	13.2	33.4	50.6	−0.4	−5.0
All Latin America	33.8	74.1	28.1	75.6	48.0	55.3	5.0	−1.9

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

become heavily dependent on maize imports over the 30-year period, however.

Crop Yields: Long–Term Growth with Regional Disparities

Although the macroeconomic boom-bust cycle examined earlier has contributed greatly to short-term variability in yield growth over the 30-year period, the long-term trend has been sustained productivity growth driven by the adoption of Green Revolution technologies. Use of fertilizer, irrigation, and improved seeds all expanded rapidly. Adoption of new technologies actually progressed most rapidly in the post-reform period, when a less-distorted environment encouraged heightened investment and increasing production scale. In contrast to the somewhat worrying yield signs coming out of Asia during the 1990s, the main story of domestic cereal production between 1990 and 1997 in Latin America is the rapid yield increase of 3.4 percent annually that the region achieved over this period. Nevertheless, recent declines in national research investment and funding for extension agencies—and increased reliance on nongovernmental organizations (NGOs) and the private sector—bodes ill for future technology improvements, particularly for smallholders who are generally ill-served by the private sector (Trigo 1995).

Despite strong trends at the regional level, a parsing of overall yield growth figures reveals that the giants of Latin American cereal production—Argentina and Brazil—have been the main sources of yield increases, with annual yield growth rates of 4.9 percent and 4.2 percent, respectively, during 1990–97 (Table 2.28). Medium and large mechanized farms increasingly dominate agricultural production in Argentina and Brazil (mainly Southern Brazil), bringing with them strong economies of scale and rapidly increasing use of agrochemicals and monocultures (Garrett 1997). For instance, fertilizer use in wheat production in Argentina rose from 25 percent of area planted in 1991 to 64 percent of area planted by 1996 (Díaz-Bonilla 1999). In Argentina and Brazil, maize has been the driving force behind high yield growth rates, averaging 5.0 percent annually in Argentina and 4.3 percent in Brazil during 1990–97. Adoption of hybrid seeds and intensive use of chemical inputs help explain the increase of yields in these countries during the 1990s, although the long-term effects of the expanding scale and intensification of agricultural production may be less positive than recent yield growth would indicate, with soil erosion, declining water quality, and disease resistance becoming increasingly problematic (Garrett 1997).

The technological transformations that have boosted Brazilian and Argentine agricultural productivity do not seem to have dramatically affected other countries in the region so far. All other countries or country groupings in the Latin American region were below the developing world average of 1.9 percent

TABLE 2.28 Growth rates of cereal yields, Latin America, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Argentina	3.2	–0.3	4.9
Brazil	1.2	2.2	4.2
Colombia	3.3	0.3	1.6
Mexico	3.5	0.4	1.6
Other Latin America	2.2	2.3	1.0
All Latin America	2.5	0.8	3.4
Developed world	1.7	2.2	1.9
Developing world	2.9	2.0	1.9

Source: Based on FAOSTAT data (FAO 2000a).
Note: The four countries listed have the largest agricultural sectors in Latin America. The rest of the countries are combined under Other Latin America.

annual yield growth between 1990 and 1997, although all exceeded 1.0 percent. Historically, the period 1967–82 was one of strong growth in Latin American yields, with Argentina, Colombia, and Mexico all experiencing yield growth of more than 3 percent per year. However, performance was mixed in 1982–90, with yields stagnating in much of the region and turning slightly negative in Argentina.

Oils and Meals

Oils and meals, particularly meals, emerged as an important agricultural export earner in Latin America between 1967 and 1997. Argentina and Brazil dominated the sector, with Argentina increasing its net meal exports from 1.0 million tons in 1967 to 10.9 million tons in 1997, and Brazil from 0.4 million tons in 1967 to 10.5 million tons in 1997. Brazil and Mexico also became world players in soybean markets, with Brazil increasing its net exports to 6.0 million tons in 1997 from only 0.2 million tons in 1967, while Mexico became a net importer of 3.3 million tons of soybeans. Argentina also became a moderate player in oils markets, exporting a net of 3.5 million tons in 1997. Latin America began to produce oils and meals during the 1940s, when export of olive oil from Europe was embargoed, but it did not achieve extraordinary success until Argentina and Brazil widely adopted soybean production in the 1960s. By 1997, soybean production had reached 27.1 million tons in Brazil and 14.1 million tons in Argentina. Strong export demand, development of a system for supplying technical inputs such as seeds and agrochemicals, and a vibrant entrepreneurial class combined with an improving macroeconomic policy environment all contributed to their success (Díaz-Bonilla 1997). Expanding soybean production has not been without its share of problems: in the Argentine pampean region, the replacement of traditional extensive farming with intensive production systems led to soil compaction and erosion (Ekboir and Parellada 2000).

The Smallholder Challenge

In many ways, the strong performance of Latin American agriculture as a whole in the 1990s obscures a widening of the gap between the agricultural superpowers of the region and other countries continuing to struggle with fairly slow yield growth rates. One of the reasons behind this trend is undoubtedly the continuing predominance of smallholders throughout the hillsides of Central America, Central and Southern Mexico, and Northeast Brazil. These smallholders tend to diversify production to reduce risks and income variation, but they lose the benefits of specialization and scale economies as a result (Garrett 1997). Smallholder production systems are becoming increasingly dependent on their ability to adopt new technologies and participate in labor and credit groups that enable them to take advantage of economies of scale (Díaz-Bonilla 1999). An important question regarding future agricultural development in Latin America is whether smallholders can enhance their productive efficiency in order to compete with large-scale agriculture, while maintaining the integrity of the natural resource base. Alternatively, large numbers of smallholders may have to be smoothly integrated into the nonagricultural sectors of the economy (Garrett 1997).

SUB-SAHARAN AFRICA

Basic indicators for food supply and demand and annual growth rates for Sub-Saharan Africa are given in Appendix C, Tables C.9 and C.10.

Introduction

Sub-Saharan Africa's agricultural performance during 1967–97 was the worst in the developing world, and the region now finds itself in much the same position as India in the 1960s, with high population and food demand growth exceeding modest production growth (Byerlee and Eicher 1997). The reasons behind Africa's poor agricultural performance are myriad. The continent has been afflicted with the triple curse of poor resource endowments (including poor land quality, large landlocked areas, endemic livestock disease, and human diseases), a colonial legacy of extraction and exploitation, and a policy environment that consistently undermined agriculture and the institutions that served it (World Bank 2000a). In addition to problems of climate and geography, the pernicious influence of years of exploitation and colonialism lingered into the post-colonial period, contributing to underdevelopment of agriculture. These factors have been intensified in recent years by adverse agroclimatic conditions including significant droughts in 1983, 1984, and 1992. Nevertheless, the blame for lagging agricultural sector performance rests mainly with poor development strategies and policy choices, including the overall unwillingness of many national leaders to recognize the importance of agriculture to overall economic growth (Abdulai and Hazell 1995).

Despite common problems across the continent, it is probably useful to disaggregate Sub-Saharan African production systems into land-constrained systems (prevalent in Eastern and Southern Africa as well as humid parts of Western Africa) and labor-constrained systems (mainly prevalent in West and Central Africa). In the land-constrained systems, primary impediments to agricultural growth have historically been structural, with high transport costs, underfinancing of research systems, and lack of support for smallholder agriculture. In the labor-constrained systems, the challenge has traditionally been to find technologies and a policy environment to permit increases in labor productivity, mainly through mechanization (Delgado 1996).

Post-Independence Agricultural Policy and Recent Reforms

In the 1960s, 1970s, and early 1980s, most African governments attempted to accelerate the process of industrial development and to ensure cheap urban food prices by taxing agriculture through measures including overvalued exchange rates and price-depressing marketing board interventions in food markets (Kherallah et al. 2000). However, unlike East Asian governments, which invested consistently and generously in smallholder agricultural and rural development even while they taxed it heavily, African governments have tended to invest little in the sector, with subsidies for fertilizer and credit generally benefiting entrenched interests—usually larger, export-oriented farmers—capable of exercising political power (Kherallah et al. 2000; World Bank 2000a; Killick 1994). While governments in East and South Asia encouraged the adoption of productivity-enhancing technologies through significant investments in the rural infrastructure necessary to enable the commercialization of smallholder agriculture, African road and communications infrastructures remain undeveloped and inadequate. The high transfer costs, limited information, and general fragmentation that resulted led Delgado (1996) to the conclusion that much of the rural economy in Sub-Saharan Africa is probably demand constrained, meaning that even if macroeconomic and trade reforms reduced price distortions, supply might not increase for a long time without strong locally generated demand. Severe underutilization of resources and low productivity characterize demand-constrained local economies.

Input markets have been inefficient and property rights weak throughout the region since independence, thus limiting long-term entrepreneurial planning and undermining both the will and ability of farmers to invest in the profitability of their land. Low-intensity agriculture has been the norm. Fertilizer application rates in 1997 were only 8 kilograms per hectare of arable and permanent cropland, compared with the Asian total of 135 kilograms per capita, although these figures mask regional differences and the far greater prevalence of irrigated systems in Asia. Fertilizer policy in Sub-Saharan Africa has been disastrous overall, with costly subsidies distorting markets during the 1970s and 1980s (World Bank 2000a).

Economic crises during the 1980s forced many Sub-Saharan African countries to undertake long-run structural adjustment programs embodying a wide range of market liberalization and public sector reforms, including major agricultural sector reforms. Guided by a belief that the introduction of market forces to the agricultural sector could jump-start growth, reforms generally focused on liberalizing input and output prices, removing regulatory controls on input and output markets, and restructuring public enterprises (including the elimination of the regulatory functions of marketing boards). Reforms to food crop markets were more comprehensive than reforms to export crop markets in Central and Western Africa, but actual reforms in Southern and Eastern Africa have been limited, with state trading and price bands remaining in effect in a number of countries, including Kenya, Malawi, and Zimbabwe (Kherallah et al. 2000). Input market reforms have been significantly less comprehensive throughout the region, as state-owned enterprises continue to dominate fertilizer, seed, and agrochemical markets, despite the penetration of some multinationals and private traders. All reform efforts have been subject to backsliding and the resistance of entrenched groups that do not wish to lose their access to rents and privileges. Most regional governments—generally lacking strong political legitimacy—have been unwilling or unable to obtain strong indigenous support for major reform efforts, with donor demands and prescriptions tending to dominate policymaking (Kherallah et al. 2000).

Cereals

Cereal Production. Despite the many problems faced by agriculture in Sub-Saharan Africa, the 30-year period has seen a certain amount of success on the cereal production side. Cereal production more than doubled from 31 million tons in 1967 to 69 million tons in 1997, rising a brisk 4.2 percent annually in 1982–90 and 2.9 percent in 1990–97. However, rapid population growth actually led to declining per capita cereal production, which fell from 128 kilograms in 1967 to 124 kilograms in 1997 (Appendix Table C.9). Nevertheless, production growth was strong during 1990–97 in Northern Sub-Saharan Africa (rising 4.9 percent annually) (Table 2.29). Production growth rates slowed moderately in Central and Western Sub-Saharan Africa, increased slightly in Southern Sub-Saharan Africa, and dropped sharply in Eastern Sub-Saharan Africa (Table 2.29).

While conflict has afflicted a number of countries in both Northern Sub-Saharan Africa and Central and Western Sub-Saharan Africa during

TABLE 2.29 Growth rates of cereal production, Sub-Saharan Africa, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Northern	2.3	2.0	4.9
Central and Western	1.9	3.4	3.0
Eastern	3.0	2.8	0.1
Southern	0.8	1.9	2.0
Nigeria	1.1	9.9	2.7
All Sub-Saharan Africa	1.8	4.2	2.9

Source: Based on FAOSTAT data (FAO 2000a).

most of the 1990s, strong production growth during this period may be an indication that market reforms are finally having a positive effect on production performance. Devaluation in Western Africa has aided local food markets by boosting prices for the imported food that local produce competes against. There is also some indication that increased use of fertilizers by cash crop producers has spilled over onto food crop production. However, it is far from certain that the fuller implementation of reforms in Central and Western Sub-Saharan Africa has boosted their performance vis-à-vis the rest of the region; while Jaeger (1992) and Faini (1992) note a positive cereal production response to adjustment policies, Seppala (1997) concludes that marketing reforms had no effect on food production. According to Seppala (1997), food production performance varied greatly between countries with similar amounts of government intervention, with differences mainly due to varying levels of food self-sufficiency, crop choice, and drought prevalence. In any event, as was noted earlier in the discussion of demand constraints on rural producers, most observers agree that structural and institutional constraints continue to exert a severe drag on agricultural performance, despite some degree of market liberalization (Kherallah et al. 2000).

TABLE 2.30 Cereal yields in Sub-Saharan Africa as a percent of cereal yields in developing countries, 1967–97

Cereal	*1967*	*1982*	*1990*	*1997*
			(percent)	
Maize	69.4	56.0	50.0	44.0
Wheat	89.4	75.9	69.6	62.3
Other coarse grains	80.5	76.2	71.3	68.5
Rice	64.4	47.3	48.2	43.1

Source: Based on FAOSTAT data (FAO 2000a).

Cereal Yields. Unlike other regions, where yield and production performance tend to closely track each other, Sub-Saharan Africa has had occasionally strong production performance accompanied by dismal yield performance (see Appendix B, Table B.5). Cereal yields have fallen steadily behind those in other developing regions, partly because African yields have stagnated and partly because cereal yields have grown rapidly in regions that have successfully adopted Green Revolution technologies on a large scale (Table 2.30). However, maize and other grains—the region's two main cereal groups—were not targeted by the Green Revolution. Therefore, the lagging performance of these crops can mainly be attributed to Sub-Saharan Africa's poor agricultural performance. In fact, cereal yield growth rates in the region have lagged well behind those of every other developing region in all three periods, and they were even negative during 1982–90 (–0.2 percent annually). The 1990–97 period has not been much better, with yield growth of only 0.3 percent annually. Market reforms were expected to boost productivity by increasing the availability of modern inputs and encouraging their use, but the limited evidence of productivity improvements in the post-reform period mainly comes from countries that heavily taxed agricultural production in the pre-reform period (mainly West Africa). In many other countries—particularly in Eastern and Southern Africa—subsidy reductions in the absence of credit markets have both limited farmer access to inputs such as fertilizer and encouraged the use of scarce inputs on export crops. Market reforms have thus failed to have the dramatic impact on productivity expected of them (Kherallah et al. 2000).

Maize. Maize shows the variability in performance that characterizes production systems in

TABLE 2.31 Growth rates of maize yields, Sub-Saharan Africa, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Northern	3.1	−0.1	0.4
Central and Western	0.4	2.2	1.1
Southern	0.1	−0.2	1.9
Eastern	3.0	0.0	−0.9
Nigeria	2.7	−1.1	1.0
All Sub-Saharan Africa	1.4	0.4	0.8

Source: Based on FAOSTAT data (FAO 2000a).

Sub-Saharan Africa (Table 2.31). Because maize is a politically important crop, particularly in Southern and Eastern Africa (and increasingly in parts of Western Africa as well), it has been the focus of a series of government initiatives to raise productivity through the adoption of seed-fertilizer technology, input and credit subsidies, price supports, and investments in marketing and infrastructure. Governments in Eastern and Southern Africa have devoted a considerable share of their miniscule agricultural research budgets to adopting technological packages originally developed for commercial farmers to the needs of smallholders (Byerlee and Eicher 1997).

Efforts to improve maize technologies have met with some success, as improved maize varieties are now grown on approximately 40 percent of maize area in Sub-Saharan Africa, although fertilizer use remains low even on improved varieties (Byerlee and Eicher 1997). Varieties of maize responsive to increased use of chemical fertilizers, herbicides, and pesticides have particularly benefited highland areas (Delgado 1996). Despite these technological developments, however, maize yields region-wide declined from 69 percent of the developing world average in 1967 to 44 percent in 1997. Central and Western Africa have had the most consistent maize yield growth rates, even though maize in these regions has been the least affected by new technologies. Southern Africa had the strongest maize yield growth during 1990–97 at 1.9 percent annually, rebounding from negative growth of −0.2 percent during the conflict-ridden period between 1982 and 1990. The worst maize yield performers in the 1990s have been Northern and Eastern Sub-Saharan Africa: yields in Eastern Sub-Saharan Africa actually declined 0.9 percent annually between 1990 and 1997, while yields in Northern Sub-Saharan Africa rose only 0.4 percent annually. The miserable performance in these regions between 1982 and 1997 stands in stark contrast to the impressive maize yield growth rates of approximately 3 percent annually that they achieved between 1967 and 1982. Nigeria has been somewhere in between these extremes, with severe negative growth in maize yields of −1.1 percent between 1982 and 1990, but with growth rebounding somewhat annually between 1990 and 1997.

The remarkable disjuncture between research effort and technological diffusion on the one hand and yield performance on the other indicates that technological development has not been the main factor behind short-term maize yield trends. This cautionary tale serves as a warning about the perils of relying on magic bullets to raise African cereal yields, especially Green Revolution technology that has largely succeeded in an Asian setting. Byerlee and Eicher blame the sluggish yield response on three main factors: first, the lack of technical progress in major producing regions of Ethiopia and Tanzania; second, the shift of much production from high-yielding, large commercial farms to low-yielding, small-scale farms;[10] and third, limited adoption of complementary inputs such as fertilizer and other soil fertility–related practices to accompany new seed varieties (Byerlee and Eicher 1997). These factors have all played out in an environment characterized by frequent intense conflicts, poorly designed and implemented policies, and weak institutional arrangements. Besides having an independent effect on yields, the environment also has a close relationship with technological development: technological progress in large maize producers such as Ethiopia, Tanzania, and Zaire has been quite slow precisely because these countries have either been racked by violence or experienced severe institutional decline.

Other Coarse Grains. Other coarse grains[11]—a major food source in Northern Sub-Saharan Africa, where they represented 70 percent of total cereal production, and Nigeria, 63 percent in 1997—had particularly dismal yield growth of −1.6 percent annually across Sub-Saharan Africa during 1982–90 (Table 2.32). This overall poor performance was driven by declines in other coarse grain yields of −5.5 percent annually in Nigeria, from 1,598 kilograms per hectare in 1982 to 1,014 kilograms per hectare in 1990.[12] Yields did turn around between 1990 and 1997, rising 1 percent annually in both Nigeria and Northern Sub-Saharan Africa. Nevertheless, other coarse grain yields in Sub-Saharan Africa fell from 80 percent of the developing world average in 1967 to 69 percent by 1997.

Cereal Trade. Cereal imports into Sub-Saharan Africa have remained low during the last three decades because of persistent poverty and the low import capacity of the region. Thus, despite widespread and persistent malnutrition, the region only increased net cereal imports from 1.5 million tons in 1967 to 12.0 million tons in 1997, with Central and Western Africa accounting for 36 percent of all cereal imports in 1997 (Table 2.33). One key component of African cereal import patterns is the dominance of wheat, historically purchased cheaply through overvalued exchange rates to support volatile and growing urban populations and thus undermining domestic prices and production. Sub-Saharan Africa imported a net 6.5 million tons

TABLE 2.32 Growth rates of production and yields of other coarse grains, Sub-Saharan Africa, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Production			
Northern	3.1	−0.1	0.4
Central	0.4	2.2	1.1
Southern	0.1	−0.2	1.9
Eastern	3.0	0.0	−0.9
Nigeria	2.7	−1.1	1.0
All Sub-Saharan Africa	1.4	0.4	0.8
Yields			
Northern	0.0	−1.7	1.0
Central	1.0	0.7	0.6
Southern	−1.7	0.0	0.5
Eastern	2.0	−0.6	−0.2
Nigeria	6.6	−5.5	1.0
All Sub-Saharan Africa	1.7	−1.6	0.8

Source: Based on FAOSTAT data (FAO 2000a).

TABLE 2.33 Net cereal trade, Sub-Saharan Africa, 1967–97

Region/Country	*1967*	*1982*	*1990*	*1997*
		(million metric tons)		
Northern	−0.3	−1.4	−2.3	−2.2
Central and Western	−1.0	−2.8	−3.5	−4.3
Eastern	0.0	−0.5	−0.3	−1.3
Southern	0.0	−1.4	−1.4	−2.2
Nigeria	−0.2	−2.1	−0.6	−1.9
All Sub-Saharan Africa	−1.5	−8.3	−8.1	−12.0

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

of wheat and 3.5 million tons of rice in 1997. Another important component of cereal trade with ramifications for food security is the fact that both Eastern and Southern Africa moved from positions of maize self-sufficiency to net import status during the period, although in both cases these imports amount to less than 1 million tons (Byerlee and Eicher 1997).

TABLE 2.34 Roots and tubers production and yields, Sub-Saharan Africa, 1997

Region/Country	*1997*	*1997*
	(million metric tons)	*(kilograms/ hectare)*
Northern	5.5	6,217
Central and Western	45.4	7,611
Eastern	16.0	6,107
Southern	14.7	5,991
Nigeria	58.3	9,981
All Sub-Saharan Africa	139.9	7,876
Developing world	461.6	11,777

Source: Based on FAOSTAT data (FAO 2000a).

Roots and Tubers

Roots and tubers are a major contributor to food security in Sub-Saharan Africa, particularly in years of bad cereal harvests. A recent study found that the most important reasons cited by Sub-Saharan African farmers for increasing production of roots and tubers were famine, hunger, and drought; the crop's low input requirements mesh well with regional resource endowments, a shortage of chemical inputs and organic products, and limited irrigation (Scott, Rosegrant, and Ringler 2000). Per capita demand for roots and tubers for food in Sub-Saharan Africa was 163 kilograms in 1997, or almost three times higher than the developing world average. Cassava was by far the dominant roots and tubers crop with per capita consumption of 119 kilograms in 1997. Roots and tubers consumption is concentrated in Central and Western Africa and Nigeria, where demand in 1997 averaged 264 and 216 kilograms per capita, respectively. Production averaged 45 million tons in the Central and Western region and 58 million tons in Nigeria in 1997 (Table 2.34) Despite the importance of roots and tubers to food security and the prevalence of relatively favorable agro-climatic conditions throughout much of the region, roots and tubers yields in all countries and subregions in 1997 were lower than the developing world average of 11,777 kilograms per hectare (Table 2.34).

Regional roots and tubers production growth has been relatively high over the past 30 years, averaging 4.6 percent in 1982–90 and 3.9 percent in 1990–97 (Table 2.35). Higher prices, increased farmer access, and rising commercialization have all played a role in expanding production throughout the region. Production growth has been particularly rapid in Nigeria, averaging 9.9 percent in 1982–90 and 7.6 percent in 1990–97. According to Ouraga-Djoussou and Bokanga (1998), a number of factors have played a role in the striking increase in the importance of roots and tubers to Nigerian diets between 1982 and 1997, including a ban on cereal imports between 1987 and 1990, the multiple uses of the crop as a contributor to food security, and the treatment of cassava as a high-value good by a rapidly expanding urban population. Production has kept up with rising demand through incentives provided by the high profitability of commercial sales of processed and fresh roots, technical improvements in processing, and the introduction of high-yielding varieties (Scott, Rosegrant, and Ringler 2000).

Outside of Nigeria, the yield performance of roots and tubers in the region has been relatively unimpressive, except for Southern Africa, where yields increased at an annual rate of 2.9 percent in 1990–97. Nutrient-poor soil, low irrigation

TABLE 2.35 Growth rates of roots and tubers, Sub-Saharan Africa, 1967–97

	Production			Yield			Area		
Region/Country	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*
					(percent/year)				
Northern	4.4	1.5	3.6	2.7	0.5	0.5	1.6	1.0	3.1
Central and Western	1.8	3.8	2.3	0.3	2.0	0.6	1.5	1.7	1.7
Eastern	5.0	1.2	−1.7	2.4	−1.4	−2.3	2.6	2.7	0.6
Southern	1.8	2.2	4.8	0.7	0.7	2.9	1.1	1.5	1.8
Nigeria	−0.6	9.9	7.6	−1.0	4.2	−0.6	0.5	5.5	8.1
All Sub-Saharan Africa	1.8	4.6	3.9	0.4	1.9	0.6	1.4	2.6	3.4

Source: Based on FAOSTAT data (FAO 2000a).

coverage, and weak infrastructure have all hampered yield performance regionwide. Sub-Saharan African governments have also neglected research into the challenges posed by roots and tubers production, preferring to expend scarce research dollars on cash crop production (Scott, Rosegrant, and Ringler 2000).

Area Trends

Given the generally dismal yield performance for both cereals and roots and tubers, area expansion has had to account for most production growth in Sub-Saharan Africa over the last 30 years. Cereal area expanded by 31 million hectares, while roots and tubers area expanded by 8 million hectares (Table 2.36). Because population growth was so high during this period, averaging 2.8 percent annually, per capita cereal area harvested declined from 0.17 hectares per capita in 1967 to 0.13 hectares per capita in 1997. However, the slowing of population growth and the 3.4 percent expansion of area combined to keep per capita cereal area harvested constant during 1990–97.

Such high levels of area expansion are clearly unsustainable over the long run, and poor yield performance in most countries and country groupings may reflect in part the extension of agricultural production systems into increasingly less favored areas. Already, efforts to expand cultivation onto previously unused land are running up against some harsh realities of the continent: almost 50 percent of all land is too arid to sustain direct rainfed cultivation and 60 percent is subject to drought (World Bank 2000a). The trend of area expansion driving overall cereal production growth seems to have slowed slightly between 1990 and 1997, with the rate of area expansion declining from 4.4 percent annually in 1982–90 to 2.5 percent annually in 1990–97 (Table 2.36). The slowing of area expansion in Nigeria from 14.5 percent to 2.2 percent in the latter half of the period accounts for much of this decline.

Conclusion

Ultimately, area expansion cannot be the solution to Africa's agricultural production problems. Yields must grow at relatively high rates, and smallholders must move more rapidly from subsistence to commercial production. The last three decades have left a legacy of increasing degradation and desertification, with insuffi-

TABLE 2.36 Cereal and roots and tubers area, Sub-Saharan Africa, 1967–97

Region/Country	Total area				Annual growth rate		
	1967	*1982*	*1990*	*1997*	*1967–82*	*1982–90*	*1990–97*
	(million hectares)				*(percent/year)*		
Cereals area							
Northern	13.4	17.8	22.1	29.2	1.9	2.7	4.0
Central and Western	6.3	7.9	9.0	10.2	1.4	1.7	1.7
Eastern	4.8	5.2	6.4	6.8	0.5	2.6	0.9
Southern	6.8	7.5	8.4	9.0	0.7	1.5	0.9
Nigeria	10.5	5.2	15.5	18.1	−4.5	14.5	2.2
All Sub-Saharan Africa	41.8	43.6	61.4	73.1	0.3	4.4	2.5
Roots and tubers area							
Northern	0.5	0.7	0.7	0.9	1.6	1.0	3.1
Central and Western	3.7	4.6	5.3	6.0	1.5	1.7	1.7
Eastern	1.4	2.0	2.5	2.6	2.5	2.7	0.6
Southern	1.6	1.9	2.2	2.5	1.1	1.5	1.8
Nigeria	2.1	2.2	3.4	5.8	0.4	5.5	8.1
All Sub-Saharan Africa	9.3	11.5	14.1	17.8	1.4	2.6	3.4

Source: Based on FAOSTAT data (FAO 2000a).

cient investment in soil improvement causing severe nutrient depletion. Poor policies and institutional failures have removed the incentive for farmers to care for the land and to invest long-term capital in yield-boosting technologies (World Bank 2000a). Despite the attention given to Asia over the last decade, the loss of the natural resource base in Sub-Saharan Africa is of far greater concern because of the seeming inability of governments in the region to address the growing problems they face. Overall, the structural and macroeconomic reforms of the 1980s and 1990s have been a disappointment as far as food production is concerned, and greater agricultural research expenditures combined with far-reaching reforms of both infrastructure and institutions will be necessary to jumpstart production in the future.

WEST ASIA AND NORTH AFRICA

Basic indicators for food supply and demand and annual growth rates for WANA are presented in Appendix C, Tables C.11 and C.12.

Introduction

The WANA region is highly disparate, with the 5 percent of the region's population who live in oil-exporting nations enjoying far higher per capita incomes than everyone else: outside of these oases of wealth, poverty is high and widespread, particularly in low-rainfall areas. All countries in the region have faced severe challenges in expanding their agricultural sectors over the 30-year period, including a limited resource base of arable land and water, low and erratic rainfall with frequent drought, growing populations, low productivity growth, and increased rural-urban migration (Oram et al.

1998). Governments have attempted to overcome long-term impediments to higher agricultural production mainly through a set of distortional policies that provided for significant production growth at the expense of deterioration of the natural resource base. Policies to expand cereal and meat production have included cheap fuel and credit for machinery, high producer and consumer subsidies, and high tariffs on imported food products. While the negative effects of these policies on the environment have become increasingly apparent, economic reform has progressed very slowly over the past 20 years because of the perceived need to keep agricultural import dependence at manageable levels (Karshenas 1999).

Cereals

Cereal Production. WANA's agricultural growth performance over the last three decades has been impressive, although substantial investments made by oil-producing states flush with petrodollars during the 1980s skewed overall regional growth upward. For example, Saudi Arabia has expanded its cereal production substantially through massive investments in irrigation, using nonrenewable water supplies and heavy application of subsidized fertilizers. Because of the economic unsuitability of these projects, costs of production in Saudi Arabia are several times higher than world prices, even without counting the scarcity price of water or subsidy costs. Partly as a result of these unsustainable policies, cereal production performance was particularly strong in the Other WANA country group[13] and in Egypt between 1982 and 1990 (Table 2.37). Growth slowed in Other WANA between 1990 and 1997, but remained strong in Egypt. Iraq has been a major drag on the production performance of Other WANA, with agricultural growth depressed by constraints linked to the imposition of sanctions. The Saudi Arabian agricultural sector has also performed poorly because farm subsidies were significantly reduced in the 1990s (Nordblom and Shomo 1995).

Weather conditions in the region as a whole were particularly variable during the 1990s, leading to sharp fluctuations in year-to-year production. In the 1990s, Algeria, Egypt, Morocco, the Syrian Republic, Tunisia, and Turkey all adopted aggressive national policies to expand irrigated area and reduce dependence on highly variable rainfed agriculture. Irrigated agriculture does play an important role throughout the region, and links between irrigated systems, rangelands, and rainfed farming that operate through the movement of food, feed, livestock, and labor are essential

TABLE 2.37 Growth rates of cereal production and yields, West Asia/North Africa, 1967–97

	Production			Yields		
Region/Country	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*
			(percent/year)			
Egypt	1.5	5.3	4.6	1.2	3.7	2.4
Turkey	3.1	1.4	1.2	2.7	1.1	0.9
Other West Asia/North Africa	1.5	5.8	1.8	1.0	3.6	2.6
All West Asia/North Africa	2.2	3.8	2.1	1.7	2.3	2.4

Source: Based on FAOSTAT data (FAO 2000a).

to overall agricultural development (Nordblom and Shomo 1995).

Cereal Yields. Between 1982 and 1990, production not only grew rapidly because of rapid area expansion, but also because yield growth rates were strong. Between 1990 and 1997, yield growth rates continued to rise in Egypt and Other WANA but lagged significantly in Turkey. Despite this strong yield growth, however, the 1,973 kilograms per hectare average cereal yield in WANA in 1997 remained well below the developing world average of 2,312 kilograms per hectare. Reasons for continued low yields include the aridity of the climate and high variability of precipitation, risk-aversion to adoption of new cultivars and fertilizer application, and continuing resource degradation (Oram et al. 1998). In addition, WANA generally possesses very low stocks of human capital in comparison with other countries at similar income levels: for example, while the region has a similar land-to-labor ratio as Latin America, labor productivity was significantly higher in Latin America (Karshenas 1999).

Cereal Area. The fact that production in Other WANA slowed significantly between 1990 and 1997 despite strong yield growth indicates that these countries have reached the effective limits of unutilized area for cereal and livestock production. The problem is exacerbated by extensive environmental degradation that is taking its toll on existing crop- and livestock-producing areas. Wind and water erosion and seed bank loss have been particularly severe on the steppes, as mechanized production of cereals—particularly barley for feed uses—has expanded onto increasingly marginal land. Rapid urbanization and the lack of appropriate technologies for rangeland management have also taken their toll. Population pressures and incentives to expand cereal production have led to overgrazing and cultivation of marginal areas, monoculture of annual crops, reduced soil fertility, and significant erosion. Additionally, overpumping of groundwater in many WANA countries has led to significant soil degradation through salinization of irrigation water and lowered water tables (Taimeh 1999).

WANA's extremely high rates of population growth over the last three decades have created many problems for the region and led to rapid declines in per capita cereal production throughout the period.[14] Massive declines in per capita harvested area were the main force behind production declines. Continued decreases in per capita area negatively affected per capita production levels even as yield growth rates seemed to be gradually increasing (Dyson 1996).

Cereal Demand. Cereal demand growth was actually most rapid regionwide between 1967 and 1982 (Table 2.38). Other WANA had a particularly rapid decline in annual demand growth, falling from 5.6 percent in 1982–90 to 2.3 percent in 1990–97. Cereal demand growth rates also declined in Turkey, while remaining strong in Egypt throughout the period. Declining population growth rates—falling to 2.2 percent annually between 1990 and 1997—saturation of demand, and declining oil revenues helped slow the overall growth of cereal demand in WANA during the 1990s (FAO 2000b).

Cereal Trade. WANA had net cereal imports of 5.9 million tons in 1967, placing it toward the middle of the pack of developing regions in terms of cereal import dependence. By 1997, exploding domestic demand had driven WANA's net imports to 44.3 million tons, or 52 percent of domestic production. Net cereal imports rose from 3.8 million tons in 1967 in Other WANA to 33.8 million tons by 1997 (Table 2.39). Egypt also had dramatic import

TABLE 2.38 Growth rates of cereal demand, West Asia/North Africa, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Egypt	4.1	3.9	3.5
Turkey	3.0	1.4	1.8
Other West Asia/North Africa	5.2	5.6	2.3
All West Asia/North Africa	4.3	4.1	2.4

Source: Based on FAOSTAT data (FAO 2000a).

growth. Despite the slowing of demand growth, net imports continued to increase in the 1990s. It is interesting to note that the growth rate of WANA's imports was not strongly related to the performance of the agricultural sector. Cereal imports increased most rapidly during 1982–90, a period when agricultural production, driven by oil-financed investments, was growing at a rate of 3.8 percent per year (although population growth was also rapid). This period was extraordinary in that a massive influx of petrodollars permitted both large-scale development of local production capacity and large quantities of cereal imports.

Livestock Sector

Cultural constraints on meat consumption as well as poverty historically have kept meat consumption to low levels in WANA. Total meat demand has actually grown substantially in the region over the last 30 years, but rapid population growth has been responsible for much of this increase. Fastest growth in total demand occurred in 1967–82, averaging 6.3 percent for the region as a whole, slowing to 3.3 percent thereafter (Table 2.40). Turkey and Egypt followed somewhat different paths, with meat demand in Turkey growing more rapidly during

TABLE 2.39 Net cereal trade, West Asia/North Africa, 1967–97

Region/Country	*1967*	*1982*	*1990*	*1997*
		(million metric tons)		
Egypt	−2.0	−7.1	−7.9	−9.4
Turkey	−0.1	0.8	−0.5	−1.1
Other West Asia/North Africa	−3.8	−22.6	−30.3	−33.8
All West Asia/North Africa	−5.9	−28.9	−38.7	−44.3

Source: Based on FAOSTAT data (FAO 2000a).
Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE 2.40 Growth rates of meat demand, West Asia/North Africa, 1967–97

Region/Country	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Egypt	4.8	3.0	6.8
Turkey	2.8	6.3	0.7
Other West Asia/North Africa	7.9	3.0	3.2
All West Asia/North Africa	6.3	3.5	3.3

Source: Based on FAOSTAT data (FAO 2000a).

1982–90, whereas it did not take off in Egypt until 1990–97. Per capita meat demand regionwide increased from 12.1 kilograms per capita in 1967 to 21.0 kilograms per capita in 1997. In general, growth has slowed significantly since 1967–82.

Conclusion

The problems confronting agricultural production in WANA are certainly substantial, but it would be a mistake to see them as inevitable. Poor government policies have worsened a situation already characterized by unfavorable initial endowments of land and water. Policies encouraging misuse of rangeland areas and the extension of crop production onto fragile rainfed soils have been guided by a desire to improve food security, but they will destroy the natural resource base over the long run. A skewed system of land distribution and insecure property rights are also important impediments to long-term sustainable agricultural growth (Oram et al. 1998). While governments in the region have taken some steps to improve agricultural policymaking over the last two decades, the region's high level of import dependence renders further major reform politically problematic. The backsliding of economic reform efforts in Libya and Turkey during the 1990s is evidence that the success of ongoing reform is in no way guaranteed.

3

THE IMPACT MODEL

IFPRI's IMPACT model offers a methodology for analyzing alternative scenarios for global food demand, supply, and trade. IMPACT covers 36 countries and regions, accounting for virtually all of the world's food production and consumption, and 16 commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes, and meals. (For a complete list of countries and commodities, see Appendix A.) IMPACT represents a competitive agricultural market for crops and livestock. It is specified as a set of country or regional submodels, within each of which supply, demand, and prices for agricultural commodities are determined. The country and regional agricultural submodels are linked through trade, a specification that highlights the interdependence of countries and commodities in global agricultural markets. The model uses a system of supply and demand elasticities, incorporated into a series of linear and nonlinear equations, to approximate the underlying production and demand functions. World agricultural commodity prices are determined annually at levels that clear international markets. Demand is a function of prices, income, and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. Its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnological and transgenic breeding contribute to the estimate of future productivity growth. Other sources of estimated growth include private sector agricultural research and development, agricultural extension and education, roads, and irrigation.

In order to examine the effects on food security, the percentage and number of malnourished preschool children (0 to 5 years old) are projected for developing countries. The projected numbers of malnourished children are derived from the estimated relationship between the percentage of malnourished children and average per capita calorie consumption, the percentage of females with access to secondary education, the quality of maternal and child care (proxied by the status of women relative to men as captured by the ratio of female to male life expectancy at birth), and health and sanitation (proxied by the percentage of the population with access to treated surface water or untreated but uncontaminated water from another source).

A wide range of factors with potentially significant effects on future developments in the world food situation can be modeled based on IMPACT. They include population and income growth, the rate of growth in crop and livestock yield and production, feed ratios for livestock, agricultural research, irrigation and other investment, price policies for commodities, and elasticities of supply and demand. For any specification of these underlying factors, IMPACT generates projections for crop area; yield; production; demand by food, feed, and other uses; prices; and trade; and for livestock numbers, yield, production, demand, prices, and trade. (Supplementary data for each crop and livestock category for 1997 and 2020 are presented in Appendix D, Tables D.1 to D.19.)

BASELINE ASSUMPTIONS

All simulations in this study begin from a base year of 1997. The base-year data on production and utilization, extracted from the FAO Agrostat database (FAO 2000a), is a three-year average centered on 1997. Key parameters defined in the model include the price and income elasticities of demand; price elasticities of area and yield; animal feed ratios; and growth rates of population, income, crop area, yield, and livestock numbers and yields. These parameters are the primary drivers in the projections of global and regional food markets.

Population and Income Growth and Urbanization

Population and income growth will remain important determinants of food supply and demand balances. A world population of 3 billion people in 1960 doubled to 6 billion by 1999, with population growth rates peaking at 2.1 percent annually between 1965 and 1970, and declining progressively since then to 1.4 percent annually between 1997 and 1998 (UN 1990). Further declines in global population growth rates are likely, with birth rates falling in many regions and declines in mortality rates leveling off.[15] The population of Sub-Saharan Africa, estimated at 561 million in 1997, is modeled over separate five-year periods, increasing at a rate of 2.4 percent per year between 1997 and 2020—with rates declining in later periods, as they do for all regions—to a population in 2020 of about 959 million people. In other regions, Pakistan is expected to have a particularly high population growth rate, projected at 2.8 percent per year, while growth rates in the two world giants—India and China—will average only 1.2 and 0.7 percent per year, respectively. Nevertheless, because the population bases of these countries are so large, they will still account for about 32 percent of the total world population increase during 1997–2020. Population growth rate assumptions for all countries and regions covered in the model are shown in Table 3.1.

GDP growth rates between 1997 and 2020 are also shown in Table 3.1. GDP growth rate disparities among countries in the developing world are projected to remain high. Growth rates will be highest in East and Southeast Asia, ranging from 3.5 to 6.0 percent per year. Strongly reformist initiatives undertaken in India involving strong implementation of macroeconomic stabilization and market reforms account for a projected improvement in income growth of 5.8 percent per year. China's economy, which has shown signs of slowing in recent years from a GDP growth rate that averaged nearly 10 percent per year over the last few decades, is projected to stabilize at an annual rate of growth of 6 percent.

A number of reforming countries in Latin America, including Chile and Argentina, have shown improved economic prospects that should continue into the future, through the attraction of large inflows of foreign investments. However, the potential for renewed macroeconomic instability in the region leads to a cautious estimate of annual regional GDP growth of 3.6 to 4.5 percent over the projection period.

GDP growth rates in Sub-Saharan African have been dismal over the last few decades: they have also been highly variable because so many countries in the region depend on rainfed agriculture and uncertain governance. Nevertheless, regional GDP growth hovered around 3 percent between 1990 and 1997, and the region possesses considerable scope for recovery. Many governments in the region have adopted reformist agendas to improve macroeconomic stability and foster development of the infrastructure and institutions necessary to generate sustained, long-term growth. Nigeria's return to democratic rule provides hope for renewed growth led by private sector development. Integration of the South African economy as a regional market is an ongoing process, which should continue to have beneficial spillover effects on the rest of Southern Africa. Nevertheless, the prevalence of HIV/AIDS and continued social and political strife give plenty of reason for caution regarding long-term growth rates. GDP growth for Sub-Saharan Africa is projected to be 3.2 to 3.8 percent during 1997–2020.

Signs of progress toward more economic stabilization, restructuring, and recovery are mixed in Eastern Europe and FSU. Some countries in Eastern Europe (Poland and Hungary, for example) have experienced a turnaround from the negative GDP growth rates of the early 1990s to strongly positive rates in the late 1990s. Their progress stands in stark contrast to Russia and most other countries in FSU, where prospects remain rather grim. Projected GDP growth rates are 4.0 percent per year in Eastern Europe and 2.0 to 3.0 percent per year in the remaining FSU countries. Growth rates in the rest of the developed world are projected to range from 2.2 to 2.7 percent per year.

Closely related to population and income changes is the transformation of demographic patterns. The most vital of these demographic characteristics, particularly in terms of projecting future food needs in fast-growing economies, is the rate of urbanization. Rural-to-urban migration—and its attendant significant effect on demand structures—has increased quite rapidly over the last few decades throughout the developing world and will continue to do so over the projections period (World Bank various years). Approximately 46 percent of the population of developing countries resided in urban areas in 1998, up from 22 percent in 1960 and 30 percent in 1980 (World Bank 2000b). Past studies have shown that urbanization accelerates changes in diet away from basic staples such as sorghum, millet, maize, and root crops, to cereals requiring less preparation (such as wheat), fruits, livestock products, and processed foods. As described in the previous chapter, in the more developed countries of Asia, urbanization has resulted in substantial increases in demand for meat and other livestock products and a shift from rice to wheat. In Sub-Saharan Africa, urbanization should encourage a shift away from staple foods such as coarse grains and roots and tubers toward higher consumption of wheat and rice. While the concept of "urbanization" is

TABLE 3.1 IMPACT population and gross domestic product (GDP) assumptions, 1997 and 2020

Region/Country	Population		GDP growth rates	Per capita GDP
	1997	*2020*	*(1997–2020)*	*2020*
	(millions)		*(percent/year)*	*(US$)*
Developed world	1,297.3	1,360.6	2.4	29,208
United States	271.6	317.0	2.7	45,585
EU15	373.1	371.1	2.2	37,032
Japan	125.6	123.5	2.2	55,990
Australia	18.2	22.3	2.5	30,914
Other developed countries	94.4	111.2	2.2	19,708
Former Soviet Union	293.1	296.8	2.1	2,910
Eastern Europe	121.2	118.7	4.0	7,474
Central Asia	54.9	69.5	3.0	1,465
Rest of Former Soviet Union	238.2	227.3	2.0	3,352
Developing world	4,490.6	6,095.7	4.6	2,455
Latin America	486.0	652.1	3.8	6,869
Mexico	94.1	124.9	3.6	6,659
Brazil	163.2	209.3	3.6	8,526
Argentina	35.7	45.4	4.5	17,438
Colombia	37.2	52.6	3.8	4,652
Other Latin America	155.8	219.9	3.6	3,759
Sub-Saharan Africa	560.9	958.6	3.6	443
Nigeria	103.9	168.2	3.8	544
Northern	142.7	253.0	3.3	219
Central and Western	137.8	246.4	3.8	532
Southern	83.5	135.9	3.2	648
Eastern	93.0	155.0	3.5	377

West Asia/North Africa	338.8	505.0	3.8	3,475
Egypt	64.5	90.2	4.0	2,057
Turkey	62.9	83.6	4.5	6,272
Other West Asia/North Africa	211.4	331.2	3.5	3,155
Asia	3,101.3	3,974.4	5.5	2,082
South Asia	1,288.5	1,780.3	5.5	1,052
India	960.1	1,266.0	5.8	1,202
Pakistan	144.1	244.3	4.5	715
Bangladesh	122.4	169.8	4.8	715
Other South Asia	61.9	100.2	4.5	549
Southeast Asia	492.4	648.7	4.9	2,515
Indonesia	203.2	262.3	4.5	1,879
Thailand	59.3	70.5	5.2	6,708
Malaysia	20.9	29.2	5.2	10,012
Philippines	70.7	101.6	5.0	2,319
Viet Nam	76.1	102.5	5.8	914
Myanmar	46.2	58.8	4.0	335
Other Southeast Asia	15.9	23.7	4.0	1,027
East Asia	1,320.4	1,545.5	5.7	3,087
China	1,249.0	1,461.4	6.0	2,330
South Korea	45.6	51.9	5.0	26,015
Other East Asia	25.8	32.3	3.5	555
Rest of world	36.5	5.6	4.0	5127
World	5,787.9	7,456.4	2.9	7,337

Source: GDP assumptions based on World Bank (2000b); population assumptions based on UN (1998).

not explicitly incorporated in the model, its effects are reflected in the assumptions of income and price elasticities, as described in the next section.

Demand and Supply Elasticities

The income elasticities of demand clearly vindicate the underlying assumption of the model that there will be a gradual shift in the demand structure from the main staples to high-value products such as meat and other livestock products, particularly in the developing countries. Several factors give rise to this hypothesis, including expected increases in per capita incomes from economic growth, rapid urbanization, and the continued commercialization of agricultural production (Bouis 1994). The IMPACT income demand parameters represent a synthesis of average, aggregate income elasticities for each country, given the income level and distribution of population between urban and rural areas as they evolve over the projection period (Table B.6).

In 1997, income food demand elasticities for livestock products were particularly high for poultry and beef products in Asia, with the exception of beef in South Asia. Poultry elasticities will decline by a third or more in Asia by 2020. Beef income elasticities in 1997 were also very high in Sub-Saharan Africa. In Latin America, where demand for beef is already quite high in many countries, the income elasticity is already low and expected to decrease further by 2020.

Pork and sheep and goat meat income elasticities of demand are expected to be lower than beef demand elasticities across almost all regions in both 1997 and 2020. Pork elasticities are relatively high in East Asia and Sub-Saharan Africa in 1997, declining slightly by 2020, while they will remain low in South Asia. Sheep and goat elasticities are about the same across all developing regions except East Asia, where they are fairly high. Income demand elasticities for poultry are significantly higher than those for pork and beef in developed countries. Income demand elasticities in the FSU countries are comparable to those in the developed countries for all meats except for sheep and goat meat, for which they are significantly higher.

Cereal food demand elasticities will be significantly lower than meat elasticities throughout the developing world, reflecting the ongoing increase in the share of meat in developing-country diets. Wheat and rice elasticities are low throughout Asia, but relatively high in Sub-Saharan Africa, with virtually no decline by 2020. In the rest of the world, wheat and rice income elasticities are lower than in Sub-Saharan Africa, with rice income elasticities slightly higher than wheat elasticities in Latin America, WANA, and most of the developed world. Maize and other grains are inferior goods throughout the world, with low or negative income elasticities. Sub-Saharan Africa is the exception.

Among the roots and tubers, marginal demand for potatoes will remain high among the developing countries, with slightly lower but still moderate elasticities in the developed countries. Income elasticities for sweet potatoes and cassava and other roots and tubers are much lower, with sweet potatoes inferior goods in South Asia and in East Asia. Sweet potato elasticities are low in all other developing regions and negative in most developed countries. The trends for cassava and other roots and tubers are similar, with income elasticities in 1997 negative and declining in Latin America and in East Asia. Demand elasticities for cassava will also be negative in most developed countries.

Egg income demand elasticities remain strong in all regions, with particularly high values in 1997 in South Asia, East Asia, and

Southeast Asia, declining by 2020. Income elasticities in the rest of the developing world in 1997 range from 0.21 in Latin America to 0.46 in Sub-Saharan Africa, declining to 0.11 and 0.32 by 2020 and actually turning negative in a number of developing countries. Sub-Saharan Africa also has the highest milk demand elasticity.

Supply Response

Supply elasticities include yield elasticities with respect to the crop price, labor price, and capital price (including fertilizer and other recurrent input prices), and crop area and livestock numbers elasticities with respect to own-commodity price and competing commodity prices. The absolute value of cross-price area elasticities with respect to other crops generally sums to an average across all regions of between one-quarter and one-half of the own-price elasticity for the given crop (Tables B.7–B.10).

Own-price crop area elasticities (and livestock number elasticities) are generally fairly small. In the developing world, pork probably has the most widely varying elasticity, ranging from 0.13 in WANA to 0.42 in Latin America. Pork number elasticities in the developed world range from 0.33 in Japan to 0.45 in the EU15. In the developing world, beef number elasticities are also high, but somewhat less variable than pork elasticities. Beef elasticities in the developed world are similar to those for pork. Sheep and goat and poultry own-price elasticities of supply are clustered between 0.2 and 0.4, with elasticities in the developed world slightly higher in both cases.

Cereal own-price area elasticities are expected to be lower than livestock number elasticities. Wheat area elasticities will range from 0.10 in South Asia to 0.21 in Sub-Saharan Africa and Latin America; maize area elasticities will range from 0.12 in Southeast Asia and East Asia to 0.2 in WANA; other grain area elasticities will range from 0.11 in Southeast Asia to 0.26 in Sub-Saharan Africa; and rice elasticities will range from 0.10 in Southeast and East Asia to 0.16 in WANA. Elasticities in the developed world will, for the most part, lie at the high end of these ranges.

Own-price elasticities for the area of roots and tubers will be similar to cereal elasticities, ranging from 0.10 to 0.18. Egg number elasticities range from 0.28 in Sub-Saharan Africa to 0.37 in WANA, and milk supply elasticities vary from 0.32 in Latin America to 0.40 in WANA, with similar elasticities for both crops in the developed world.

Own-price area elasticities of supply for most products in the FSU countries are approximately two-thirds of those in the developed countries, reflecting the difficulties that producers in the FSU will continue to have in rationalizing agricultural production in the aftermath of the collapse of centralized production systems.

Crop prices also affect yields, reflecting the greater incentive to farmers of generating higher yields at higher crop prices. Own-price yield elasticities for wheat range from 0.13 in Southeast Asia to 0.19 in Sub-Saharan Africa, while maize and rice elasticities have a slightly lower if similar spread. Other grain (coarse grain) yields are less responsive to price changes than the other three cereal crops, with a range of elasticities from 0.09 in Southeast Asia to 0.14 in Sub-Saharan Africa. Own-price yield elasticities for roots and tubers crops will be similar to those for cereals.

Capital and labor are the two other main variables for which yield elasticities are specified. The absolute values of yield elasticities with respect to capital and labor sum to the crop price elasticity. The yield elasticity with respect to capital is generally higher than that of labor in the developed countries, while the opposite holds true in the developing countries.

COMMODITY PRICES AND TRADE POLICY

Agricultural commodity prices are endogenous in the IMPACT model. Domestic producer and consumer prices are a function of world prices (expressed in the respective country-group currencies via the exchange rate to the U.S. dollar), producer subsidy equivalents (PSEs), consumer subsidy equivalents (CSEs), and marketing margins. The effects of country- and region-specific trade and price policies are thus expressed in terms of trade-distorting PSEs and CSEs, and marketing margins between the world price and producer and consumer prices. PSEs and CSEs measure the level of taxation or subsidy borne by producers or consumers relative to world prices and account for the wedge between domestic and world prices (see Box 3.1). Marketing margins reflect factors such as transport costs. In the model, PSEs, CSEs, and marketing margins are expressed as percentages of the world price.

The world price of a commodity is the equilibrating mechanism such that when an exogenous shock is introduced in the model, the world price will adjust and each adjustment is passed back to the effective producer and consumer prices via price transmission equations. Changes in domestic prices subsequently affect commodity supply and demand, necessitating iterative readjustments until world supply and demand balance and world net trade is again equal to zero.

Comprehensive estimates of trade-distorting PSEs and CSEs for agricultural commodities are available only for OECD countries. For other countries and regions, PSEs and CSEs are proxied by estimates of nominal or effective protection rates or tariffs. The estimated PSEs and CSEs utilized in the IMPACT model are synthesized from a variety of sources[16] and are summarized in Appendix B, Tables B.11–B14.

PRODUCTIVITY AND AREA GROWTH

One of the main assumptions for nonprice supply (area and yield) projections is that they cannot be constrained to be constant over the projections period, so growth rate estimates are individually specified over five-year periods: 1997–2000, 2001–05, 2006–10, 2011–15, and 2016–20. Projections are estimated to be consistent with historical experience in terms of

BOX 3.1 PSEs and CSEs

According to OECD (1999):

- PSEs are "an indicator of the annual monetary value of gross transfers from consumers and taxpayers to support agricultural producers, arising from policy measures which support agriculture."
- CSEs are "an indicator of the annual monetary value of gross transfers to consumers of agricultural commodities, arising from policy measures which support agriculture, regardless of their nature."

The IMPACT model operationalizes these measures as proportianal price wedges between world and domestic prices. Thus, a PSE of 0.10 indicates that prices for domestic producers are 10 percent higher than world prices (hence, a subsidy to producers), while a CSE of –0.10 indicates that prices for domestic consumers are 10 percent higher than world prices (hence, a tax on consumers).

slowing rates of public investment in agricultural research and rural infrastructure, including roads. Thus, projected future yield trends explicitly account for the slowdown in yield growth that has occurred across most commodities in most regions over recent decades. The growth contribution of modern inputs such as fertilizers is accounted for in price effects in the yield response function and as a complementary input with irrigation and modern varieties generated by research. The methodology makes use of ex-post and ex-ante studies of agricultural research priority setting, syntheses of sources of agricultural productivity growth studies, examinations of the role of industrialization on growth, and "expert opinion" to generate the projected time path of yield growth. Yield growth projections also account for expected effects on yields of environmental degradation.

4

PROJECTIONS OF GLOBAL FOOD SUPPLY AND DEMAND AND CHILD MALNUTRITION

BASELINE PROJECTIONS TO 2020

Cereals

Demand. Total cereal demand will increase by 1.3 percent per year between 1997 and 2020, particularly in developing countries, but it will decrease from historic rates because population growth rates are slowing and income elasticities of food demand for cereals are gradually declining in many countries. Nevertheless, the amount of additional cereal needed to meet effective demand by 2020 is as large as the increase during the previous 23 years. Between 1974 and 1997, global cereal demand grew by nearly 636 million tons, developing-country cereal demand by 553 million tons, and developed-country cereal demand by 83 million tons. By comparison, cereal demand in developing countries is projected to grow by 49 percent (557 million tons) between 1997 and 2020,

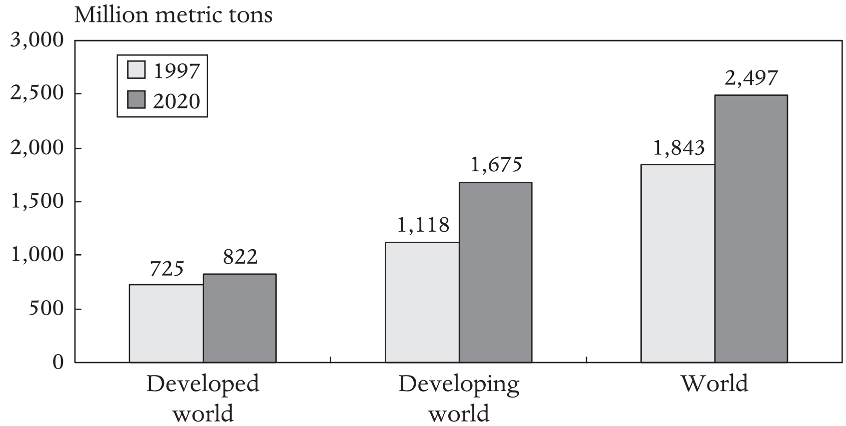

FIGURE 4.1 Total cereal demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

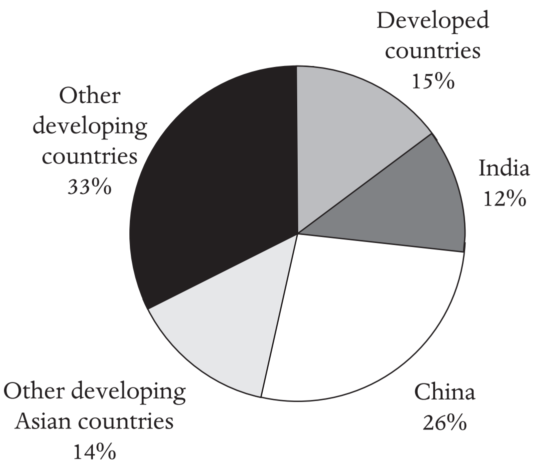

FIGURE 4.2 Share of regions in cereal demand increase, 1997–2020

Source: IMPACT projections, June 2001.

while cereal demand in the developed world is projected to increase by 13 percent (97 million tons) (Figure 4.1). Developing Asia will account for 52 percent (344 million tons) of the global increase in cereal demand between 1997 and 2020, with China alone accounting for 26 percent (173 million tons). India will account for an additional 12 percent (78 million tons) of worldwide cereal demand growth, and other developing Asian countries will account for 14 percent (92 million tons) (Figure 4.2).

Cereal Demand Composition. The composition of cereal demand will change significantly between 1997 and 2020 as incomes and urbanization rise, especially in Asia. In terms of total cereal demand, rice and wheat were the major cereal crops in developing countries in 1997, accounting for 33 and 30 percent, respectively, of total cereal demand (Figure 4.3). Maize will overtake these two cereals by 2020, rising from 26 percent of total cereal demand in 1997 to 30 percent in 2020, while the shares of both rice and wheat will decline to 29 percent. In Asia, rice accounted for 43 percent of total cereal demand in 1997 but will only account for 39 percent in 2020. Maize will be the beneficiary of this decline in relative rice demand, with its share rising from 22 percent in 1997 to 28 percent in 2020.

Per capita food demand for the various cereals reveals a slightly different story than aggre-

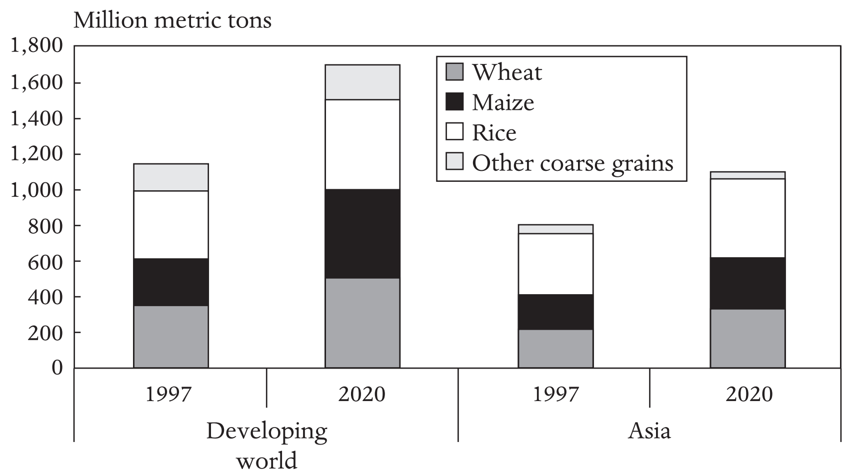

FIGURE 4.3 Cereal demand composition by crop, 1997 and 2020

Source: IMPACT projections, June 2001.

TABLE 4.1 Per capita food demand for cereals by crop and region, 1997 and 2020

	Developing world		Developed world		Asia		World	
Crop	*1997*	*2020*	*1997*	*2020*	*1997*	*2020*	*1997*	*2020*
				(kilograms/capita)				
Wheat	64.2	67.7	99.7	103.8	63.8	70.0	72.1	74.3
Maize	18.9	18.6	11.9	11.4	11.1	9.3	17.3	17.3
Rice	72.0	70.9	11.0	11.4	94.7	96.4	58.3	60.0
Other coarse grains	12.0	13.5	8.8	7.4	8.0	7.5	11.3	12.4

Source: IMPACT projections, June 2001.

gate demand, as per capita food demand for maize in the developing world remains constant between 1997 and 2020, while per capita food demand for wheat increases 6 percent (4 kilograms per capita) (Table 4.1). Per capita food demand for rice declines 1 percent and demand for other coarse grains increases 17 percent. In fact, while per capita food demand for other coarse grains declines in all regions except Sub-Saharan Africa, where it will increase 11 percent above 1997 levels, the large increase in per capita demand worldwide is the result of the sharp increase in consumption in Sub-Saharan Africa (49 kilograms per capita by 2020).

Per capita food demand for rice in Asia will stay relatively constant, increasing by only 1.8 percent, but per capita food demand for maize will decline by a significant 16 percent from 1997 levels. Much of this decline comes from a shift in consumption to wheat, which is expected to experience demand growth of 9 percent between 1997 and 2020. As noted earlier, rapidly growing incomes and urbanization will drive this consumption shift.

Feed Demand for Cereals. Animal feed use, driven by rising meat demand, will be responsible for most of the increasing demand for maize in developing countries as a whole and Asia in particular between 1997 and 2020. Whereas feed accounted for 21 percent of total worldwide cereal demand in 1997, it will account for 35 percent of the cereal demand increase between 1997 and 2020 (Figure 4.4). Feed demand for cereals is projected to grow by 2.5 percent per year in developing countries and 0.6 percent per year in developed countries, accounting for total feed demand in-creases of 84 percent in the developing world and 16 percent in the developed world. That will amount to an increase of 198 million tons in the developing world and 68 million tons in the developed world (Table 4.2). Sub-Saharan Africa will have particularly rapid growth in demand for cereal feed at 2.8 percent annually, resulting in a total increase of 98 percent. Feed demand for maize in the developing world will lead all other cereal crops with a rate of increase of 2.9 percent annually, for a total increase of 92 percent, and it will grow at an even faster 3.1 percent per year in Asia, for an overall increase of 111 percent.

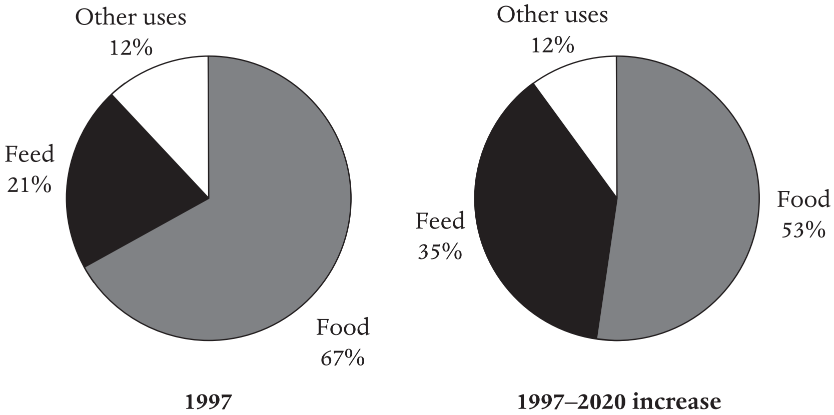

FIGURE 4.4 Share of food, feed, and other uses in total cereal demand of developing countries, 1997 and 1997–2020 increase

Source: IMPACT projections, June 2001.

Cereal Production. Global cereal production is projected to grow at a rate of 1.26 percent per year during 1997–2020, slightly lower than the 1.32 percent per year increase in demand. The difference is caused by the slightly higher level of cereal production, compared with demand in the 1997 base year, due to the net accumulation of global cereal stocks in that year. The net increase in stocks in the base year is drawn down during the first three years of the projections period to achieve long-run equilibrium, that is, a supply-demand balance with no annual change in stocks. Regional production increases will not satisfy rising Asian cereal demand, and East Asian demand in particular will seriously outstrip production (Figure 4.5). The only developing region projected to have surplus cereal growth between 1997 and 2020 is Latin America, with a surplus of 10 million tons. The developed world, with surplus cereal growth of 73 million tons between 1997 and 2020, will provide the bulk of excess cereal production. Asia's share of worldwide cereal production will increase 2 percent to reach 41 percent by 2020. Meanwhile, Sub-Saharan Africa's share will increase from 4 to 5 percent and Latin America's from 7 to 8 percent. The share of the developed countries in total world cereal production will decline through 2020.

TABLE 4.2 Feed demand for cereals by region, 1997 and 2020

Region	*1997*	*2020*
	(million metric tons)	
Latin America	57.7	98.1
West Asia/North Africa	35.9	59.4
Sub-Saharan Africa	3.9	7.7
South Asia	2.9	6.4
East Asia	118.9	233.2
Southeast Asia	15.1	27.1
Developed world	425.0	492.6
Developing world	234.5	432.0

Source: IMPACT projections, June 2001.

Cereal Area. Sub-Saharan Africa and Latin America will be able to increase their share of worldwide cereal production because they will expand cereal area significantly between 1997 and 2020, and will therefore not be as dependent as the rest of the world on cereal yield

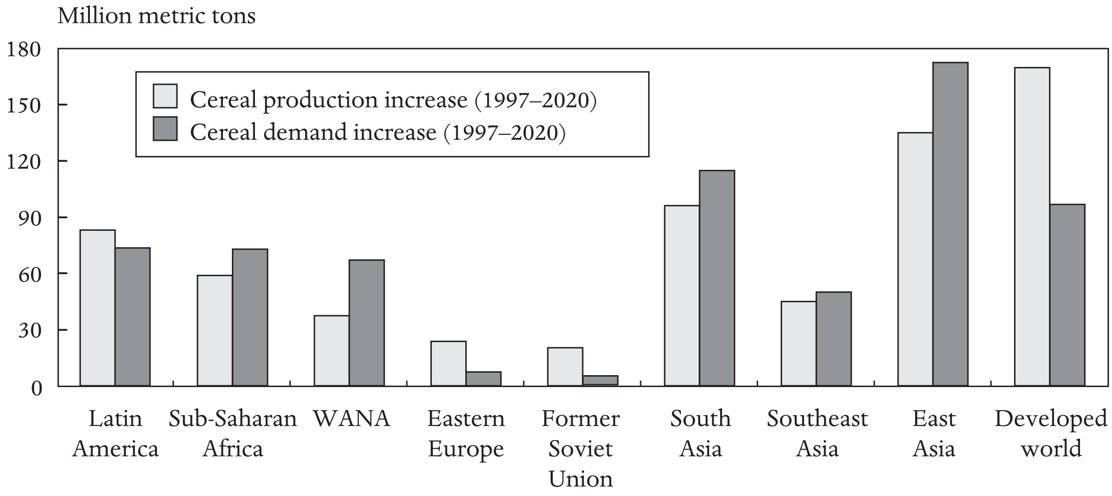

FIGURE 4.5 Cereal production and demand increases by region, 1997–2020

Source: IMPACT projections, June 2001.

increases to drive production growth (Figure 4.6). Area under cereal production in Sub-Saharan Africa is projected to expand 27 percent, with area expansion responsible for 32 percent of total production growth. Area under cereal production will also expand by a significant 15 percent in Latin America, where it will be responsible for 23 percent of production growth during 1997–2020. These two regions will be exceptions, as cereal area is projecte to expand only 9 percent between 1997 and 2020 in the developing world as a whole, providing for only 15 percent of cereal production growth during this period. Asia, in particular, possesses little arable land not already under cultivation.

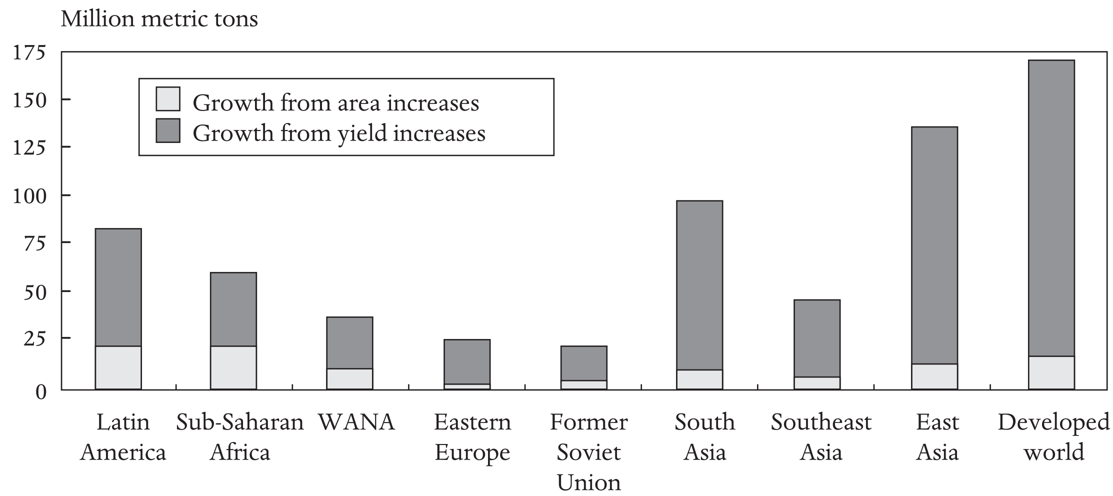

FIGURE 4.6 Share of area and yield increase in regional cereal production growth, 1997–2020

Source: IMPACT projections, June 2001.

Cereal Yields. Despite the importance of yields to overall growth in cereal production, yield growth rates will continue to slow across all cereals and all regions, with the notable exception of Sub-Saharan Africa, where yields are projected to recover from the 1982–97 period of stagnation (Figure 4.7). The pattern of growth of cereal yields began to slow significantly after 1982. In the developed world, the slowdown in crop area, yield, and production growth was primarily policy induced, as North American and European governments drew down cereal stocks and scaled back farm price-support programs in favor of direct payments to farmers. The economic collapse and subsequent economic reforms in the former centrally planned economies in Eastern Europe and the FSU further depressed crop production for developed countries as a whole. A number of factors have contributed to the slowing of cereal productivity growth in developing countries, particularly in Asia, since the early 1980s. Increased intensity of land use—and the high levels of input use already achieved in much of Asia—has led to higher and higher input requirements in order to sustain yield gains. Public investment in crop research and irrigation infrastructure has also slowed considerably, with consequent effects on yield growth.

These forces are expected to continue to slow cereal yield growth rates from 1.6 percent annually in 1982–97 to 0.9 percent annually in 1997–2020, with cereal yields increasing 25 percent (0.7 tons per hectare) worldwide during this period. In the developing world, cereal yield growth rates are expected to decline from 1.9 percent annually in 1982–97 to 1.1 percent annually in 1997–2020, with average cereal yields increasing a total of 32 percent (0.7 tons per hectare) during this period. Because high-yielding varieties of maize were introduced later in developing countries, maize will have the fastest yield growth of any cereal crop in 1997–2020 by a total of 43 percent (1.2 tons per hectare) (Figure 4.8). Nevertheless, even maize yield growth rates in the developing world will decline from 2.2 to 1.6 percent annually.

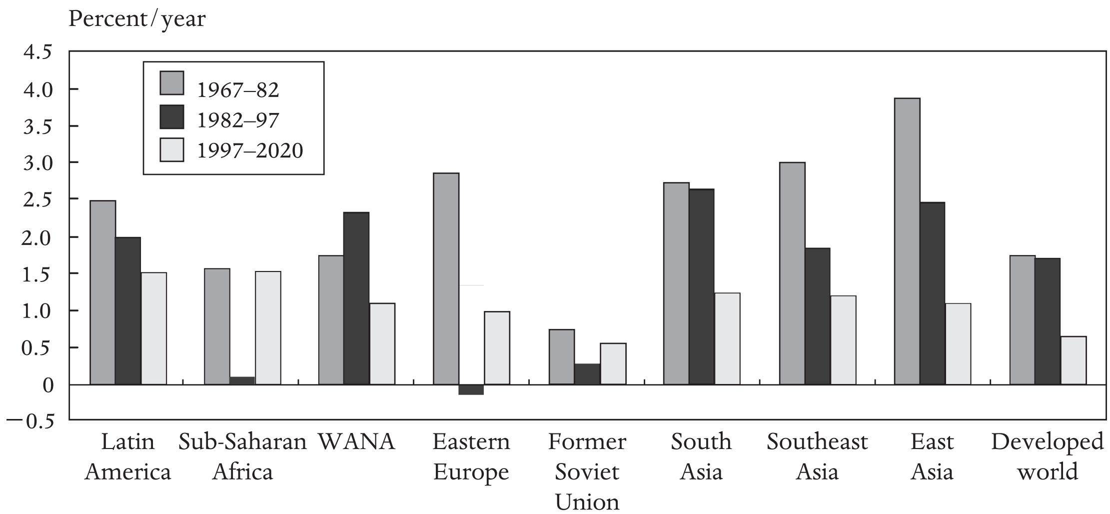

FIGURE 4.7 Yield growth rates by region, all cereals, 1967–82, 1982–97, and 1997–2020

Source: IMPACT projections, June 2001.

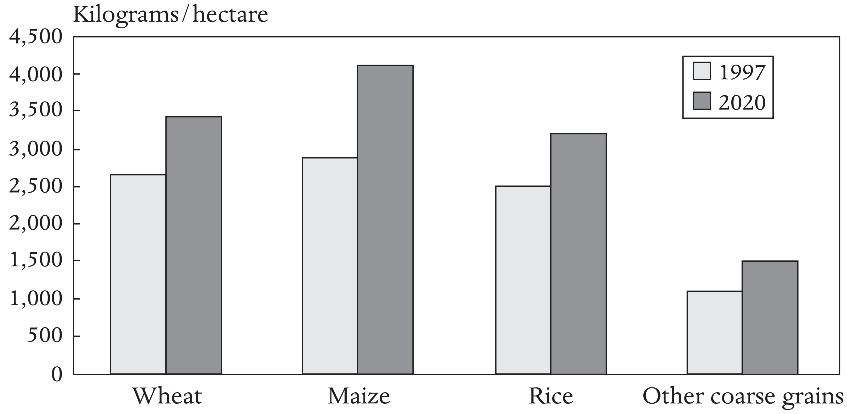

FIGURE 4.8 Cereal yields by crop in developing countries, 1997 and 2020

Source: IMPACT projections, June 2001.

The one region with improving cereal yield growth rates, Sub-Saharan Africa, will experience yield growth of 1.5 percent annually between 1997 and 2020 for a total yield increase of 46 percent, thus substantially surpassing the yield growth rate of 0.1 percent achieved between 1990 and 1997. Cereal yields in the developed world are expected to grow at 0.7 percent per year for a total increase of 18 percent between 1997 and 2020, with growth rates declining from 1.1 percent per year between 1990 and 1997.

Cereal Prices. International cereal prices are projected to decline between 1997 and 2020, although these declines will slow significantly from those achieved in the recent past. Between 1982 and 1997, real world wheat prices declined by 28 percent, rice prices by 29 percent, and maize prices by 30 percent.

During 1997–2020, wheat prices are projected to decline 8 percent; rice prices, 13 percent; other grain prices, 11 percent; and maize prices to remain fairly constant with a percent drop (Table 4.3). These price declines will really only begin to take effect after 2010. In fact, between 1997 and 2010, wheat prices are projected to decline by 3 percent, maize and rice prices to stay constant, and other grain prices to decline by 4 percent. This tighter predicted price scenario indicates that additional shocks to the agricultural sector, particularly failure to meet demands for agricultural water and other inputs, could put serious upward pressure on food prices.

Cereal Trade. Rapid growth in world cereal trade will accompany slow declines in cereal prices, as the United States and the European Union increase their cereal exports to keep pace with rising world demand. U.S. cereal

TABLE 4.3 World prices by cereal crop, 1997 and 2020

Crop	*1997*	*2020*
	(US$/metric ton)	
Wheat	133	123
Maize	103	102
Rice	285	250
Other coarse grains	97	86

Source: IMPACT projections, June 2001.

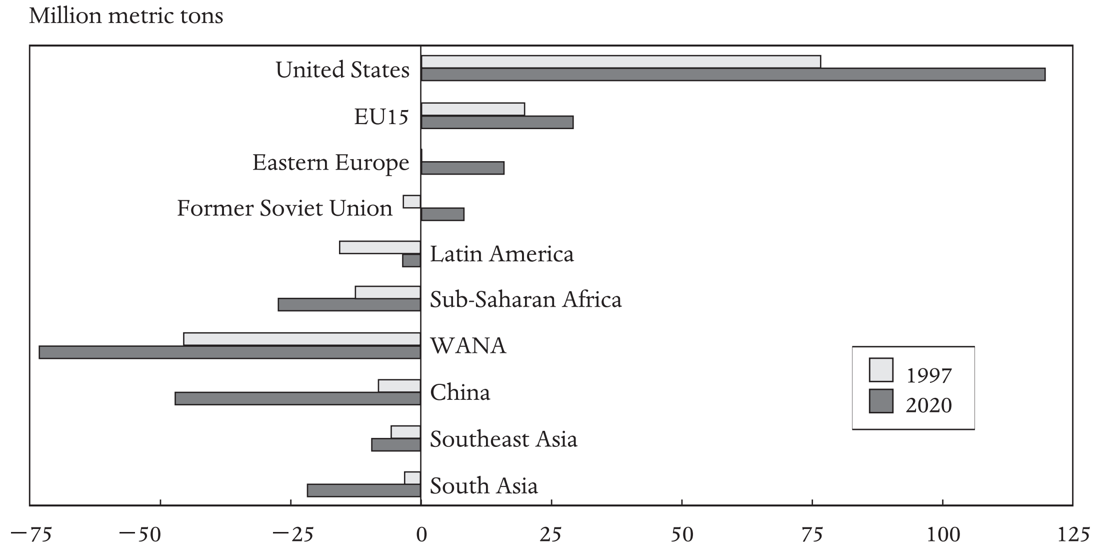

FIGURE 4.9 Net cereal trade by region, 1997 and 2020

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

exports will increase from 77 million tons in 1997 to 120 million tons in 2020, while EU15 cereal exports will increase from 20 to 29 million tons (Figure 4.9). Southeast Asia's large net exports of relatively high-value rice mask its rising volume of net imports of total cereals, which are expected to increase from 3 million to 9 million tons of cereal imports by 2020, whereas the value of cereal trade will shift from minor net imports in 1997 to net exports valued at US$0.8 billion in 2020 (Table 4.4).

Chinese import markets will absorb much of the increase in cereal exports from the United States and the EU15, consuming a net of 48 million tons of imported cereal in 2020, or 40 million tons more than in 1997. Net cereal imports will undergo the most dramatic shift in South Asia, increasing 18 million tons above a slight trade deficit in both volumetric and value terms in 1997. WANA, the largest cereal importer in the world in both 1997 and 2020, will require 73 million tons of imported grain in 2020. Net cereal imports into Sub-Saharan Africa will rise a hefty 15 million tons between 1997 and 2020, and the region will require 27 million tons of cereal imports to satisfy demand in 2020.

Meat

Meat Demand. Rising meat demand will drive increased cereal feed demand. Global meat demand, 208 million tons in 1997, is projected to grow 57 percent (118 million tons) by 2020 (Table 4.5). Meat demand in the developing countries, rising a projected 92 percent (102 million tons) between 1997 and 2020, will account for the lion's share of the increase in global demand, and Asia, led by China, will in turn account for the major share of the increase in meat demand in the developing countries. In fact, China alone will account for 43 percent of additional meat demand worldwide between 1997 and 2020. India, following its traditional pattern of low meat consump-

TABLE 4.4 Net cereal trade value by region, 1997 and 2020

Region/Country	*1997*	*2020*
	(US$ billion)	
United States	10.1	13.3
EU15	4.8	3.1
Former Soviet Union	–0.3	0.9
Eastern Europe	–0.1	1.6
Latin America	–3.1	–0.4
Sub-Saharan Africa	–2.3	–3.9
West Asia/ North Africa	–7.8	–8.8
China	–1.9	–4.9
Southeast Asia	–0.0	0.8
South Asia	–0.2	–2.7

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE 4.5 Meat demand by region, 1997 and 2020

Region	*1997*	*2020*
	(million metric tons)	
Latin America	26.0	44.9
Sub-Saharan Africa	5.5	11.2
West Asia/North Africa	7.1	13.0
Eastern Europe	8.0	9.5
Former Soviet Union	12.0	13.5
East Asia	55.5	108.7
Southeast Asia	8.9	18.6
South Asia	7.3	15.8
Developed world	97.7	114.3
Developing world	110.5	212.3
World	208.1	326.5

Source: IMPACT projections, June 2001.

tion, will only account for 4 percent of additional meat demand. The rest of Asia, however, will exhibit strong growth, accounting for 13 percent of the global increase. Meat prices will remain relatively stable throughout the projection period.

While per capita meat demand in the developing world will increase substantially between 1997 and 2020, per capita meat consumption in the developing countries in 2020 will still be far below that in the developed countries (Figure 4.10). While per capita livestock demand in the developed world will be 84 kilograms in 2020, livestock demand in the two highest meat-consuming developing regions, Latin America and East Asia, will only reach 69 and 70 kilograms per capita, respectively. Other developing regions will have much lower per capita meat demand.

Despite very rapid growth, Chinese meat demand will only surpass the per capita meat demand of one developed country, Japan, by 2020, reaching 71 kilograms per capita to Japan's 52 kilograms per capita. Japan has the lowest meat consumption of any developed country, largely because its consumption of fish is exceptionally high.

While demand for all meat products will increase substantially over the IMPACT projections period, the demand for poultry will increase the most, rising 131 percent in the developing world and 34 percent in the developed world. Poultry demand is projected to rise from 26 to 32 percent in the developing world and from 29 to 33 percent in the developed world.

Per capita poultry demand in the developed world will rise from 22 kilograms per capita in 1997 to 28 kilograms per capita in 2020, and from 7 to 11 kilograms in the developing world. Poultry will represent the only meat product for which per capita demand in the developing world rises less than per capita demand in the developed world, thus widen-

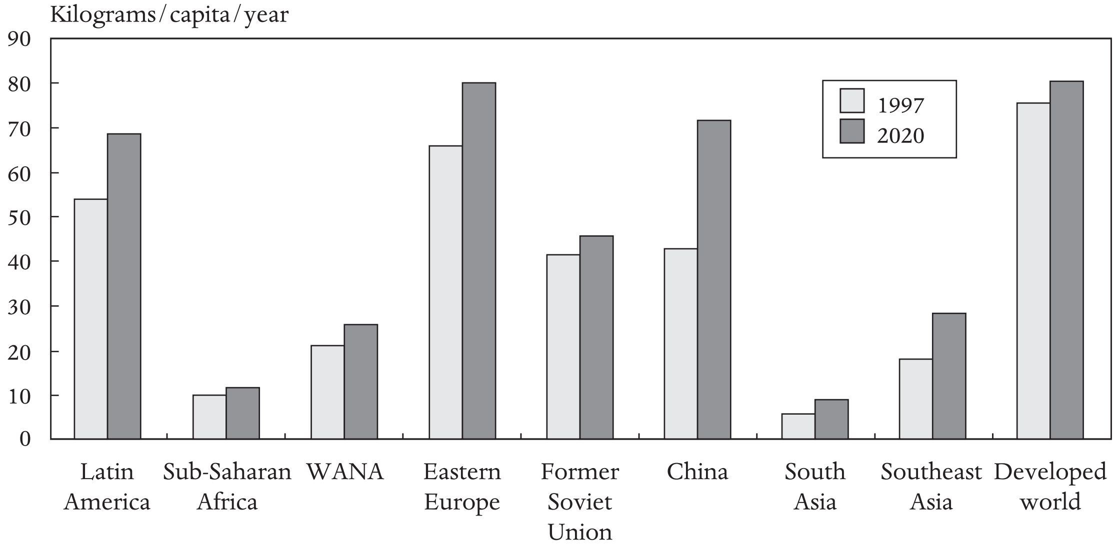

FIGURE 4.10 Per capita meat demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

ing the deficit between developing and developed world consumers even further. Poultry's relative share of meat demand will expand primarily at the expense of pork, which in 1997 accounted for 37 percent of total meat demand in the developed world and 42 percent in the developing world. The developed and developing worlds' increase in pork demand will only account for 18 and 31 percent, respectively, of their increase in meat demand in 2020.

Empirical observations of changing meat consumption patterns in both the developing and developed worlds bear out these results. Meat demand in China will have a particularly important effect on worldwide consumption trends. A number of studies (including Gao, Wailes, and Cramer 1996; Wang et al. 1998) have noted that pork consumption, while very high in China because pork prices are low, rises slowly with income, and that higher-income groups tend to substitute poultry for pork, considering poultry a luxury good. Wang et al. (1998) find that urban Chinese consumers gradually shift away from pork to beef and poultry, mainly because they desire greater variety and beef and poultry products are more available in urban than rural markets. They find that the demand for poultry is highly elastic, compared with other meats, thus indicating that marginal expenditures on poultry are likely to increase in the future. The greater availability of poultry and beef will depend in large part on ongoing structural changes to livestock production within China, and the poultry sector is industrializing rapidly, not only in China but throughout Asia (Hoffman 1999). We expect replication of these trends to a greater or lesser degree throughout the developing world, as shifting demand toward meat focuses heavily on poultry as a low-cost source of animal protein.

A number of studies claim that higher poultry demand in the developed world is the result of shifting taste patterns driven by concerns about the health risks of consuming large quantities of red meat (Ward and Lambert 1993; Capps and Schmitz 1991; McGuirk and

Mundlak 1991; and Kinnucan et al. 1997). The debate over the extent of this demand shift has not been resolved in the literature, with Eales and Unnevehr (1993) and Davis (1997), among others, positing that the shift to poultry is actually the result of productivity-driven price declines in the poultry sector. But even if the effects of health concerns have not been overstated in the literature, Eales et al. (1998) point out that structural shifts on the supply side are playing a powerful role in driving poultry consumption higher. Whatever the reason, per capita poultry demand in the United States rose 10 percent between 1996 and 2000, while red meat consumption only increased 2 percent (USDA 2000).

Meat Trade. As was the case for cereals, projected international meat trade will expand tremendously between 1997 and 2020 because regional supply and demand will be out of balance (Figure 4.11). The three main meat exporters, the United States, Latin America, and the EU15, all will experience significant increases in the value of their meat exports by 2020. Meat exports will rise sharply in the United States, where growing poultry exports (79 percent of all meat exports) will drive overall meat exports. The United States will also see a shift from a trade balance in pork in 1997 to exports of 1 million tons in 2020. Latin American meat exports are projected to expand between 1997 and 2020, but they will decline in value because poultry exports will replace high-value pork exports. Meat exports in the EU15 will also increase.

Among the meat-importing countries, China will experience the largest projected rise in meat imports, from near trade balance in 1997 to 4 million tons of imports in 2020. Poultry and pork products will drive this increase, with poultry imports rising from virtually zero in 1997 to 2 million tons in 2020, and pork imports rising 1 million tons from a trade surplus in 1997 to a trade deficit of 1 mil-

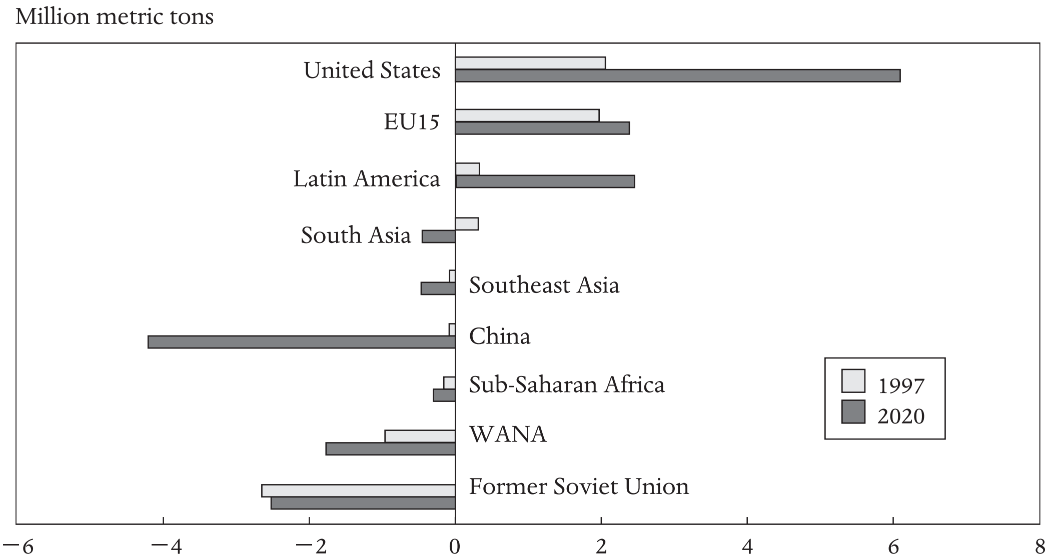

FIGURE 4.11 Net meat trade by region, 1997 and 2020

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

lion tons in 2020. Meat imports into WANA and Southeast Asia will each increase by about 1 million tons, while South Asia will change from a meat exporter in 1997 to a meat importer in 2020. Sub-Saharan Africa will have only a minimal increase in meat imports.

Roots and Tubers

Aggregate roots and tubers demand in the developing world will increase by 55 percent (248 million tons) between 1997 and 2020 (Figure 4.12). Sub-Saharan Africa accounts for 44 percent of this increase, indicating that roots and tubers will continue to be an important part of the diet in that region. Asia will also account for a significant amount of the total increase, with East Asia accounting for 21 percent and South Asia, 14 percent (Figure 4.13).

Cassava and other roots and tubers will remain the dominant roots and tuber category in Sub-Saharan Africa, representing 68 percent of the total increase in roots and tubers demand between 1997 and 2020 (Figure 4.14). Cassava will also drive roots and tubers demand increases in Southeast Asia, accounting for 80 percent of the total. Potato demand represents 93 percent of the total increase in roots and tubers demand in South Asia, and potato and sweet potato demand represents 71 percent and 27 percent, respectively, of China's total increase.

In the developing world, the supply of roots and tubers is expected to increase only 51 percent between 1997 and 2020, thus slightly lagging demand growth. In Asia, roots and tubers demand will increase 43 percent and production only 35 percent. In Southeast Asia, however, demand will increase 60 percent, while production will only expand 10 percent, thus bringing regional supply and demand into greater overall balance. Supply and demand growth will be identical in Sub-Saharan Africa and in Southeast Asia. In the developed world, roots and tubers demand will increase by only 3 percent and production by 9 percent, reflecting the relative inferiority of roots and tubers as a food commodity.

Rapidly improving yields will be necessary to drive roots and tubers production increases throughout the developing world, and the area planted to roots and tubers will actually shrink significantly in the developed world. Sub-Saharan Africa is the exception: area expansion will be responsible for a significant

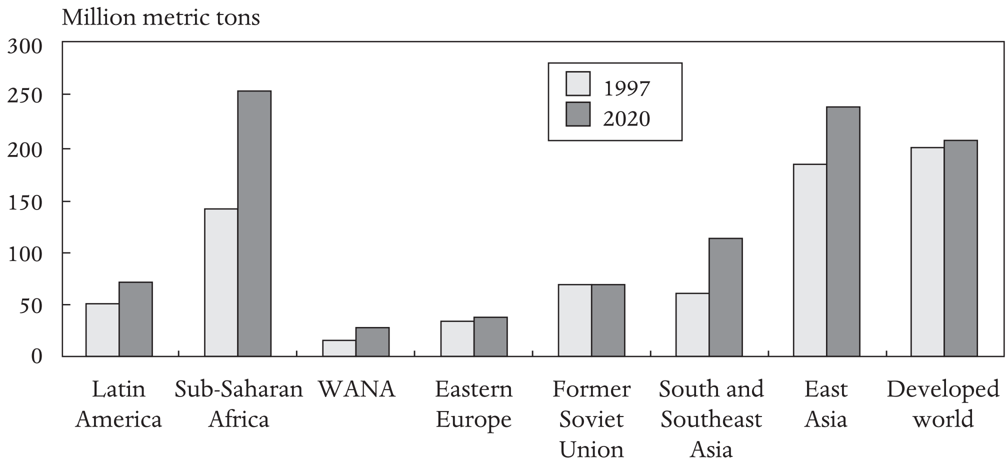

FIGURE 4.12 Roots and tubers demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

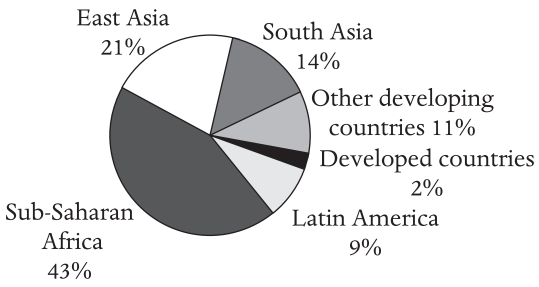

FIGURE 4.13 Share of roots and tubers demand increase by region, 1997–2020

Source: IMPACT projections, June 2001.

27 percent of additional roots and tubers production there.

Trade in roots and tubers will change substantially between 1997 and 2020 (Figure 4.15). A decline of 10 million tons in roots and tubers exports out of Southeast Asia and a corresponding decline in the EU15's net imports from 8 million tons in 1997 to 2 million in 2020 will be primarily responsible for the projected 3 million tons decline in worldwide roots and tubers trade between 1997 and 2020. With the exception of China, no developing country will import more than 1 million tons of roots and tubers in 2020.

Soybeans

Latin America will retain its dominant position as the top regional consumer of soybeans in the developing world, with demand increasing 78 percent between 1997 and 2020. Production will more than meet demand with an increase of 81 percent. Among the developing countries, China will challenge Brazil for the position of top soybean-consuming nation in the developing world, as China's demand increases by 96 percent, compared with a 63 percent increase in Brazil (Table 4.6). Brazilian production will increase by 78 percent and Argentine production by 91 percent. China, on the other hand, will not be able to supply domestic demand increases from domestic production, as soybean production there will only increase by 78 percent. As a result, Chinese soybean demand will outstrip domestic production by 12 million tons

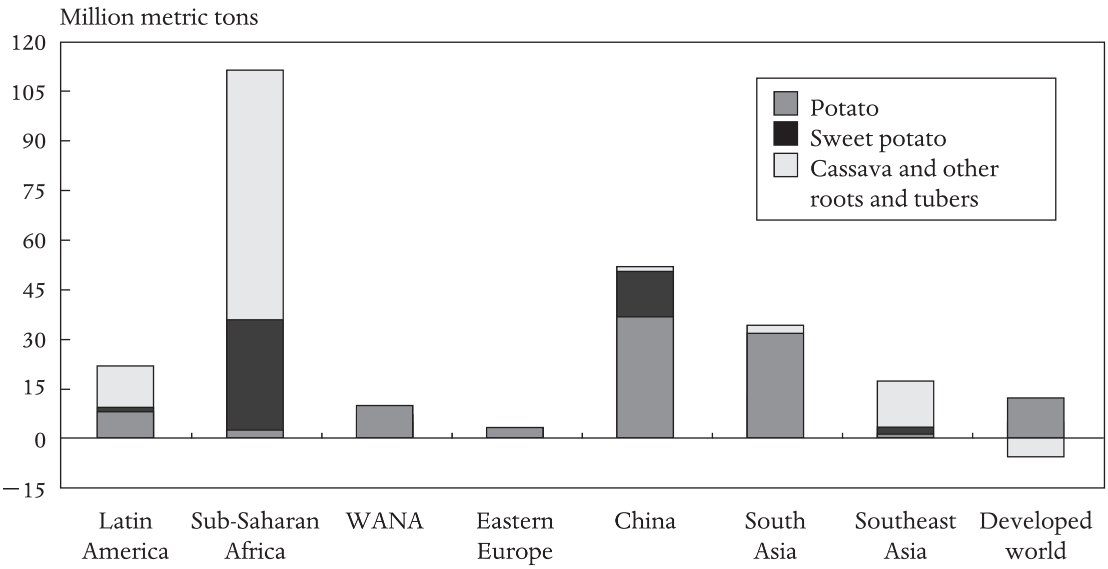

FIGURE 4.14 Increase in roots and tubers demand by crop and region, 1997–2020

Source: IMPACT projections, June 2001.

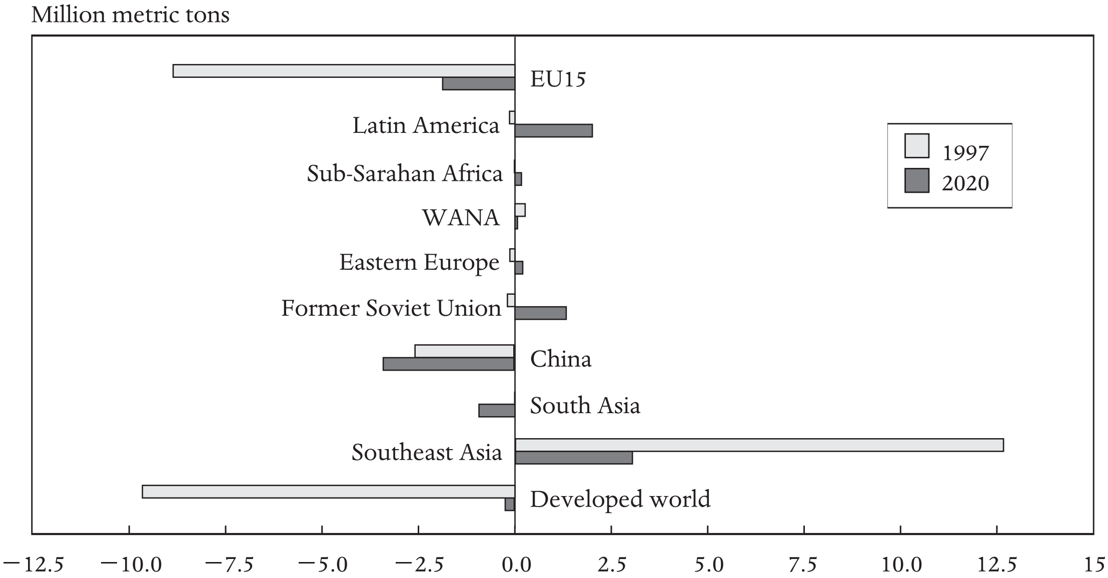

FIGURE 4.15 Net roots and tubers trade by region, 1997 and 2020

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

in 2020, while Latin American soybean production will exceed domestic demand by 14 million tons. This surplus should enable Latin America to challenge the United States for a substantial share of the soybean export market in years to come. The European Union, however, will remain the main market for soybean imports, as the deficit between domestic supply and demand will be a tremendous 19 million tons.

TABLE 4.6 Soybean supply and demand, selected countries, 1997 and 2020

	Production		Demand	
Region/Country	*1997*	*2020*	*1997*	*2020*
		(million metric tons)		
Argentina	14.1	26.8	13.0	22.2
Brazil	27.1	48.1	21.8	35.6
United States	70.9	94.9	46.0	62.9
EU15	1.4	1.9	16.6	21.3
China	14.3	25.5	19.2	37.6
Southeast Asia	2.0	3.1	3.2	5.6

Source: IMPACT projections, June 2001.

Supply and demand changes will result in a significant increase in international soybean trade from 32 million tons in 1997 to 52 million tons in 2020. The United States will strengthen its position as the world's dominant soybean exporter, increasing net exports by 8 million tons in 2020 (Figure 4.16). Together, the United States and Latin America will supply the majority of world import needs. The European and Chinese markets will dominate imports of soybeans, with imports of 19 million and 12 million tons, respectively, in 2020.

Soybean prices are projected to remain fairly constant between 1997 and 2020, actually rising from \$247 per ton in 1997 to \$250 per ton on the strength of rising feed demand as production of livestock increases worldwide.

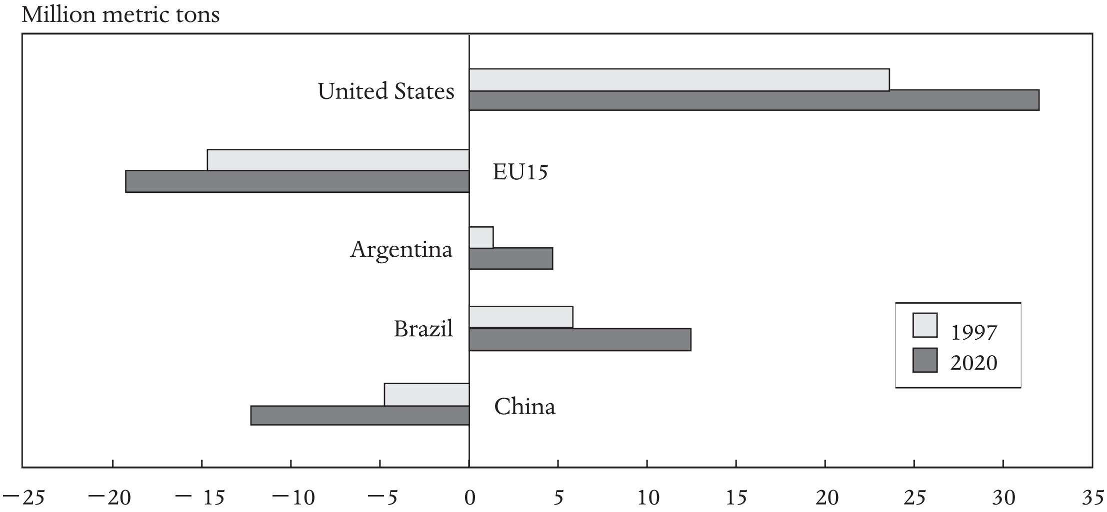

FIGURE 4.16 Net soybean trade by selected countries, 1997 and 2020

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

Edible Oils

Southeast Asia, the largest producer of edible oils, will increase its already sizeable production surplus, with production growth exceeding demand growth by 7 million tons between 1997 and 2020. Much of the excess will be exported to East Asia, which will increase its edible oil imports from 4 million tons in 1997 to 10 million tons in 2020 (Figure 4.17). Sub-Saharan Africa, although it will remain the smallest producer and consumer of edible oils in the developing world in 2020, will require 2 million tons of imports to satisfy domestic demand in 2020. Latin America will increase its edible oil exports by 3 million tons. Edible oilseed prices will decline slightly between 1997 and 2020, from $539 to $490 per ton.

Eggs and Milk

Eggs have limited tradability, so trends in production and demand will stay close together during 1997–2020. Egg demand will grow fastest in South Asia (113 percent) from admittedly low levels. Although the increase in demand for eggs in China trails all other developing regions, China will continue to dominate egg consumption in the developing world, at a per capita consumption level of 19 kilograms per capita (Figure 4.18). Per capita egg demand will actually fall slightly in the developed world by 2020.

Milk demand in Sub-Saharan Africa is projected to increase by 110 percent and production by 111 percent between 1997 and 2020. Nevertheless, per capita milk consumption will only increase by 1 percent per year (Figure 4.19). South Asia will continue to dominate milk consumption and production in the developing world, with demand increasing from 43 to 47 percent of the developing world total, and production increasing from 46 to 50 percent. Per capita demand in South Asia will grow at a rate of 2 percent annually. Per capita milk demand will also remain quite low in both East Asia and Southeast Asia at only 19 kilograms per capita in 2020.

Agricultural Trade

The United States, Latin America, the EU15, and Southeast Asia will be the four main net

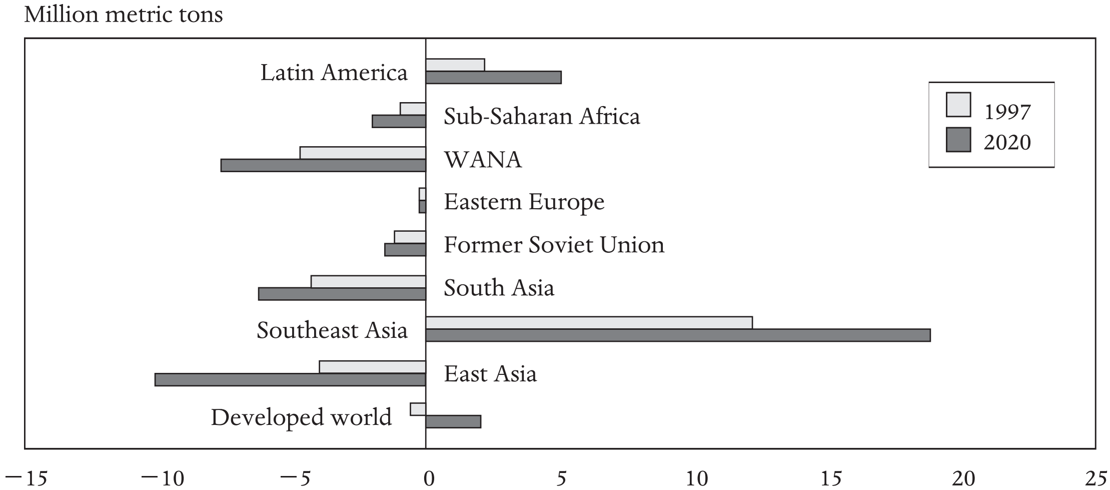

FIGURE 4.17 Net trade in edible oils by region, 1997 and 2020

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE 4.7 Value of regional agricultural trade, 1997 and 2020

Region/Country	1997	2020
	(US$ billion)	
United States	17.8	31.2
EU15	0.8	5.1
Former Soviet Union	–3.5	–1.6
Latin America	7.4	14.1
Sub-Saharan Africa	–3.5	–6.5
West Asia/North Africa	–12.2	–18.7
China	–5.1	–21.5
South Asia	–1.7	–8.0
Southeast Asia	5.7	4.6

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

exporters of agricultural goods in value terms in 2020, while all other developing countries will be net importers of agricultural goods (Table 4.7).[17] The United States' agricultural trade revenues will increase by $13 billion, for net exports of $31 billion in agricultural goods by 2020. Net agricultural exports as a percentage of agricultural production will increase from 11 percent in 1997 to 16 percent in 2020 (Table 4.8). Latin America

TABLE 4.8 Value of agricultural trade as a percentage of total agricultural production, 1997 and 2020

Region/Country	*1997*	*2020*
	(percent)	
Southeast Asia	9.0	5.0
South Asia	–1.5	–4.4
China	–2.1	–6.1
West Asia/North Africa	–32.6	–33.5
Sub-Saharan Africa	–7.9	–8.9
Latin America	4.7	8.0
Former Soviet Union	–4.6	–2.1
EU15	0.5	3.2
United States	11.5	16.4

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

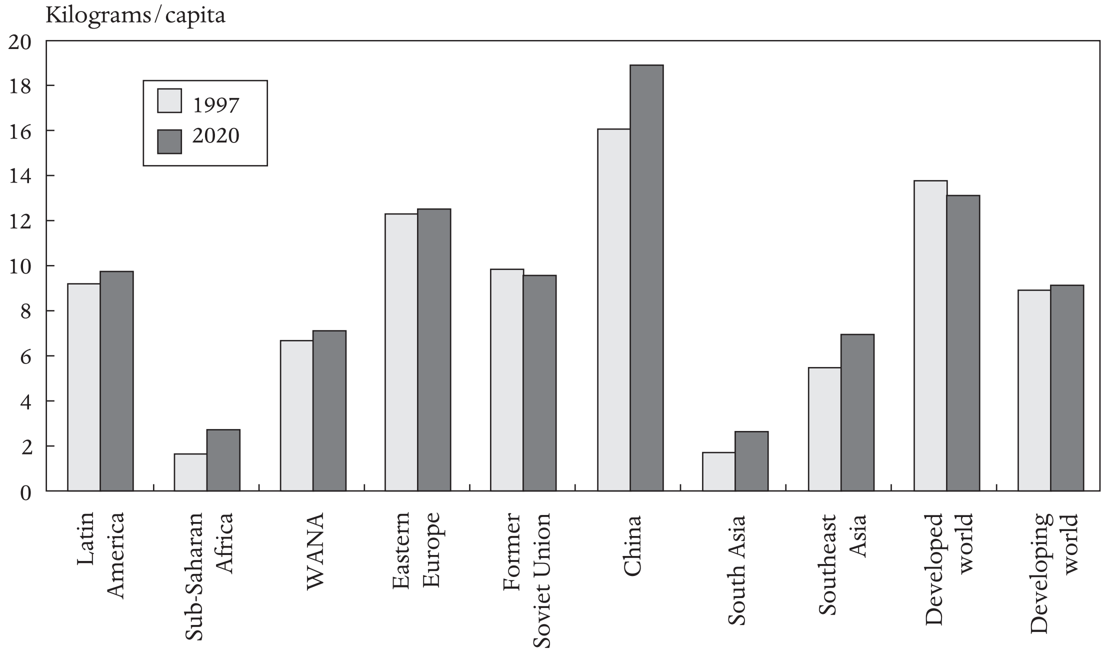

FIGURE 4.18 Per capita egg demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

will retain its position as the second largest agricultural exporter. Exports as a percentage of agricultural production will rise from 5 to 8 percent. The European Union's export status will switch from minor to major between 1997 and 2020. Net agricultural exports will represent 3 percent of total production in 2020. Finally, Southeast Asia, a major player in worldwide agricultural markets in 1997 with $6 billion in exports, will experience a decline of $1 billion. Thus the importance of its agricultural exports as a percentage of total agricultural production will decrease from 9 to 5 percent.

Among the agricultural importing regions, China will move past WANA to become the largest importer in the world of agricultural commodities in value terms by 2020. Chinese agricultural imports will increase from $5 billion to $22 billion by 2020. Chinese net agricultural imports as a percentage of total agricultural production will only increase from 2 to 6 percent, however, indicating the enormous size and continued rapid growth of China's agricultural sector. Growth in demand for oil crops, particularly for feed, will help boost its rapidly growing import bill.

WANA had by far the largest net agricultural import bill as a percentage of total agricultural production in the world in 1997 at 33 percent, but despite its large absolute increase in net agricultural imports, the share of total production will only rise to 34 percent by 2020.

South Asia will experience a drastic shift from being a small importer of agricultural products in 1997 to a major agricultural importer in 2020, translating into a substantial rise in net agricultural imports as a percentage of total agricultural production from 2 to 4 percent.

Sub-Saharan Africa's net agricultural import bill will rise a modest $3 billion between 1997 and 2020. Nevertheless, net agricultural imports will represent a substantial 9 percent

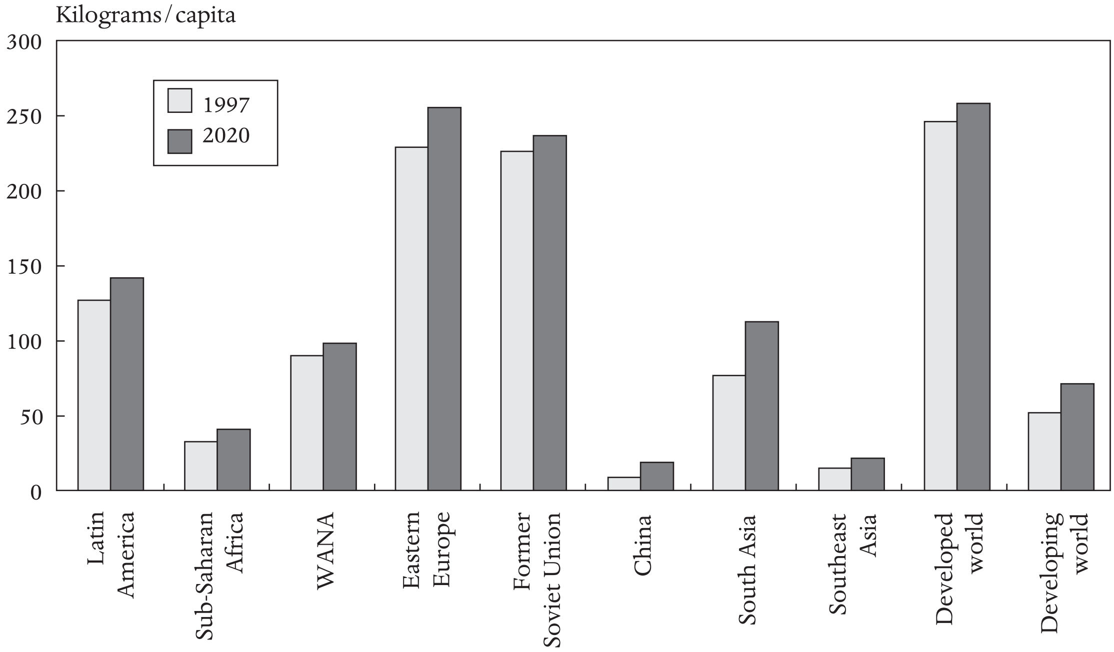

FIGURE 4.19 Per capita milk demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

of total Sub-Saharan African agricultural production in 2020, a slight increase.

Per Capita Calorie Availability

At 3,536 calories per day, an increase of 392 calories a day, China's per capita calorie availability will be higher than the average for the developed world by 2020 (Figure 4.20). Under the baseline scenario, per capita calorie availability will increase in all developing regions, from an average of 2,667 calories per capita in 1997 to 3,015 calories per capita in 2020. WANA and Sub-Saharan Africa, the two most import-dependent countries in 2020, will experience the smallest increases in per capita calorie availability at 156 and 211 kilocalories, respectively. But Sub-Saharan Africa will be in far worse shape: WANA will average 3,208 calories per person per day, compared with 2,442 calories in Sub-Saharan Africa. South Asia, primarily India, will also see large increases in kilocalorie availability at 610 additional calories.

Projections of the Number of Malnourished Children: Slow Progress

The number of malnourished children under the age of five in the developing world is projected to decline by only 21 percent from 166 million in 1997 to 132 million in 2020. An increase of child malnutrition in Sub-Saharan Africa of 34 percent, or 3 million children, is an indicator of a disturbing trend, particularly in the northern part of the region (Figure 4.21). All of the other regions will see declines in the number of children who are malnourished. China, at 54 percent, will have the largest decline, followed closely by Latin America, with a 52 percent decline. Although child malnutrition is expected to decline by 31 percent in South Asia, India will still be home to 44 mil-

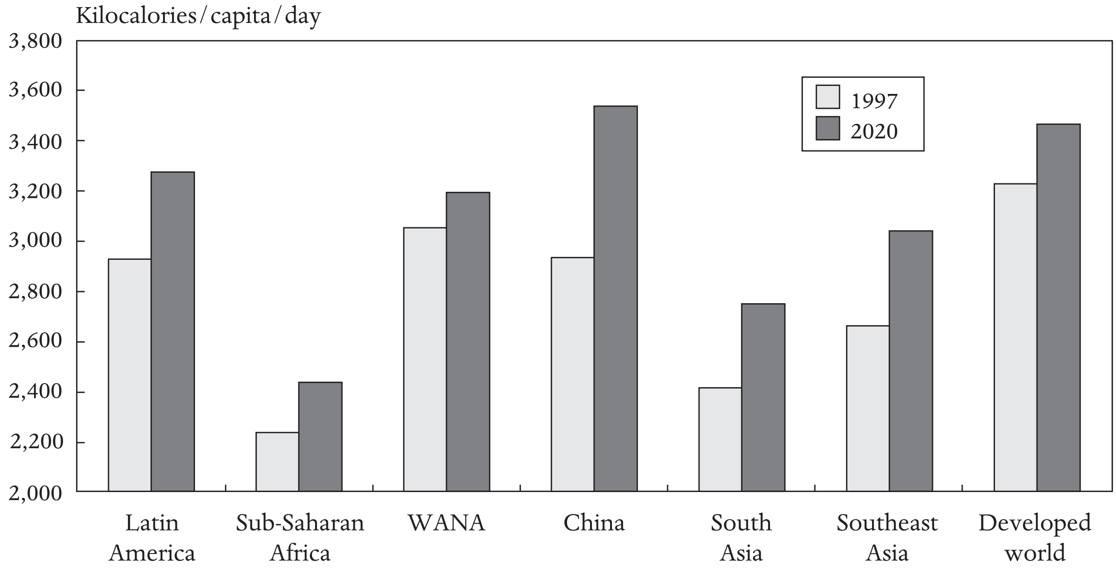

FIGURE 4.20 Daily per capita calorie consumption by region, 1997 and 2020

Source: IMPACT projections, June 2001.

lion malnourished children in 2020, representing 34 percent of the total in the developing world.

The regions with the highest prevalence of childhood malnutrition in the world, South Asia and Sub-Saharan Africa, will both see declines in the share of children under the age of five who are malnourished—South Asia of 10 percent and Sub-Saharan Africa, 4 percent (Figure 4.22). Although per capita kilocalorie availability is projected to be 426 calories higher in India than in Sub-Saharan Africa in 2020, the

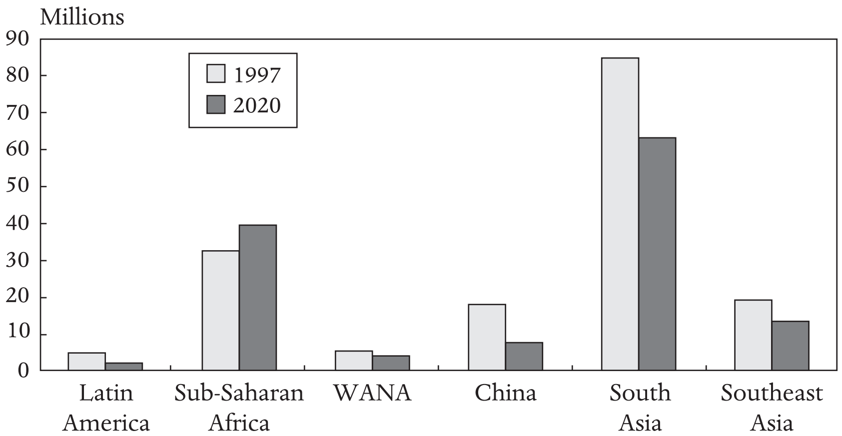

FIGURE 4.21 Number of malnourished children by region, 1997 and 2020

Source: IMPACT projections, June 2001.

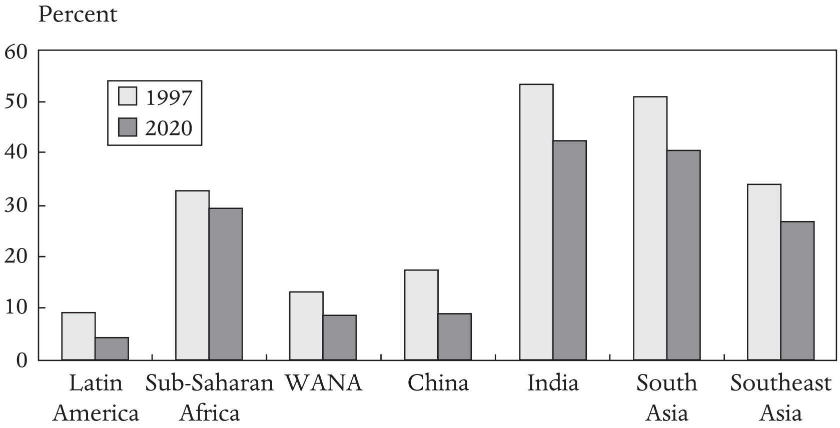

FIGURE 4.22 Malnourished children as a percentage of total children under five years by region, 1997 and 2020

Source: IMPACT projections, June 2001.

percentage of children who are malnourished will be 13 percent higher in India than in Africa. These figures indicate that aggregate food consumption is only one of many factors that determine rates of childhood malnutrition. The low status of women and limited female education in India relative to Africa are important contributors to the high relative levels of childhood malnutrition in India.

LAND AND WATER: LIMITING FACTORS TO GLOBAL FOOD SUPPLY?

The IMPACT baseline results show a future in which effective demand will be met in the context of constant or slowly declining prices, but also a future in which progress in reducing childhood malnutrition is very slow. In this section we assess whether land and water constraints will pose serious threats to long-term cereal production growth. We will also look at the effects of land degradation and conversion of land to urban uses on agricultural production and the effects of increasing water scarcity on future global food supply. This assessment not only demonstrates the plausibility of the baseline results with respect to land and water availability, it also indicates the risks of reduced investments and policy efforts, which could lead to heightened resource constraints (especially water supply), slow production growth, and significantly worse than projected outcomes in child malnutrition.

Cropland Potential and Land Loss to Urbanization

Crop area harvested totaled 1,500 million hectares in 1997, of which about 1,000 million hectares were in the developing world and 500 million hectares in developed countries (FAO 2000a). Cereal crop area harvested totaled 738 million hectares in 1997, with 258 million hectares in the developed world and 480 million hectares in the developing world. Under the baseline projections, cereal crop area is projected to expand by 46 million hectares between 1997 and 2020, almost all accounted for by developing countries. Roots and tubers and soybean area is projected to increase by another 16 million hectares. Can the existing land base support this projected increase in cereal crop area harvested?

In order to estimate cropland potential, the entire land area potentially convertible to agricultural uses must be taken into account. According to FAO (2000a), in 1994, total land resources were 13,044 million hectares, of which 1,353 million hectares were classified as arable land, 114 million as having permanent crops, 3,399 million as pasture, 4,172 million as forest and woodland, and 4,003 million hectares as other land, including built-on areas, roads, and barren land. Out of this area, Buringh and Dudal (1987) identified 700 million hectares as prime agricultural land and 2,600 million hectares with low or medium capability for crop production. This would yield a potential land area suitable for crop production of at least 3,300 million hectares, or a crop area potential about 1,800 million hectares above existing crop area.

As most of the currently cultivated land constitutes relatively good agricultural land, the productivity of other landforms convertible into cropland should be lower than the existing stock of land. Conversion may also eliminate forest and rangelands that now serve important functions. According to Kendall and Pimentel (1994), the world's arable land could expand at most by 500 million hectares, with productivity below present levels. About 87 percent of potential cropland is located in developing countries, mainly in Sub-Saharan Africa and Latin America. In Asia, on the other hand, nearly 80 percent of the potentially arable land is already under cultivation, and land for agricultural production is scarce in parts of China, Indonesia, and elsewhere (Plucknett 1995). Although global per capita arable land has been decreasing steadily—from 0.35 hectares in 1970 to 0.24 hectares in 1994—per capita area harvested has declined much more slowly—from 0.23 to 0.20 hectares in the same period. The ratio of crop area harvested to arable land, representing an aggregate cropping intensity index, has improved steadily over the past three decades worldwide, from 1.05 in 1970 to 1.20 in 1994, and from 1.28 to 1.56 for developing countries during the same period, making it less necessary to bring new land under cultivation (computed from FAO 2000a).

The world's urban population is expected to be 4.3 billion by 2020, implying an overall urban growth rate of 2 percent between 1995 and 2020, and 57 percent of the worldwide population will reside in urban areas, up from 45 percent in 1995. With urban populations expected to be nearly stable in Europe and North America during this period, approximately 90 percent of urban population growth will occur in developing countries. Roughly 185,000 people will be added to the urban population every day between 1995 and 2020. In China and much of the rest of Asia, the urban population's share of total population is expected to double over that time. Sub-Saharan Africa is expected to have almost half of its population living in urban areas by 2020; Latin America, 81 percent; and WANA, 68 percent (FAO 2000a).

There is no doubt that this rapid urbanization will remove some agricultural land from production. Indeed, the conversion of land from agricultural to higher-valued uses on the fringes of urban areas is part of the process of economic development, generating in most cases significant economic benefits (Crosson 1986). Strategies biased toward urban and industrial growth, together with the neglect of the agricultural sector, have also led to significant damage to prime agricultural land (Bhadra and Brandão 1993). However, there is little evidence that the process of converting land to urban uses poses a serious threat to future global food production. For developing countries, urbanization is expected to lead to the conversion of 476,000 hectares of arable land annually, a loss totaling 14 million hectares between 1990 and 2020 (USAID 1988). Meanwhile, the baseline projected increase in crop area harvested of 62 million hectares necessary to meet effective global food demand by 2020 is much lower than both the theoretical maximum additional potential crop area of 1,833 million hectares and the more realistic potential for economically feasible conversion of land resources to agricultural uses of 500 million hectares. A possible loss of 14 million hectares of agricultural land to urban uses in the developing countries appears small compared with potential expansions in crop area, but could eliminate highly productive land. The primary constraint to further crop area expansion is not a physical limit: rather, it is the projected flat or slowly declining real cereal prices that render expansion of cropland unprofitable in many cases.

Physical Limits to Crop Productivity

Global food production can rise either through expansion of cropping area and greater cropping intensity or through increases in agricultural productivity. Crop area harvested is expected to grow only slowly between 1997 and 2020, thus placing the burden for increases in agricultural productivity on higher yields. Are the projected 1997–2020 yield growth rates biologically achievable? Will agricultural productivity be able to keep up with global food requirements? Or are biophysical yield limits looming as a major constraint in the near future?

The earth's food production systems would reach biophysical limits when all agricultural land is being cultivated and irrigated at maximum potential yields, with remaining land suitable for grazing fully used. Maximum theoretical yields are calculated for specific crops as the highest limit of biological potential for a given location on the basis of photosynthetic potential, land quality, length of the growing season, and water availability. Maximum theoretical yields in grain equivalents calculated by Linneman et al. (1979) and Luyten (1995) range from about 7.6 tons per hectare per season in FSU to just over 8 tons per hectare per season in China, India, and the rest of South Asia, to in excess of 9 tons per hectare per season in Southeast Asia, Sub-Saharan Africa, North America, and Western Europe. Baseline yield levels simulated by IMPACT for 2020 are below maximum theoretical yields. Nevertheless, Cassman (1999) points out that these country average yields imply that the most productive cereal areas in northern India, southern China, and the North American plains will be approaching biophysical limits. Achieving consistent production at these high levels without environmental damage will require improvements in soil quality and farm management driven by continuing agricultural research investment (Cassman 1999).

Land Degradation

The most comprehensive assessment of global land degradation, by Oldeman, Hakkeling, and Sombroek (1991), classifies the main types of land degradation as soil erosion from wind and water, chemical degradation (loss of nutrients, soil salinization, urban-industrial pollution, and acidification), and physical degradation (compaction, waterlogging, and subsidence of organic soils). Out of the total land resource base, Oldeman, Hakkeling, and Sombroek estimate that 1,964 million hectares have suffered some degree of degradation. Water erosion accounted for 56 percent, wind erosion for 28 percent, chemical degradation for 12 percent, and physical degradation for 4 percent. However, chemical degradation was the prime culprit, accounting for 40 percent (an estimated 562 million hectares) of degraded agricultural land. Land degradation leads to reductions in crop yields, may reduce total factor productivity by requiring the use of higher input levels to maintain yields, may lead to the conversion of land to lower-valued uses, and may cause temporary or permanent abandonment of plots.

Crosson (1995), based on the analysis by Oldeman, Hakkeling, and Sombroek (1991), estimates the 1945–90 cumulative crop productivity loss from land degradation worldwide at approximately 5 percent, which is equivalent to a yield decline of 0.11 percent per year. While this loss is not insignificant, the impact of degradation was dwarfed by crop yield growth of 1.9 percent annually between 1967 and 1997. Nevertheless, crop yield losses due to past erosion show cumulative crop yield reductions that range from 2 to 40 percent across all African countries, with a mean of 8.2 percent for the entire continent and 6.2 percent for Sub-Saharan Africa (Scherr and Yadav 1996). These national-level estimates confirm that land degradation can be devastating in some countries, especially in fragile environments within country subregions. Moreover, while the estimated aggregate rates of yield loss from land degradation are not huge, increases in these rates as a result of poor policy or reduced investments could be a significant drag in the future, given the relatively low baseline projections for crop yield growth during 1997–2020.

Water and Irrigation

Between the 1950s and 1980s, irrigation expanded rapidly. It currently accounts for 72 percent of global water withdrawals and 90 percent of withdrawals in low-income developing countries. Dramatic yield increases during and after the Green Revolution were achieved, in large part, through the adoption of high-yielding varieties of wheat and rice, which depend on timely nutrient and pest control management as well as irrigation applications to secure and control soil moisture. Thus, irrigated agriculture was a major factor in achieving rapid growth in cereal yields during the peak and post–Green Revolution periods.

By the mid-1990s, irrigated agriculture supplied nearly 40 percent of world food production on 17 percent of total cultivated land. In India, for example, irrigated areas (one-third of total cropped area) account for more than 60 percent of total production. Irrigation also furthers stability through greater production control and wider scope for crop diversification. Moreover, in many developing countries, supplementary irrigation constitutes an important element of rural development policies, raising rural incomes and employment and permitting increased agricultural and rural diversification through secondary economic activities derived from extended and more varied agricultural production (as compared with rainfed agriculture) (Wolter and Burt 1997).

Thus, irrigation plays a vital role in achieving food security and sustainable livelihoods in developing countries, both locally, through increased income and improved health and nutrition, and nationally, by bridging the gap between production and demand. However, new irrigation development has slowed since the late 1970s due to escalating construction costs for dams and related infrastructure, low and declining prices of staple cereals, declining quality of land available for new irrigation, and increasing concerns over the environmental and negative social impacts of large-scale irrigation projects. Declining expenditures are reflected in the declining growth in crop area equipped for irrigation. According to FAO's FAOSTAT database (2000a), the annual growth rate in global irrigated area declined from 2.2 percent during 1967–82 to 1.5 percent during 1982–95. The decline was slower in developing countries, falling from 2.0 to 1.7 percent annually during the same period, with some recovery during the early 1990s.

In 1997, cereal harvested irrigated area was 218 million hectares, of which developed countries accounted for 42 million hectares and developing countries for 176 million hectares.[18] Reflecting both the slowdown in the expansion of irrigated area and the rapid growth of non-agricultural water use demand, cereal irrigated area is projected to grow under the baseline scenario to 248 million hectares, with an increase of only 1 million hectares in developed countries and 29 million hectares in developing countries. Rosegrant and Cai (2000), using a prototype model linking IMPACT to a global water simulation model, show that long-term food production growth is highly dependent on rates of growth in investment in irrigation and water infrastructure and improvements in water use efficiency. Water will likely be a major constraint to the achievement of food security in many developing countries in the future. This is especially true of the countries of Central and Western Asia, North Africa, and much of Sub-Saharan Africa, where population growth is expected to continue to be high and exploitable per capita water resources quite low. Water is important for food production not only because of direct effects on yields and cultivated area, but also because reliable water supplies induce farmers to invest in other essential crop inputs, such as improved germplasm, fertilizers, and capacity building for better resource management.

As this analysis indicates, the area and yield expansions projected under the IMPACT baseline fall within the realm of feasibility, although they may not be easily achievable. Since area under cultivation already constitutes a relatively high proportion of the most productive land, crop yields in these regions may suffer as agriculture expands onto increasingly marginal areas, simultaneously raising the risk of severe environmental damage. Shortfalls in investment in yield-enhancing technologies and in research into the optimal use of marginal agricultural land could lead to slower than projected growth rates of area and yields.

5

ALTERNATIVE GLOBAL SCENARIOS FOR FOOD SUPPLY, DEMAND, TRADE, AND SECURITY

As we approach 2020, the developing world will increasingly define the global food situation. The IMPACT projections confirm that demand for cereals, meat, and dairy products will increase rapidly in many developing regions. The fast growth of meat demand in Asia, for example, will pull cereal feed demand upward as well. At the same time, however, significant malnutrition will persist throughout the developing world, and trends will be particularly worrying in some regions. As earlier discussions on area expansion in Latin America and Sub-Saharan Africa and malnutrition in South Asia and Sub-Saharan Africa suggest, some trends may be inherently less predictable than others, hinging critically on fundamental assumptions about technology development and policy action. In South Asia, poverty is particularly intractable because population growth rates are so high. In Sub-Saharan Africa, the future is even less predictable because many African countries face major economic crises and political instability, as well as the HIV/AIDS epidemic. More concerted international and regional efforts must be made to improve the outlook for South Asia and to place Sub-Saharan Africa on a trajectory of sustainable growth.

Our baseline results reflect our best assessments of a wide range of underlying policy, technological, and behavioral assumptions. But baseline outcomes may change significantly in the face of a range of realistic but widely varying policy strategies and development paths for key drivers of the global food economy. Investments in agriculture, water resources, and social sectors may decline, and slow progress on economic policy reform may dampen income growth. Alternatively, policymakers may take more aggressive steps toward improving agriculture and other rural economic sectors, boosting investment, and accelerating the pace of policy reform.

Real causes for concern over the future of crop yield growth rates, outlined more fully below, lead to the almost unavoidable conclusion that yield growth will be slower in the future than it has been in the past in most regions—an assumption already incorporated in the baseline projections. Nevertheless, the prospects for future yield performance remain unclear. They will depend significantly on (1) trends in public and private sector agricultural research investment, (2) the capacity for ongoing agricultural research to push in controversial new directions (such as biotechnology) in an increasingly watchful international environment, (3) continued investment in irrigation infrastructure, and (4) the rate of yield loss from environmental degradation. Worse than expected performance in any of these areas could cause even larger yield growth decline than projected under the baseline scenario.

From among many potential scenarios assessing sources of variability in the world food situation, we focus on two sets of scenarios: one set exploring changes at the global level, the other set examining changes in a number of variables specific to Asia and Sub-Saharan Africa. Among the global trends, the scenarios that follow will assess the potential effects of (1) slower population growth rates, (2) varying rates of yield growth, (3) higher livestock productivity, and (4) full trade liberalization in 2005–06. Among our regional scenarios, two will focus on Asia, with one scenario assessing the impacts of slower agricultural growth in India and China and another scenario simulating the effects of higher feed ratios due to rapid industrialization of the livestock sector. Two other scenarios will focus specifically on Sub-Saharan Africa, presenting an optimistic and pessimistic future for that region, while a final regional scenario will simulate the effects of dramatically higher meat demand growth in India. Last, we will present two alternative growth and investment scenarios for the world in 2020: one containing a series of investment declines, combined with slower policy reform; the other consisting of increased policy efforts and investments in agriculture, irrigation and water, and social sectors. Strikingly, policies and investments that moderately disfavor agriculture and rural development lead to much worsened food security vis-à-vis the baseline, while policies that move aggressively to strengthen agricultural and economic policy reform yield much improved—though far from utopian—outcomes. Together, the alternative scenarios and the baseline establish a range of possible pictures of the world food situation in 2020 that are vastly different in terms of human suffering and that are highly dependent on decisions made by policymakers.

OVERVIEW OF GLOBAL SCENARIOS

What if population growth rates, often touted as the chief underlying cause of food insecurity, were to slow more dramatically than expected? Would world food problems vanish? Will a technology revolution succeed in achieving higher levels of yield growth, or will environmental damage and other factors mean much slower yield growth over the projections period? With meat consumption on the rise, are prospects for higher production via increased efficiency of feeding ratios promising? In short, how different would the world food picture in 2020 be under alternative scenarios for crop and meat productivity growth? IMPACT results for these global scenarios point to areas where policy action must focus to enhance future world food prospects.

Low Population Growth

Introduction. Many who paint a dire scenario of human existence in the year 2020 point to high population growth rates in the developing world as the main force behind continued malnutrition and environmental degradation in many regions. Were population growth rates to slow more quickly than baseline projections indicate and instead follow a slower growth path, would food security problems vanish? In this chapter, under the IMPACT low population growth scenario, we assess the effects of replacing the United Nations' (UN) medium population growth assumptions with their low population growth assumptions in an effort to determine the effects of low population growth on food security.

Alternative UN population projections to 2020 tend to cluster fairly close together because the momentum inherent in the current young age structure will be the primary factor behind future population growth everywhere except Europe, where the population tends to be older, and Africa, where high fertility is the dominant factor. Within the almost assured range, however, population growth rates may vary as the ongoing demographic transition in the developing world toward relatively low fertility and mortality takes unexpected turns (Bongaarts and Bulatao 1999). Uncertainty about the pace of the demographic transition in developing countries remains a caveat behind all population projections, with the large fertility decline since the 1960s representing one surprising past trend. The potential future impact of the AIDS epidemic injects a particularly important source of uncertainty into population projections. Caldwell (2000), for example, states that "AIDS has probably reduced the world's current annual population growth rate from 1.5 to 1.4 percent." The effects of AIDS on population growth in certain regions, such as Sub-Saharan Africa, will be considerably more substantial. (See the subsequent sections on Sub-Saharan Africa.)

Population growth affects both future food demand and supply. The effects of population growth on the demand side are fairly clear, with an exogenous increase in population growth at constant aggregate income levels implying lower per capita income and food consumption. The effects of population growth on food production are generally less clear and highly dependent on context. The size and composition of the labor force, speed of technical innovation, and extent of environmental degradation all represent potential avenues through which population growth can influence food production (Srinivasan 1988). Pessimists (Brown and Kane 1994; Ehrlich, Ehrlich, and Daily 1993), guided by the belief that many current agricultural practices are unsustainable and that the limits of further expansion of agriculture have already been reached or exceeded, generally focus on the potentially negative effects of exogenous population growth on the environment—hence crop yields—through soil degradation and erosion (Srinivasan 1988; Bongaarts 1996). Ruttan (1994), surveying the link between population and food in a number of countries, noted several factors frequently limiting the flexibility of farmers to respond to rising population densities: (1) the resistance of yield ceilings to further increases, (2) the falling incremental response of yields to higher fertilizer use, (3) the increasing cost of irrigation expansion, and (4) the limited capacity of research and extension institutions (cited in Ahlburg 1998). Where these conditions hold true, slower population growth could relieve the pressure on the natural environment and reduce the strain on institutions and coping mechanisms in regions threatened by high population densities.

Optimists such as Simon (1981), on the other hand, stress the role of population growth in encouraging Boserupian-style technological innovation, countering the static analysis of the pessimists with an emphasis on the dynamism of individual economic actors under changing circumstances. The history of agricultural development shows that the relative proportions of land and labor endowments, nonagricultural demand for labor, and the demand for final agricultural products influence technical change in agriculture. As

Boserup (1981) noted, farmers will adjust to growing land scarcity by intensifying land use through reductions in fallow periods, increased land investments, and implementation of more advanced farming techniques. Historically, countries in Asia with high population density have responded to land scarcity through the development and implementation of biological and chemical technologies as well as substantial expansion of irrigation infrastructure (Pingali and Binswanger 1988). A body of work (Ruttan and Hayami 1984; Hayami and Kikuchi 1983) provides empirical support for the claim that population growth tends to spur innovation through the response of technical and institutional change to emerging scarcities, and that, conversely, slower population growth tends to slow the pace of innovation (Srinivasan 1988). More recently, Bongaarts (1996) found strong positive effects from higher population density on crop yields in both longitudinal and cross-sectional data, indicating that farmers do respond to high population densities in a Boserupian fashion. In a study of slowing population growth in Northern India, Evenson (1988) found that the loss of Boserupian-induced structural change reduced the real income gains from slower population growth by 36 percent.

The evidence for the impact of population growth on agricultural growth and crop yields is thus mixed. Empirical evidence measuring the impact of population growth on general economic growth is also mixed. Pritchett's (1996) study of the impact of population growth on overall economic development concludes that the capital stock is dynamically related to population growth, but it also finds a slight negative relationship between the residual of output not accounted for by factor accumulation and population growth. In the face of such contradictory evidence, and given the relatively small changes in population growth between the baseline and low population scenario, we take a moderate position. As a result, our low population growth scenario assumes no second-order effects on aggregate income and crop yields from slowing population growth other than those that operate through international prices. Thus, aggregate income growth is maintained at the baseline rates, resulting in an increase in per capita income growth under the low population scenario.

Projections. The low population growth scenario reduces the world population in 2020 from an estimated 7,456 million people to 7,068 million people, a decline of 388 million people. Southeast Asia has the highest percentage change—a 7 percent decline—from the total under the UN's medium scenario (Table 5.1). The decline of 109 million people in South Asia represents 28 percent of the total worldwide decline in projected population. Under the UN's low growth scenario, the projected population of the developing world as

TABLE 5.1 UN medium and low population projections in 2020, by region

Region	Medium UN projection	Low UN projection	Change
		(millions of people)	
South Asia	1,780	1,671	109
Southeast Asia	649	604	45
East Asia	959	914	45
Sub-Saharan Africa	1,545	1,477	68
Latin America	652	613	39
West Asia/ North Africa	505	483	32
Developing world	6,096	5,757	339
Developed world	1,361	1,311	50

Source: IMPACT projections, June 2001.

TABLE 5.2 Per capita cereal and meat demand under various UN population projections in 2020, by region

Cereal demand				
Region	Medium UN projection	Low UN projection	Change	Percentage change
	(kilograms/capita)			*(percent)*
South Asia	198	204	6	3.0
Southeast Asia	254	261	8	2.8
East Asia	384	394	11	2.6
Sub-Saharan Africa	163	171	7	4.9
Latin America	323	339	16	5.0
West Asia/North Africa	387	399	12	3.1
Developing world	275	284	9	3.3
Developed world	604	620	15	2.6
Meat demand				
Region	Medium UN projection	Low UN projection	Change	Percentage Change
	(kilograms/capita)			
South Asia	8.9	9.4	0.5	5.6
Southeast Asia	28.7	30.3	1.6	5.6
East Asia	70.3	73.3	3.0	4.3
Sub-Saharan Africa	11.7	12.5	0.8	6.8
Latin America	68.9	73.0	4.1	6.0
West Asia/North Africa	25.7	27.0	1.3	5.1
Developing world	34.9	36.7	1.8	5.2
Developed world	84.0	86.0	2.0	2.4

Source: IMPACT projections, June 2001.

a whole will decline 6 percent, by 339 million people.

Slower population growth would have a modest impact on per capita cereal and meat consumption (Table 5.2). Per capita cereal consumption would increase 3 percent above the baseline level in both the developing and the developed world, with the highest percentage increases occurring in Latin America and Sub-Saharan Africa. Per capita meat consumption would increase by a similarly modest 5 percent in the developing world and 2 percent in the developed world. All developing regions would have per capita meat production increases of 5 to 6 percent, except for East Asia, where the increase in consumption would be slightly lower, and Sub-Saharan Africa where meat consumption would increase by 7 percent. East Asia's baseline projections are slightly more robust in the low population growth scenario because China's one-child policy has already slowed population growth rates significantly below levels in other developing regions.

TABLE 5.3 Cereal prices under various UN population projections in 2020

Crop	Medium UN projection	Low UN projection	Percentage change
	(US$/metric ton)		*(percent)*
Wheat	123	109	11
Maize	102	93	9
Rice	250	212	15
Other coarse grains	86	77	10

Source: IMPACT projections, June 2001.

Projected cereal prices under the low population growth scenario shift significantly more from their baseline levels than does per capita consumption (Table 5.3). Rice prices are the most elastic, declining 15 percent in 2020, while maize is the least elastic with a price decline of 9 percent from the baseline level. These price declines affect yields in turn by reducing incentives to farmers to invest in production, with cereal yields falling by 0.1 ton per hectare in Latin America, WANA, South Asia, and East Asia (Table 5.4). Cereal yields in Southeast Asia and Sub-Saharan Africa drop by less than 0.1 tons per hectare.

TABLE 5.4 Cereal yields in various regions under medium and low UN population projections in 2020

Region	Medium UN projection	Low UN projection
	(metric tons/hectare)	
South Asia	2.5	2.4
Southeast Asia	3.0	3.0
East Asia	5.5	5.4
Sub-Saharan Africa	1.4	1.4
Latin America	3.7	3.6
West Asia/North Africa	2.6	2.5
Developing world	3.1	3.0
Developed world	4.0	3.9

Source: IMPACT projections, June 2001.

Dramatic declines in the number of malnourished children under the age of five in the developing world will occur under the low population growth scenario. Per capita kilocalorie consumption under the low population growth scenario will increase by 88 kilocalories above baseline levels, with Latin America leading the way with an increase in per capita consumption of 109 kilocalories (Table 5.5). Not only is the population under five smaller, but consumption of calories per capita is higher due to lower food prices and higher incomes resulting from lower population growth. The number of malnourished children in the developing world is projected to drop by an additional 29 million under the low population growth scenario, to 102 million malnourished children in 2020 (Table 5.6). While this number is still unacceptably high, a 28 percent decline in child malnourishment is truly remarkable; it reveals the extent to which high population growth in impoverished regions adds millions of children to populations that are already highly food stressed and unable to cope with the additional burden.[19] South Asia stands out in this analysis: under the low population growth scenario, child malnourishment in that region drops 25 percent (16 million children) below baseline levels. Unfortunately, even low population growth rates cannot reverse the tragic trend of increasing absolute numbers of malnourished children in Sub-Saharan Africa, where despite a 15 percent decline (6 million malnourished children) from baseline levels, the number of malnourished children will still increase from 33 to 34 million children by 2020.[20]

The results show that per capita consumption of cereal and meat products and cereal

TABLE 5.5 Total per capita kilocalorie availability under UN population projections in 2020, by region

Region	Medium UN projection	Low UN projection	Change
		(kilocalories/capita)	
South Asia	2,755	2,838	83
Southeast Asia	3,036	3,122	86
East Asia	3,500	3,587	87
Sub-Saharan Africa	2,442	2,530	88
Latin America	3,274	3,383	109
West Asia/North Africa	3,208	3,283	75
Developing world	3,015	3,103	88
Developed world	3,462	3,523	61

Source: IMPACT projections, June 2001.

prices certainly react to changes in population growth projections, but these adjustments do not dramatically modify the broad food supply and demand situation in 2020 painted by the baseline analysis. South Asia and particularly Sub-Saharan Africa will still lag behind other developing regions in per capita food consumption. The developed world benefits more than the developing world from low population growth because levels of per capita consumption are so much higher in the developed world that much lower percentage increases in

TABLE 5.6 Number of malnourished children under UN population projections in 2020, by region

Region	Medium UN projection	Low UN projection	Change
		(millions of children)	
South Asia	63.3	47.6	15.7
Southeast Asia	14.0	10.3	3.7
East Asia	8.5	6.2	2.3
Sub-Saharan Africa	39.3	33.7	5.6
Latin America	2.5	1.5	1.0
West Asia/North Africa	4.0	3.0	1.0
Developing world	131.5	102.3	29.2

Source: IMPACT projections, June 2001.

per capita consumption still lead to higher absolute increases than in the developing world.[21] Nevertheless, while population growth rates may not dramatically affect the food security of populations in the aggregate, lower population growth rates significantly reduce childhood malnutrition. Dramatic declines in childhood malnutrition across all developing regions—but particularly South Asia—under the low population growth scenario argue strongly for continued efforts to encourage voluntary use of contraception and family planning services in developing countries. Beyond the narrow focus on population growth, however, these results also point to the importance of institutions that both lower the environmental costs of high population density and encourage technology uptake in farming systems undergoing the process of population-induced innovation in farming techniques.

Low-Yield and High-Yield Growth Rate Scenarios

Introduction. Declining yield growth rates over the last two decades have generated much concern about the future of agricultural production. For a number of reasons, however, dire predictions regarding the imminent collapse of agricultural yield growth rates should be received skeptically. First, declining yield growth rates can be consistent with long-term linear increases in cereal yields and may simply reflect constant unitary increases over an increasing base level. Second, as the share of lower-yield regions in world agricultural production grows, the aggregate worldwide yield growth rate may decline even if yield growth rates in each individual region do not (Dyson 1996).[22] However, despite these important structural elements behind declining yield growth rates, several worrisome trends are evident, particularly the fact that yield growth rates have clearly slowed somewhat at the regional level. It appears that many yield gains in recent decades can be attributed to advances that may not be replicable, including higher crop planting density through changes to plant architecture, higher usable food product weight as a fraction of total plant weight, multiple harvesting, introduction of strains with greater fertilizer responsiveness, and better management practices. Crop yields may be approaching their physical limits in many high-yield systems, primarily in developed countries. For example, the maximum yield potentials of rice and maize have changed little over the past three decades (Fedoroff and Cohen 1999)

These real causes for concern lead to the almost unavoidable conclusion that crop yield growth rates will be slower over the projections period than they have been in the past. The vast number of factors that will determine yield growth to 2020 include (1) rates of fertilizer and pesticide application, (2) the pace of research investment and advances in biotechnology, (3) physical and human capital development, and (4) the degradation and misuse of the natural resource base, with soil erosion and water shortages particularly relevant.

Rapid factor accumulation is often downplayed in discussions about the new seed technologies that represent the most visible catalyzing agent for the Green Revolution. As Murgai (1999) reports, however, fertilizer and capital input accumulation—rather than growth in total factor productivity (TFP)—were responsible for the preponderance of yield growth in the Punjab region during the actual period of adoption of high-yielding varieties between 1965 and 1973; TFP growth only accelerated rapidly between 1974 and 1984. Mundlak, Larson, and Butzer (1997) also find in a cross-country analysis of the determinants of agricultural production that capital accounts for about 40 percent of total output in the core technology. They conclude that "agricultural technology is cost-capital intensive compared to nonagriculture." These results reinforce the oft-made observation that the key to sustainable yield growth is not a "silver bullet" technological breakthrough, but rather dynamic interactions among a number of individual factors—a caveat that must be kept in mind when assessing the potential benefits of biotechnology (Pinstrup-Andersen and Cohen 2000). Dynamic interactions are also not necessarily benign; while agricultural research and high input applications hold the key to boosting—or even stabilizing in some particularly high-stress regions—crop yields in environmentally fragile areas, the negative repercussions on the environment of high rates of input application are already apparent in many parts of Asia. Only time will tell, but the unavoidable conclusion is that worse than expected performance in any of the key areas could cause even larger yield growth declines than under the baseline scenario.

TABLE 5.7 Percentage of baseline yield growth rates achieved and cereal yields realized under high- and low-yield scenarios, 2020

Scenario	Developed world	Developing world
Share of baseline growth rate	*(percent)*	
Low-yield 1	60	80
Low-yield 2	50	60
High-yield 1	110	120
High-yield 2	120	140
Cereal yields	*(metric tons/hectare)*	
Low-yield 1	3.8	2.2
Low-yield 2	3.8	2.1
High-yield 1	4.0	3.1
High-yield 2	3.9	3.4

Source: IMPACT projections, June 2001.

Projections. In order to assess the sensitivity of cereal prices to yield growth rates, we modeled four alternative yield scenarios and charted the projected price trends for the four cereals over the 23-year period between 1997 and 2020. One possible general trend over the coming years involves significant declines in the resources available for agricultural research and irrigation development. We assess this trend in the IMPACT model for two separate scenarios, both of which assume no growth in irrigated area during the projections period. Additionally, the first low-yield scenario assumes a decline in specified yield growth rates for meats, milk, and all crops in the developed world of 40 percent from the baseline level, and a decline of 20 percent in all developing regions. The second low-yield scenario assumes a decline in specified yield growth rates of 50 percent from baseline assumptions in the developed world and 40 percent in the developing world. Table 5.7 summarizes these assumptions.

But it is also possible that potential threats to world agricultural production will galvanize governments, multilateral institutions, and private firms into increasing their investments into agricultural research and irrigation, thus leading to significant yield increases and expansion of irrigation infrastructure. IMPACT high-yield scenarios assume an increase in the expansion of irrigated area of 1 percent per year greater than the baseline growth rate. Additionally, the first high-yield scenario assumes an increase in specified yield growth rates for livestock, milk, and all crops of 10 percent above baseline assumptions in the developed world and 20 percent in the developing world. The second high-yield scenario assumes an increase in specified yield growth rates of 20 percent above baseline growth rates in the developed world and 40 percent in the developing world.

Our low-yield scenarios thus envision a greater downside for yield growth rates in the developed world than in the developing world. This assumption meshes with empirical observations showing that recent worldwide yield slowdowns are largely the result of trends in the developed world, where crop yields are highly sensitive to price incentives and the ongoing removal of agricultural protection (Dyson 1996). Overall, crop yields in the developed world are also closer to ceiling levels than yields in the developing world. Similar considerations underlie our assumption that the upside for yields in the developing world is greater than the upside for yields in the developed world. In much of the developing world the gap between current crop yields and yield ceilings offers greater room for substantial increases given appropriate incentives and investments.

It should be noted that IMPACT simulations lead to changes in realized yields different from those that would result from straight-line calculations made from the initially specified yield growth rates, because the model captures the feedback effects between changes in yields and output prices.[23] For example, if cereal yield growth assumptions are lower than the baseline, cereal prices increase relative to baseline prices, which subsequently leads to partially countervailing increases in cereal yields (and area) in response to higher price incentives. Thus, developing-country cereal yields in 2020 under the first low-yield scenario will only decline to 2.2 tons per hectare from the baseline 2020 projection of 3.1 tons per hectare, and developed-country cereal yields will decline from 4.0 to 3.8 tons per hectare. Under the second low-yield scenario, realized developing-country cereal yields will decline to 2.1 tons per hectare, while realized developed-country yields will decline to 3.8 tons per hectare. As for the high-yield scenarios, realized developing-country cereal yields under the first high-yield scenario will improve to 3.1 tons per hectare, while developed-country yields will remain at 4.0 tons per hectare. Under the second high-yield scenario, realized developing-country yields will improve to 3.4 tons per hectare, while developed-country yields will actually decline to 3.9 tons per hectare due to countervailing price declines (Table 5.7).

Changes in the rate of growth of crop yields have huge impacts on projected cereal prices. Wheat prices increase by 20 percent under the first low-yield scenario. Rice prices increase by 34 percent and maize prices by 22 percent above the baseline 2020 price under this same scenario (Table 5.8).

The second low-yield scenario presents an additional decline in yield growth rates from

TABLE 5.8 Cereal prices under baseline and various yield scenarios in 2020

Crop	Low-yield 1	Low-yield 2	Baseline	High-yield 1	High-yield 2
			(US$/metric ton)		
Wheat	148	164	123	106	92
Maize	124	140	102	87	75
Other coarse grains	107	122	86	72	62
Rice	334	392	250	193	156

Source: IMPACT projections, June 2001.

those predicted in the first low-yield scenario, and prices react accordingly. Wheat prices increase by 33 percent above the projected 2020 price under the baseline scenario. Other grain prices react similarly. Rice and maize prices are the hardest hit, increasing 57 and 37 percent above 2020 projected baseline prices to $392 per ton for rice and $140 per ton for maize.

Prices for all crops decline under the high-yield scenarios, although the individual cereals have significantly varying sensitivity to yield growth rate changes. Under the first high-yield scenario, cereal prices decline from projected prices in 2020 under the baseline scenario by 15 to 24 percent. Price trends under the second high-yield scenario are higher in magnitude but similar in form to those under the first high-yield scenario. Prices under the second high-yield scenario decline relative to projected 2020 prices under the baseline scenario by 26 percent ($27 per ton) for maize, 25 percent ($31 per ton) for wheat, 28 percent ($24 per ton) for other grains, and 38 percent ($94 per ton) for rice.

As these projections indicate, yield growth will play an important role in ensuring even the mild declines in cereal prices projected by the IMPACT baseline, with changes in yield growth rates at the margins exercising a significant influence on international cereal prices. Rice prices are particularly sensitive to the low-yield growth scenario because a high proportion of rice is produced in developing countries, which are affected the most under this scenario. Clearly, the rates of crop yield growth achieved over the next few decades—and therefore rates of investment growth for agricultural research and infrastructure development—will fundamentally determine the price of food for the poor.

One particular point worth noting is that the developing countries cannot rely on the developed world to supply the preponderance of their future food needs. Trade will be an important component of food security in the developing world into the next century, but trade cannot substitute for well-targeted and well-funded investments in domestic food production as well as proper policies that provide incentives to local farmers. Production shortfalls due to changing incentives and policies in the developed world could have significant price implications and a devastating impact on the poor if the degree of food dependency in the developing world is too high. Additionally, the potential upside of investments in agricultural production are higher in the developing world, with the empowerment of local research capacity in developing countries necessary to ensure the widespread diffusion of technologies from the developed to developing worlds. Historically, rates of return to agricultural research in the developing world have been tremendous; in a meta-analysis, Alston et al. (2000) found median rates of return ranging from a low of 34.3 percent in Sub-Saharan Africa to a high of 49.5 percent in Asia and the Pacific. Even if these high rates of return are discounted significantly, they still indicate considerable underinvestment in crop research in the developing world. Local research can be particularly relevant to the pace at which local farmers appropriate available technologies. For example, Murgai (1999) points out that the difference between early and late adopters of Green Revolution technologies in the Punjab region of India was probably due to their proximity to Punjab Agricultural University in Ludhiana and access to extension programs in the central districts.

Higher Livestock Productivity via Lower Feeding Ratios

Introduction. Rapid meat demand growth is already prompting greater production efficiency, but what if feed ratios were reduced through improved technology to allow for greater feedgrain efficiency in meat production? Would falling feed ratios dramatically reduce international cereal prices, and if so, what impact would lower cereal prices have on food security and the incidence of childhood malnutrition in the developing world? The low feed ratio alternative scenario will explore the potential ramifications for livestock production and prices, grain prices, and cereal food consumption of a decline in feed ratios of 5 percent in the developing world and 10 percent in the developed world, compared with the projected levels in 2020 under the baseline.

As was shown in the historical section, in recent years feed usage has declined in importance as a driving factor behind overall cereal demand growth. While overall food demand grew 21 percent between 1984/86 and 1995/97, feed demand for cereals only rose 8 percent during this period. Meanwhile, worldwide meat production rose 34 percent; milk production, 5 percent; and egg production, 54 percent (FAO 2000b). Lagging growth in cereal feed demand represented a departure from the previous 10-year period, when feed demand increases trended much more closely to food demand increases. A number of factors—outlined fully in the historical section of this volume—have played a role in slowing feed demand, including price trends in cereal markets, substitution of oil crops for cereals, higher productivity in the meat production sector itself, and the sharp downturn in the livestock sector in the transition economies of Eastern Europe and the FSU.

The projected annual growth in feed demand under the baseline scenario of 1.5 percent worldwide between 1997 and 2020 is slightly lower than the projected annual growth in meat production of 1.8 percent over the same period, but it still represents substantial recovery from the slow rates of growth achieved between 1984/86 and 1995/97 (FAO 2000b). The higher growth rate in feed demand is largely because most additional meat production between 1997 and 2020 will occur in the developing world, where annual growth rates in meat production will average 2.8 percent, compared with 0.7 percent in the developed world. It is thus not surprising that feed demand growth is projected to average 2.7 percent a year in the developing world and 0.7 percent in the developed world.

Based on a number of factors, we conclude that feed demand growth will be rapid over this period. First, livestock production in the developing world, especially Asia, will increasingly shift toward higher cereal intensity and industrialized systems. Second, the shift toward poultry production in the developed world over the last 20 years has already gone through its most rapid growth phase, with poultry production already surpassing beef and veal output. It will be muted by the increasing dominance of the developing world in worldwide meat production (Smil 2000). Thus, whereas worldwide annual growth in poultry production averaged 5.0 percent between 1982 and 1997, it will only average 2.6 percent between 1997 and 2020. Third, consumer preference for leaner animals is increasingly driving meat production in the developed world, and leaner animals are inherently less efficient to produce. Historically, this trend has been most evident in the pork sector, where the feed-to-meat production ratio actually increased between 1930 and 1997, but it will become increasingly evident in other livestock sectors as well (the growing popularity of free-range chickens, for example) (Smil 2000).[24]

Nevertheless, it is possible that advances in feeding efficiency could lead to significant declines in meat production feed ratios, especially if the developing world experiences a shift in meat preference toward poultry similar to what occurred in the developed world over the last two decades of the twentieth century. Techniques to improve feeding efficiency include better processing of concentrates and roughage feeds and the use of additives like supplementary amino acids. Other factors that could contribute to lower cereal feed ratios include continued strong growth in the use of oilcrops for feed and use of other alternatives such as bananas, as well as the possibility of a slowdown in the commercialization of Asian livestock production (Smil 2000; Hoffman 1999). The pace of income growth and overall economic development in Asia over the next 20 years will play an essential role in determining the extent of industrialization and commercialization of livestock production (Steinfeld and Kamakawa 1999).

Projections. Lower feed ratios under this scenario result in lower livestock prices than the baseline (Table 5.9). Poultry prices are most affected by the low feed ratio scenario, with prices falling 8 percent from the baseline level in 2020. Pork and beef prices will decline 4 percent and sheep and goat prices by only 2 percent. Dairy products are similarly affected, with egg prices falling 7 percent and milk prices 3 percent. These price declines will boost meat demand worldwide: poultry demand will increase 4 percent; pork, 3 percent; and beef, 2 percent (Table 5.10).

More significant price responses take place in the grains sector, where the decline in

TABLE 5.9 Meat prices under the baseline and low feed ratio scenarios, 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**Low feed ratio**
		(US$/metric ton)	
Beef	1,808	1,740	1,670
Pork	2,304	2,239	2,123
Sheep and goat	2,918	2,832	2,764
Poultry	735	703	644
Eggs	1,231	1,191	1,111
Milk	318	289	281

Source: IMPACT projections, June 2001.

TABLE 5.10 Meat and dairy demand under the baseline and low feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**Low feed ratio**
		(million metric tons)	
Beef	57	85	87
Pork	83	119	122
Sheep and goat	11	17	17
Poultry	57	105	109
Eggs	51	67	69
Milk	545	768	777

Source: IMPACT projections, June 2001.

TABLE 5.11 Cereal prices under the baseline and low feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**Low feed ratio**
		(US$/metric ton)	
Wheat	133	123	106
Maize	103	102	73
Other coarse grains	97	86	61
Rice	285	250	233

Source: IMPACT projections, June 2001.

derived demand for maize leads to a steep 28 percent decline in the maize price (Table 5.11). Reverberations of this price decline reach the food sector, particularly in the developing world, where food demand for maize climbs 10 percent (13 million tons) above the baseline level, thus partially counteracting the effects on total demand of sharply lower feed demand. Food demand increases are particularly high in Sub-Saharan Africa at 11 percent, Latin America at 7 percent, and South Asia at 3 percent. Although prices of all cereals decline, total demand for cereal crops decreases by 4 percent worldwide, with demand falling for maize and other coarse grains but not for wheat and rice (Table 5.12).

The low feed ratio scenario has a notable impact on regional cereal trade patterns (Table 5.13). Cereal imports increase sharply in South Asia and Sub-Saharan Africa as low food prices stimulate food demand, and the relative unimportance of the livestock industry in these regions mutes the countervailing influence of lower feed ratios. Compared with the 2020 baseline, net imports into Sub-Saharan Africa increase by 89 percent, and those into South Asia rise by 81 percent. Those regions with larger livestock sectors see their net imports decline, in some cases significantly. Reduced feed demand has its largest impact on cereal imports into East and Southeast Asia. Net imports into Latin America fall 100 percent to achieve trade balance, albeit from a very low base. WANA, the largest cereal importer in the world in 2020, will see net cereal imports drop 8 percent. Interestingly, cereal trade in the developed world responds only minimally to the low feed ratio scenario, with net exports rising just 1 percent.

These results indicate that significant advances in the efficiency of feed ratios would have moderate effects on livestock demand and

TABLE 5.12 Total cereal demand under the baseline and low feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Region	**Base year**	**Baseline**	**Low feed ratio**
	(million metric tons)		
Developed world	725	822	770
Developing world	1,118	1,765	1,623
Latin America	138	211	196
Sub-Saharan Africa	83	156	170
West Asia/North Africa	129	196	185
South Asia	238	353	362
Southeast Asia	114	165	161
East Asia	415	594	549

Source: IMPACT projections, June 2001.

TABLE 5.13 Net cereal trade under the baseline and low feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Region	**Base year**	**Baseline**	**Low feed ratio**
	(million metric tons)		
Developed world	104	202	204
Developing world	750	1,040	1,076
Latin America	−15	−3	0
Sub-Saharan Africa	−13	−27	−51
West Asia/North Africa	−45	−73	−67
South Asia	−3	−21	−38
Southeast Asia	−7	−9	−6
East Asia	−21	−67	−42

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE 5.14 Cereal food demand under the baseline and low feed ratio scenarios in 1997 and 2020

Region	*1997* Base Year	*2020* Baseline	Low feed ratio
	(million metric tons)		
Developed world	170	182	184
Developing world	750	1,040	1,076
Latin America	60	82	88
Sub-Saharan Africa	65	122	136
West Asia/ North Africa	73	107	109
South Asia	215	317	326
Southeast Asia	88	122	123
East Asia	248	289	293

Source: IMPACT projections, June 2001.

prices and important effects on cereal demand and trade in several regions. Declining feed ratios would drive down maize prices and drive up consumption of maize as food by a substantial amount, leading to a total cereal food consumption increase of 3.5 percent (36 million tons) in the developing world (Table 5.14). However, 39 percent (14 million tons) of this increase in consumption is in Sub-Saharan Africa, where maize and other coarse grains are important staple foods. The impact of this higher cereal consumption on child malnutrition is actually quite significant, with a decline in the number of malnourished children under five in the developing world of 2.7 million children, for a total of 128.8 million in 2020. Indeed, child malnutrition in Sub-Saharan Africa in 2020 would fall by 1.6 million children under this scenario, compared with the baseline.

Full Trade Liberalization

As we have noted, most governments, both developed and developing, have been unwilling to fully liberalize agricultural markets. They intervene in many ways in agriculture in order to promote domestic food production, to keep domestic food prices low, or to reduce dependence on foreign suppliers. Many studies have shown that these measures result in market distortions and inefficiencies that leave most people worse off. Reduction of agricultural trade distortions has been a major thrust of recent trade negotiations. The scenario described in this section simulates the effects on food production, prices, and trade of removing all agricultural subsidies and trade barriers in food markets (for the commodities covered in IMPACT).

In the full trade liberalization scenario, all price wedges (PSEs and CSEs) between domestic and international cereal prices are removed, with the reductions phased in between 2005 and 2006 (see Appendix B, Tables B.11 and B.12 for PSE baseline values and Tables B.13 and B.14 for CSE baseline values). Special caution is warranted when interpreting the results for this scenario because IMPACT is a partial equilibrium model, which does not account for the cross-sectoral linkages that would undoubtedly accompany widespread trade liberalization. A general equilibrium model best assesses such linkages (see for example, Diao, Somwaru, and Roe 2001). Nevertheless, the direction and relative magnitude of the changes that result from implementation of the full trade liberalization scenario are instructive in assessing the importance that should be placed on the agricultural trade liberalization agenda.

As this scenario shows, full liberalization would have a significant effect on cereal prices in 2020 (Table 5.15), with moderate increases above the projected baseline level for all cere-

TABLE 5.15 World prices under the baseline and full trade liberalization scenarios in 2020

Commodity	Baseline	Full trade liberalization	Percentage change from baseline
	(US$/metric ton)		*(percent)*
Wheat	123	133	8.1
Rice	250	285	14.0
Maize	102	111	8.8
Other coarse grains	86	93	8.1
Beef	1,740	2,044	17.5
Pork	2,239	2,484	10.9
Sheep and goat	2,832	3,368	18.9
Poultry	703	785	11.7

Source: IMPACT projections, June 2001.

als. Rice will increase the most, by 14 percent, followed closely by maize, wheat, and other coarse grains. Meat prices will respond to full trade liberalization with even sharper price increases above baseline levels, because meat prices are more distorted than cereal prices under the baseline scenario. The removal of distortions therefore has a greater impact on

TABLE 5.16 Net cereal trade under the baseline and full trade liberalization scenarios in 2020

Region/Country	Baseline	Full trade liberalization	Percentage change from baseline
	(million metric tons)		*(percent)*
United States	119	120	1
EU15	29	23	−21
Japan	−30	−38	27
Australia	30	31	3
Latin America	−3	−2	−33
Sub-Saharan Africa	−27	−29	7
West Asia/ North Africa	−73	−77	5
South Asia	−21	−21	0
Southeast Asia	−9	−10	11
East Asia	−67	−65	−3

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

livestock producers and consumers than on cereal producers and consumers.[25] Sheep and goat and beef prices will rise by 19 percent and 18 percent respectively, while pork and poultry prices increase by a lesser amount (Table 5.15).

Major changes in regional trade balances under a full liberalization scenario accompany moderate price movements in international markets (Table 5.16). Among the developed-country exporters, EU15 cereal exports are projected to fall 21 percent (6 million tons) below baseline levels by 2020; production will fall by 4 percent in response to reduced producer subsidies. Australian and U.S. cereal exports do not change substantially. The main developed-world cereal importer, Japan, will see net cereal imports rise from 30 to 38 million tons. Trade shifts vary in the developing world, but are not particularly large overall. Net cereal imports rise by 11 percent in Southeast Asia, 7 percent in Sub-Saharan Africa, and 5 percent in WANA, and decline by 33 percent in Latin America and 3 percent in East Asia.

Regional cereal production and demand figures generally bear out the regional trade data, with full trade liberalization eliciting relatively small responses (Table 5.17). The one exception is Sub-Saharan Africa, where cereal production is expected to rise 5 percent and cereal demand, 6 percent, indicating that full trade

TABLE 5.17 Regional cereal production and demand under the baseline and full trade liberalization scenarios in 2020

Region/Country	Baseline	Full trade liberalization	Percentage change from baseline
	(million metric tons)		*(percent)*
Production			
United States	424	422	0
EU15	213	204	−4
Latin America	207	209	1
Sub-Saharan Africa	129	136	5
West Asia/North Africa	122	121	−1
South Asia	332	332	0
Southeast Asia	156	155	−1
East Asia	527	528	0
Demand			
United States	305	302	−1
EU15	183	181	−1
Latin America	211	211	0
Sub-Saharan Africa	156	165	6
West Asia/North Africa	196	197	1
South Asia	353	352	0
Southeast Asia	165	165	0
East Asia	594	593	0

Source: IMPACT projections, June 2001.

TABLE 5.18 Net meat trade under the baseline and full trade liberalization scenarios in 2020

Region/Country	Baseline	Full trade liberalization	Percentage change from baseline
		(million metric tons)	
United States	6.1	8.9	46
EU15	2.4	1.8	−25
Japan	−3.2	−3.5	9
Former Soviet Union	−2.5	−3.3	32
Latin America	2.4	5.3	121
Sub-Saharan Africa	−0.3	−1.5	400
West Asia/North Africa	−1.8	−1.3	−28
South Asia	−0.5	−2.3	360
Southeast Asia	−0.5	−1.3	160
East Asia	−5.4	−6.6	22

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

liberalization would be a significant boon to Sub-Saharan Africa, stimulating both cereal production and demand. Sub-Saharan Africa realizes substantial production and consumption increases from both the removal of protection in the EU15 and other developed regions and from the fact that some Sub-Saharan African regions tax both consumption and production of cereal crops.

As indicated by the larger livestock price changes, the full trade liberalization scenario has a greater effect on regional livestock trade, production, and demand than it does on cereals, because existing levels of protection are generally higher for livestock products than for cereals (Table 5.18). Among the major livestock exporting regions, livestock exports will increase substantially in Latin America and the United States and will fall in the EU15. Most of the other regions will see substantial increases in their meat imports, but WANA's net imports of meat will decline 28 percent.

Production declines are mainly responsible for the EU15's falling livestock exports, while demand increases are almost entirely responsible for the sharp rise in meat imports into Sub-Saharan Africa (Table 5.19). Slight production increases combined with slight demand declines will be responsible for the increase in net exports realized by both the United States and Latin America and will also be responsible for the slight decline in WANA's net meat imports. A moderate production decline combined with rising demand will be responsible for the significant increase in net imports in South Asia. While the percentage increase in Southeast Asia's imports appears large, it starts from a very low base and is mainly the result of a slight production decline combined with a slight demand increase. Meat

TABLE 5.19 Regional livestock production and demand under the baseline and full trade liberalization scenarios in 2020

Region/Country	Baseline	Full trade liberalization	Percentage change from baseline
		(million metric tons)	
Production			
United States	46.5	47.8	3
EU15	37.1	36.3	−2
Latin America	47.4	48.6	3
Sub-Saharan Africa	11.0	10.9	−1
West Asia North Africa	11.2	11.4	2
South Asia	15.3	14.3	−7
Southeast Asia	18.2	17.7	−3
East Asia	103.3	102.8	0
Demand			
United States	40.4	38.9	−4
EU15	34.7	34.5	−1
Latin America	44.9	43.3	−4
Sub-Saharan Africa	11.3	12.4	10
West Asia/North Africa	13.0	12.7	−2
South Asia	15.8	16.6	5
Southeast Asia	18.6	19.0	2
East Asia	108.7	109.5	1

Source: IMPACT projections, June 2001.

production and demand actually change only a little in East Asia.

The full trade liberalization scenario will have small overall effects on regional kilocalorie availability, with the most important improvement being an increase of nearly 2 percent in Sub-Saharan Africa. The number of malnourished children under the age of five in the developing world in 2020 is projected to decline by 1 million children from baseline levels, with more than half of this improvement occurring in Sub-Saharan Africa. In light of these modest welfare changes, it should be stressed again that the IMPACT model does not consider the dynamic efficiency improvements that would result from greater agricultural trade liberalization.

Much more dramatically, trade liberalization generates significant net economic benefits. In the partial equilibrium approach used here, the net economic benefits resulting from full trade liberalization are estimated as the net

TABLE 5.20 Net welfare effects of global trade liberalization for IMPACT commodities

Region/Country	Net benefits, 2020	Percent value of agricultural production, 2020	Percent value of GDP, 2020
	(US$ billion)	*(percent)*	
World	35.7	2.99	0.07
Developed world	14.2	3.02	0.04
United States	4.3	2.53	0.03
EU15	4.2	3.04	0.03
Japan	3.0	22.27	0.04
Developing world	21.5	2.98	0.14
Latin America	3.0	2.09	0.07
West Asia/North Africa	2.3	5.9	0.13
Sub-Saharan Africa	4.4	10.4	1.03
China	3.6	1.34	0.11
Other East Asia	2.4	28.72	0.18
India	2.1	1.93	0.14
Other South Asia	1.3	3.34	0.36
Southeast Asia	2.5	3.49	0.15

Source: IMPACT projections, June 2001.

benefits to producers (change in producer surplus) plus the net benefits to consumers (change in consumer surplus) plus the tax savings due to removals of subsidies under trade liberalization, compared with the baseline results in 2020. It is projected that liberalization of trade for the 16 commodities included in the model would generate global benefits of $35.7 billion in 2020 (Table 5.20). Both developed and developing regions benefit, with the former gaining $14.2 billion and the latter $21.5 billion. Although these gains are not significant by GDP, in many regions they are significant by value of agricultural production. In proportion to their agricultural sectors, the biggest gainers are Japan and South Korea (the latter included in Other East Asia in Table 5.20). But most important, the biggest single gainer is Sub-Saharan Africa, at $4.4 billion, or 10 percent of the 2020 value of production of the commodities examined here. This is partly because African farmers would face less competition from subsidized exports from Europe and other developed countries under trade liberalization. However, a significant part is also due to the removal of the costly subsidies and taxes that many African governments impose on food production and consumption.[26]

OPTIMISTIC AND PESSIMISTIC SCENARIOS

Assumptions

The global pessimistic and optimistic scenarios assume alternative outcomes across a broad range of policy-sensitive variables that affect food security and are subject to some degree of uncertainty. These include national GDP growth rates; social service investment, such as sanitation, health, and education; agricultural technology investment, affecting yield growth rates; environmental degradation of both soil and water, influencing the potential for expansion of area cultivated and irrigated; removal of barriers to trade; and projected population growth over the next 20 years. Table 5.21 summarizes all shifts under the optimistic and pessimistic scenarios.

Since unpredictable events and choices made at the national level can substantially affect GDP growth, the pessimistic scenario posits that national GDP growth will suffer a 25 percent decline (and growth under the optimistic scenario will accelerate by 25 percent) from the baseline's moderate levels. For example, if projected GDP growth for a given country is 4 percent per year in the baseline scenario, it is 5 percent in the optimistic scenario and 3 percent in the pessimistic scenario.

Beyond food availability, a broad range of factors related to social spending strongly influence rates of childhood malnutrition in developing countries (notably rates of school-

TABLE 5.21 Percentage changes from baseline conditions under optimistic and pessimistic scenarios

Change	Pessimistic scenario	Optimistic scenario
Malnutrition indicators	Multiply schooling and sanitation indicators by 0.9, subtract 0.04 from life expectancy ratios	Multiply schooling and sanitation indicators by 1.1, add 0.04 to life expectancy ratios
GDP growth rates	25 percent decline in GDP growth rates in developing world	25 percent increase in GDP growth rates in developing world
Agricultural research investment	Yield growth in developed countries declines 50 percent; yield growth in developing countries declines 40 percent	Yield growth in developed countries increases 10 percent; yield growth in China and India rises 20 percent; yield growth in other developing Asia rises 15 percent; yield growth in other developing countries rises 10 percent
Environmental degradation	Area growth declines by 0.15	Area growth increases by 0.10
Irrigation growth	0 percent growth in irrigated area	1 percent growth in irrigated area above baseline levels
Population growth	UN high scenario	UN low scenario
Trade measures	PSEs = 0.2 in 2005 through 2009; PSEs = 0.4 in 2010 through 2020 CSEs = –0.20 in 2005 through 2009; CSEs = –0.4 in 2010 through 2020	No change

Source: IMPACT projections, June 2001.

ing, the extent of sanitation, and female life expectancy). The pessimistic scenario assumes a decline in both the percentage of people with access to safe water and the percentage of females with access to secondary education of 10 percent relative to the baseline percentage in 2020 and a decline in female life expectancy of 4 percent. The optimistic scenario assumes that the levels of these three indicators rise in symmetric fashion with respect to the baseline (that is, gains of 10 percent in female access to education and access to clean water, and 4 percent in the female life expectancy ratio).

Yield growth scenarios depend on the outcomes of debates over the environmental and health implications of genetically modified organisms and on the level of support for international agricultural research as well as irrigation and water resources investment in both the developed and developing worlds. Worse than expected future performance in the areas of agricultural research and development, irrigation infrastructure and trade liberalization, among others, could cause even larger drops in yield growth than projected under the baseline. Alternatively, it is possible that potential threats to world agricultural production and changes in incentives will galvanize governments, multilateral institutions, and private firms into increasing their investments in agricultural research and irrigation, thus leading to significant yield increases and expansion of irrigation infrastructure. Under the pessimistic scenario, yield growth rates are assumed to decline from baseline levels by 50 percent in developed countries and 40 percent in developing countries. Under the optimistic scenario projected yield growth will increase relative to the baseline. Yield growth rates are projected to be 10 percent higher in the developed countries, 20 percent higher in India and China, 15 percent higher in the rest of developing Asia, and 10 percent higher in the rest of the developing world. Higher upside technological potential for parts of Asia in the optimistic scenario is based on the projected greater potential for uptake of biotechnology and other technological advances in these regions. Declines in yield growth rates under the pessimistic scenario are higher than the parallel increases under the optimistic scenario, reflecting our assessment that there is a greater likelihood of a significant downside risk relative to the baseline assumptions.

Much attention in recent years has focused on the importance of soil erosion and overfarming in reducing the amount and quality of land suitable for agricultural exploitation. The rate at which environmental degradation is actually occurring is far from clear, however, in part because good management practices can reverse the deteriorative process and bring previously unsuitable land under cultivation. The pessimistic scenario models heightened environmental degradation by reducing the growth rate of agricultural area by 15 percent in developing countries. The optimistic scenario assumes improved environmental management in developing countries and therefore increases area growth rates by 10 percent over the baseline scenario.

As we have already mentioned, water availability could be the most important limiting resource to agricultural production growth over the next 25 years. Most easily accessible irrigation water has already been exploited, and the scope for further large-scale irrigation development is limited. The baseline assumes a continued slowdown in irrigation expansion, but still allows for an increase in irrigated area of 30 million hectares between 1997 and 2020. However, it is possible that net increases in irrigated area over the next 25 years will be negligible if committed investment is countered by sedimentation of existing water storage and increased rates of salinization and waterlogging. The pessimistic scenario therefore assumes zero growth in irrigated area over the projections period. Alternatively, many national governments possessing adequate resources may decide to pursue a heightened program of irrigation development, and expansion of private investment could increase at higher than anticipated rates. The optimistic scenario models this possibility by assuming an additional 1 percent per year growth in developing-country irrigated area above the baseline rate, which would add an additional 35 million hectares over the baseline irrigated area in 2020.

UN population projections have undergone frequent downward revisions over the past couple of decades, as demographic shifts in the developing world led to lower population growth rates in most regions. The baseline adopts the UN medium population growth rate projections, and our optimistic and pessimistic scenarios adopt the low and high projections, respectively.

The slow start of the Millennium Round of the World Trade Organization calls into question the commitment of nations in both the developing and developed worlds to further trade liberalization. The pessimistic scenario assumes a worsening of the world trade environment, together with an increased desire to protect slow-growing agriculture in developing countries. Increased protection is represented by a phased increase in the PSE and a decrease in the CSE by 20 percent between 2005 and 2009 and by an additional 20 percent between 2010 and 2015.

Results

The pessimistic scenario will significantly affect worldwide agricultural production, prices, demand, trade, and child malnourishment in the developing world. Worldwide cereal production will increase 29 percent (54 million tons) between 1997 and 2020 under the pessimistic scenario, compared with a 33 percent (63 million ton) increase under the baseline scenario and a 38 percent (71 million ton) increase under the optimistic scenario. Worldwide per capita cereal consumption under the 2020 pessimistic scenario will be 28 kilograms per capita lower under the pessimistic scenario than under the baseline, and it will be 30 kilograms higher than the baseline under the optimistic scenario.

Production. Per capita cereal production in 2020 will decline across all regions under the pessimistic scenario (Table 5.22). Among the developing regions, Sub-Saharan Africa will have a slight decline in per capita cereal production of 4 percent from the baseline level by

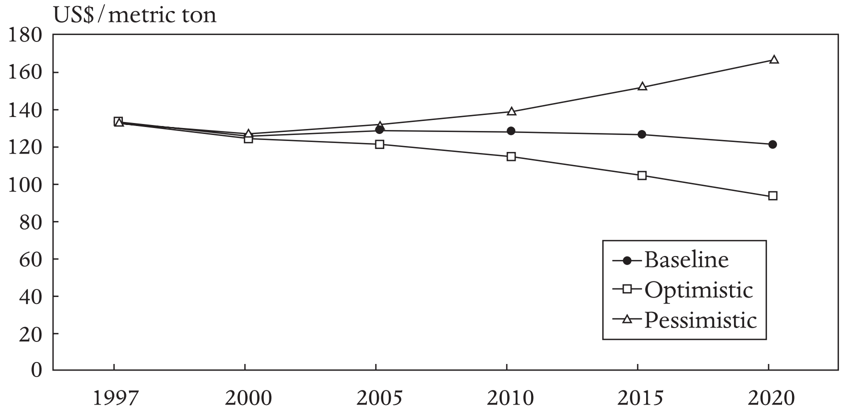

FIGURE 5.1 Wheat prices, alternative scenarios, 1997–2020

Source: IMPACT projections, June 2001.

TABLE 5.22 Per capita cereal production in 2020 by region, alternative scenarios

Region/Country	Baseline	Optimistic	Pessimistic
		(kilograms/capita)	
United States	1,339	1,398	1,240
EU15	573	589	561
Eastern Europe	871	886	780
Former Soviet Union	487	497	456
Latin America	318	350	286
Sub-Saharan Africa	134	144	128
West Asia/North Africa	243	263	220
South Asia	186	215	160
Southeast Asia	241	277	220
China	355	394	328
World	335	365	307

Source: IMPACT projections, June 2001.

2020. Projected total per capita cereal production will be significantly lower than under the baseline scenario in all other developing regions, with particularly large declines in South Asia at 14 percent, WANA at 9 percent, and Latin America at 10 percent.

Per capita cereal production under the optimistic scenario in 2020 will increase above levels projected by the baseline in all regions. South Asia, Southeast Asia, and China will have particularly strong production responses.

Prices. The optimistic and pessimistic scenarios will dramatically affect world cereal prices (Figures 5.1 to 5.4). Prices for all cereals in the optimistic scenario decline at an accelerating rate

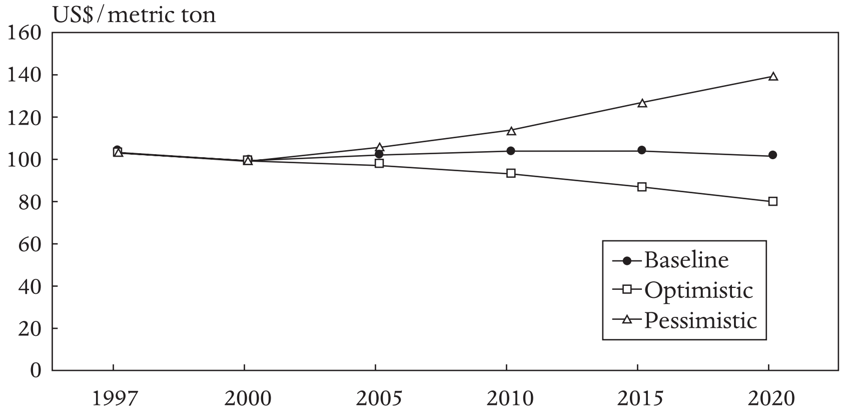

FIGURE 5.2 Maize prices, alternative scenarios, 1997–2020

Source: IMPACT projections, June 2001.

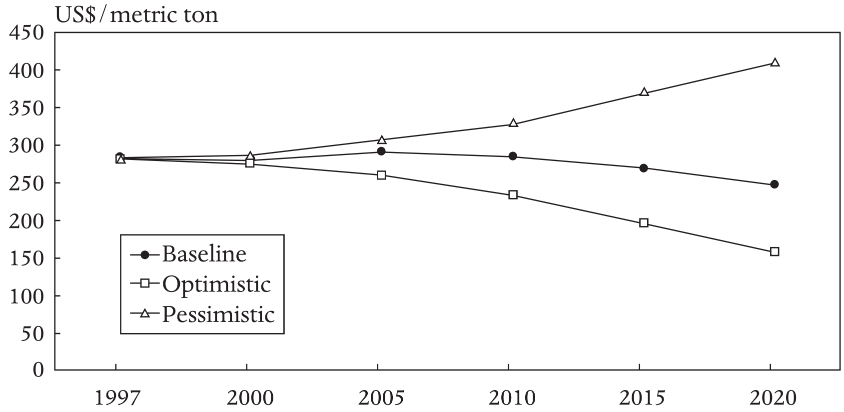

FIGURE 5.3 Rice prices, alternative scenarios, 1997–2020

Source: IMPACT projections, June 2001.

throughout the projections period, with rice prices declining 44 percent; other grain prices, 33 percent; wheat prices, 29 percent; and maize prices, 22 percent. Cereal prices will rise in the pessimistic scenario, with other grain prices rising 29 percent; wheat prices, 26 percent; and rice prices, 45 percent. Maize prices are actually projected to rise 36 percent between 1997 and 2020 to a price of $140 per ton in 2020, almost twice the corresponding decline under the optimistic scenario. Thus declines for other coarse grains and wheat will be greater under the optimistic scenario than corresponding increases under the pessimistic scenario, while the reverse will be true for maize and rice.

Meat production is not greatly susceptible to the varying scenarios, with meat production in 2020 falling an average of 5 percent below baseline levels in the pessimistic scenario and rising an average of 2 percent above baseline levels in the optimistic scenario (Figure 5.5).

Trade. The pessimistic scenario is projected to affect total world cereal trade more than the optimistic scenario is, but the overall effects on total volume of trade are not large. The pes-

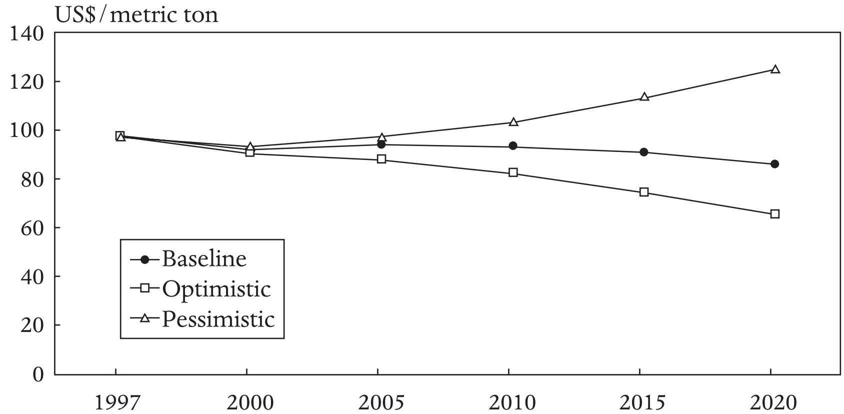

FIGURE 5.4 Other coarse grain prices, alternative scenarios, 1997–2020

Source: IMPACT projections, June 2001.

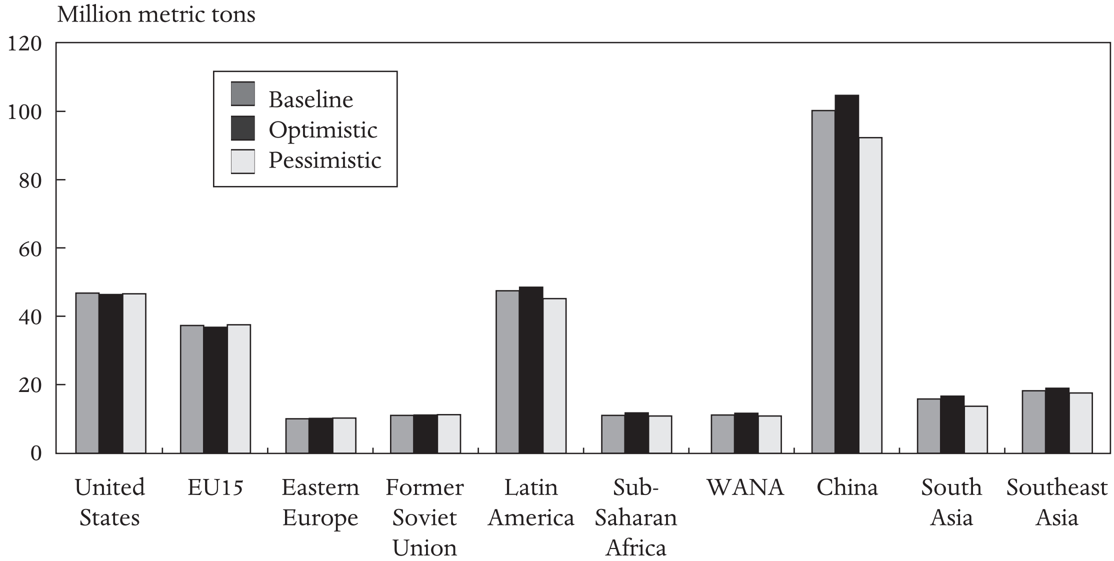

FIGURE 5.5 Meat production in 2020 by region, alternative scenarios

Source: IMPACT projections, June 2001.

simistic and optimistic scenarios begin to diverge gradually from the baseline between 2000 and 2005. Projected world cereal trade in 2010 under the pessimistic scenario is 7 million tons higher than under the baseline scenario, eventually increasing to a total difference between the two scenarios of 20 million tons by 2020. Projected world cereal trade under the optimistic scenario in 2010 is more than 6 million tons lower than the baseline, but in 2020 this difference will be reduced to 5 million tons for a total of 296 million tons.

The impact of the scenarios on the value of world cereal trade is slightly different from volumetric trends, mainly due to the effects of changing commodity prices. The value of world cereal trade under the pessimistic and baseline scenarios diverges sharply between 2000 and 2005 and is ultimately $24 billion higher under the pessimistic scenario in 2020 (Figure 5.6). The value of world cereal trade under the optimistic scenario trends below the value of trade under the baseline and pessimistic scenarios from the beginning of the projections period, and it grows moderately faster between 2015 and 2020. World cereal trade in 2020 under the optimistic scenario is $9 billion less than under the baseline scenario. The relatively small changes in total trade are due to countervailing forces within each of these alternative scenarios. In the pessimistic scenario, rising world cereal prices and declining incomes, combined with increased trade barriers in developing countries, tend to drive down food import demand, while slower production growth and higher population growth would tend to boost import demand.

By contrast, in the optimistic scenario, more rapidly increasing production and lower population growth tend to reduce imports; higher income growth tends to increase import demand.

The effects that the optimistic and pessimistic scenarios have on regional imports in 2020 will vary by region, but net cereal imports into the developing world as a whole will decline slightly in both scenarios relative to the baseline. When

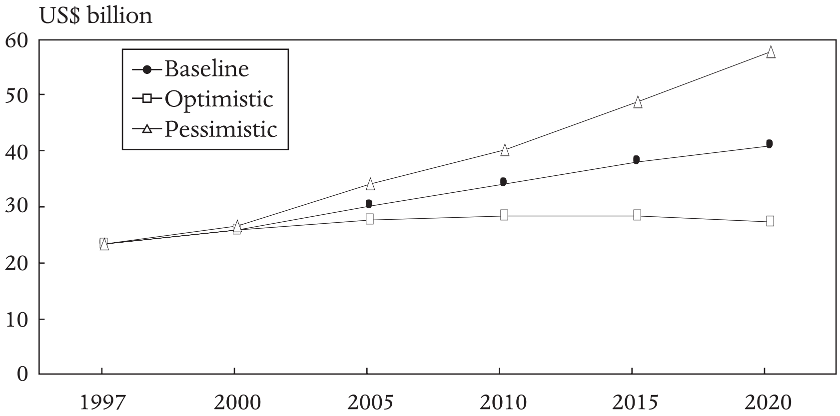

FIGURE 5.6 Value of world cereal trade under alternative scenarios, 1997–2020

Source: IMPACT projections, June 2001.

the net cereal imports are broken down by region, the different regions have widely divergent trade responses to the different scenarios, depending on the balance of countervailing forces in any given region (Figure 5.7). The net effect on imports for any given country depends in particular on the demand and supply elasticities and rate of change in yield and area growth.

The volume of cereal imports into East Asia (mainly China) in 2020 will decline by 18 percent from baseline levels under the optimistic scenario and 21 percent under the pessimistic scenario. Cereal imports into Sub-Saharan Africa in 2020 under the pessimistic scenario decline 42 percent, while Latin America becomes a net exporter of 2 million tons of

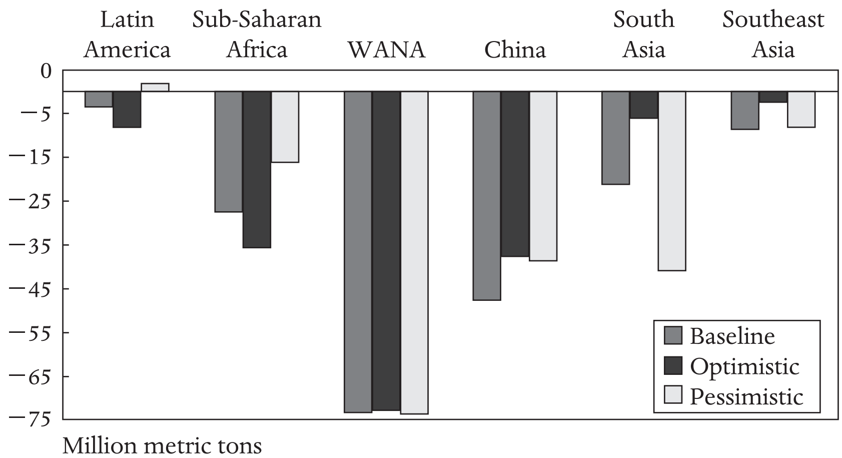

FIGURE 5.7 Net cereal trade in 2020 by region, alternative scenarios

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

cereals in 2020. The remaining regions will experience rising import dependence under the pessimistic scenario, with South Asia experiencing the largest percentage increase of 90 percent, as well as the largest absolute increase of 19 million tons. Cereal imports under the optimistic scenario will increase in both Latin America and Sub-Saharan Africa by significant amounts, but they will decline in all of the other regions.

As was the case for total world cereal trade, changing cereal prices somewhat modify the volumetric cereal import picture as a result of both regional differences in the composition of cereal demand and price changes over the projection period (Figure 5.8). South Asia's import bill rises from $3 billion under the baseline scenario to $12 billion under the pessimistic scenario, even though the volume of net cereal imports only approximately doubles. Meanwhile, Southeast Asia, which showed a trade deficit in volume under all three scenarios, actually has a positive trade balance in value terms across the board, due to the preponderance of high-value rice in its cereal exports.

Demand. The optimistic and pessimistic scenarios will have significant effects on per capita kilocalorie availability and childhood malnutrition. In terms of per capita kilocalorie availability, the pessimistic scenario will hurt South Asia, Latin America, and Sub-Saharan Africa the most, with per capita kilocalorie consumption in 2020 that is 7 percent lower than under the baseline scenario (Figure 5.9). (The declines in consumption in all of the other regions are quite close to that, however.) Sub-Saharan Africa, South Asia, and Latin America will also benefit from the optimistic scenario, with per capita kilocalorie consumption in 2020 improving approximately 6 percent above the baseline in these regions, with gains in the other regions close behind.

Childhood Malnutrition under Alternative Scenarios. The most devastating result from the pessimistic scenario is the impact on childhood malnutrition. The pessimistic scenario has a highly detrimental effect on the welfare of children in the developing world (Figure 5.10). Under the pessimistic scenario, the number of malnourished children in the developing world actually

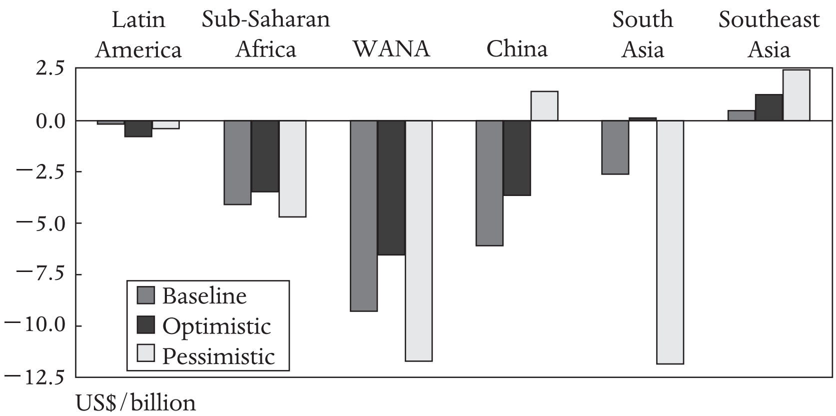

FIGURE 5.8 Net cereal trade value in 2020 by region, alternative scenarios

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

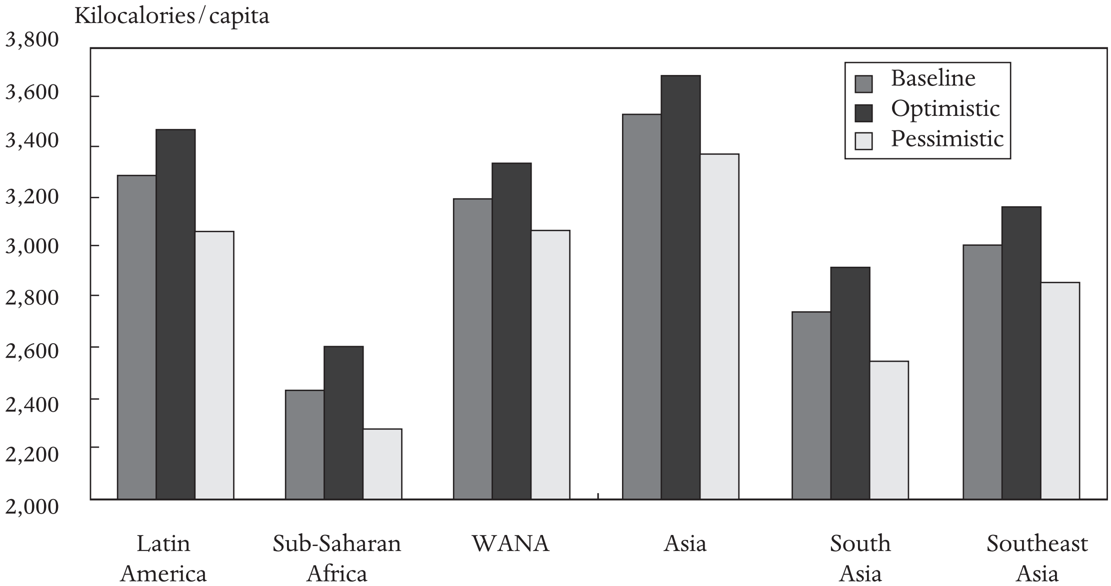

FIGURE 5.9 Per capita kilocalorie availability in 2020 by region, alternative scenarios

Source: IMPACT projections, June 2001.

increases, from 166 million children in 1997 to 178 million children in 2020, a full 46 million more malnourished children than in the baseline 2020 projection. The optimistic scenario, in contrast, generates significant reductions in the number of malnourished children, down to 94 million children in 2020. Whereas the baseline scenario projected 2 million malnourished children in Latin America in 2020, a decline of 3 million children from the 5 million children malnourished in 1997, the pessimistic scenario projects this number to rise to 7 million children. WANA, which was to reduce its number of malnourished children under the baseline from 6 mil-

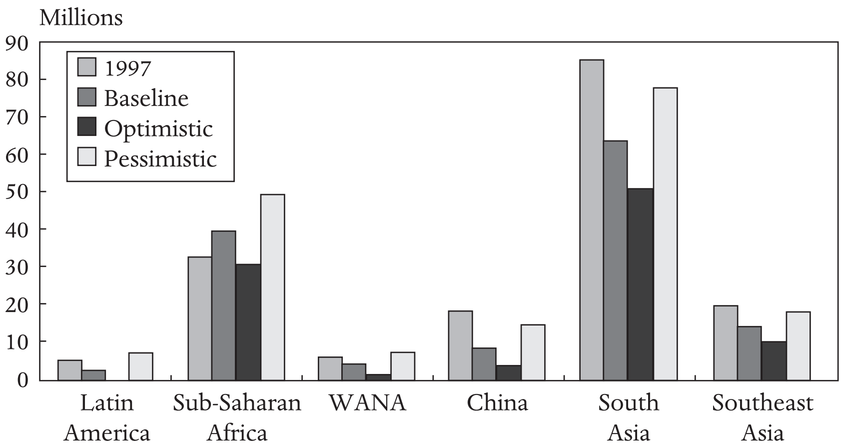

FIGURE 5.10 Malnourished children in 2020, alternative scenarios

Source: IMPACT projections, June 2001

lion children in 1997 to 4 million in 2020, would experience an increase to 7 million children in 2020 under the pessimistic scenario. China, projected to more than halve its number of malnourished children to 8 million children between 1997 and 2020, will see hardly any improvement in the pessimistic scenario, with its number of malnourished children only declining to 15 million children. South Asia and Sub-Saharan Africa will have the largest absolute increases in the projected number of malnourished children in 2020, with increases of 14 million and 10 million children above baseline levels, respectively.

The optimistic scenario projects impressive improvements, with Latin America completely eliminating child malnourishment, WANA experiencing a decline to only 1 million malnourished children, and China reducing the number of malnourished children to 3 million by 2020. Child malnourishment in South Asia in 2020 declines from baseline levels by a sizeable 13 million malnourished children in the optimistic scenario, and an impressive 8 million children in Sub-Saharan Africa.

These results indicate that the alternative scenarios have profound effects on food security as measured by childhood malnutrition. For the pessimistic scenario, reductions in per capita income and increased food prices reduce per capita food consumption as described above. The reduction in food consumption reduces per capita calorie consumption, which in turn increases the percentage of the childhood population that is malnourished. Reductions in public investment in the social sector—including female health, education, and water and sanitation—result in further increases in the percentage of malnourished children. The total childhood population also increases due to the higher fertility rates incorporated in the high population growth scenario. The combined result of these effects is an increase in the number of malnourished children.

The optimistic scenario has the opposite effect on child malnutrition. Under the optimistic scenario, three broad courses combine to reduce projected levels of malnutrition: the first is through broad-based and rapid agricultural productivity growth and economic growth to increase effective incomes, effective food demand, and food availability; the second is through a reduction in population growth rates; and the third is through investments that improve access to education, female life expectancy (as a proxy for quality of life for females), and health (the latter proxied by access to clean water in the model). The relative contribution of these three paths to reducing malnutrition were estimated by undertaking a series of simulations embodying specific interventions, including crop productivity–enhancing investments, lower population growth, and higher social investments. These disaggregated simulations indicate that each of these factors accounts for about one-third of the improvement in childhood malnutrition.

6

ALTERNATIVE REGIONAL SCENARIOS

Not all likely or potentially important deviations from projected baseline trends are global in nature. Indeed, the baseline findings indicate that the increasing importance of developing regions in the world economy could lead to unforeseen positive or negative developments in one region having far-reaching global consequences for overall food security and trade patterns. The alternative scenarios examined here focus on alternative growth scenarios for Asia, because of its importance to global growth, and Sub-Saharan Africa, because of the significant risk that this region will fail to grow at the levels projected in the baseline. Regional scenarios examine not only projected effects on a particular region, but also the extent to which regional disturbances reverberate worldwide.

ASIAN SCENARIOS

India and China: Agricultural Growth Slowdown

Continued agricultural growth in India and China—even the slowing yield growth projected under the baseline—depends on a number of assumptions regarding the possibility for continued yield increases, moderate (not overly burdensome) levels of land degradation, and the country's ability to manage pressures from growing competition among the agricultural, urban, and industrial sectors over land and water resources. Many observers believe that these assumptions are not appropriate, and that both nations will face more severe impediments to the expansion of agricultural production. Indeed, there are a number of sources of downside risk to crop yield growth, as described in the section on global yield growth scenarios. Given these uncertainties, a scenario invoking a decline of 50 percent in area and yield growth rates in India and China, a decline of 25 percent in livestock numbers growth, and a 25 percent decline in GDP growth (the latter due to the economy-wide effect of the dramatic slowdown in agricultural growth), represents a plausible negative scenario for these regions.[27] As with the global yield scenarios presented earlier, the IMPACT model translates such changes in yield and growth rate assumptions into somewhat different actual declines in the output value of these variables, because the price increases caused by the lower yield growth induces the yields to recover partially (Table 6.1). Thus, while all assumed values were halved, these changes result in an actual decline of Indian annual cereal yield growth rates from 1.2 to 0.7 percent for wheat, from 1.0 to 0.6 percent for maize, from 1.0 to 0.5 percent for other grains, and from 1.4 to 0.8 percent for rice. Actual Chinese annual yield growth rates decline by less than half. Area growth rates vary little from the negligible rates projected under the baseline.

As expected, declining yield and area growth rates have a severe effect on total crop production in India and China. Indian cereal production declines 15 percent, from 254 million tons under the baseline scenario to 217 million tons. As a result, India goes from near self-sufficiency in cereals in 2020 under the baseline scenario to imports of 30 million tons (a cost of $5.9 billion at projected international prices). Cereal production in China also declines 15 percent from the baseline level, from 518 to 438 million tons. China's cereal trade deficit nearly doubles under this scenario, increasing from 48 million tons under the baseline scenario to 89 million tons ($12.7 billion).

TABLE 6.1 Realized annual cereal yield growth rates under the baseline and India and China slow-growth scenarios, 1997–2020

	Baseline		Slow growth	
Commodity	India	China	India	China
	(percent/year)			
Wheat	1.2	0.9	0.7	0.5
Maize	1.0	1.6	0.6	0.9
Other coarse grains	1.0	1.4	0.5	0.7
Rice	1.4	0.8	0.8	0.5

Source: IMPACT projections, June 2001.

Moving beyond a narrow focus on cereals, India's overall agricultural trade balance under the slow-growth scenario will shift from a 1997 surplus of $1.7 billion to a deficit of $9.2 billion in 2020, while China's overall trade deficit will grow from net imports of $5.9 billion in 1997 to net imports worth $33.5 billion in 2020 (Table 6.2). In relative value terms, India's trade deficit in 2020 will represent 7 percent of agricultural production and China's, 10 percent. These overall trends represent the combined effects of substantial increases in cereal imports as well as a decline in meat imports in China and a shift from small imports of meat to small exports in India, due to lower demand caused by declining income growth rates and higher meat prices.

Area and yield declines in India and China affect world cereal prices by significant, but not disastrous, amounts (Table 6.3). Wheat prices under this scenario increase 1 percent ($1 per ton) between 1997 and 2020 to $134 per ton, compared with an 8 percent ($10 per ton) decline under the baseline scenario. Maize and rice prices increase sharply under the slow-growth scenario and decline under the baseline scenario. Other grains decline under both scenarios.

Chinese meat production in 2020 under the slow-growth scenario will decline from 100 million tons under the baseline to 88 million tons, and Indian meat production will decline from 9.2 million tons to 8.2 million tons (Table 6.4). The combination of production declines and the decline in demand from lower income growth will lead to varying price effects among the different livestock products (Table 6.5). World prices for beef and sheep and goat meat will only decline by small amounts, while world poultry and pork prices will actually rise slightly.

TABLE 6.2 Net commodity trade under the baseline and India and China slow-growth scenarios in 2020

	India		China	
Commodity	Slow-growth scenario	Baseline	Slow-growth scenario	Baseline
		(US$ billion)		
Wheat	−2.0	−0.8	−3.0	−1.6
Maize	−0.1	0	−5.6	−3.2
Rice	−3.5	−0.1	−3.7	0.3
Other coarse grains	−0.3	0	−0.5	−0.4
Potatoes	−1.3	−0.1	−2.0	−0.3
Sweet potatoes	0	0	−1.7	−0.1
Cassava and others	−0.1	0	−0.2	−0.1
Soybeans	−0.6	−0.1	−3.3	−3.0
Oils	−3.3	−1.2	−5.7	−4.5
Meals	−0.3	0.3	−3.2	−2.0
Beef	0.2	−0.1	−0.1	−1.1
Pork	0	−0.1	−2.5	−2.6
Sheep and goat	0	−0.1	−0.3	−0.5
Poultry	0	0	−0.7	−1.6
Milk	2.1	−0.1	−0.4	−0.8
Eggs	0	0	−0.6	−0.1
Total	−9.2	−2.4	−33.5	−21.6

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

Indian kilocalorie consumption in 2020 declines from 2,868 kilocalories per capita under the baseline scenario to 2,697 kilocalories per capita under the slow-growth scenario, while Chinese kilocalorie consumption declines from 3,536 kilocalories per capita to 3,272 kilocalories. More important, under the slow-growth scenario, the number of malnourished children in China and India each will increase by 2 million children over the baseline. The rate of increase in malnourished children is dependent on the ability and willingness of India and China to finance massive agricultural imports under this scenario. China, in particular, would be importing agricultural products worth 10 percent of total agricultural production. Political exigencies may render such a high level of imports unacceptable. Measures to lower agricultural import dependency in India and China, including high import tariffs and subsidies to domestic production, could considerably worsen the ultimate impact of negative shocks to these agricultural production systems.

A slowdown in technological change in agriculture and heightened resource degradation in China and India would primarily affect the countries themselves. The implications of such

TABLE 6.3 Crop prices under the baseline and India and China slow-growth scenarios in 1997 and 2020

	1997	*2020*	
Cereal	**Base year**	**Baseline**	**Slow-growth scenario**
		(US$/metric ton)	
Wheat	133	123	134
Maize	103	102	111
Other coarse grains	97	86	94
Rice	285	250	315

Source: IMPACT projections, June 2001.

a production shock for world prices are significant but not devastating. The results also indicate that world markets are in fact quite resilient and can absorb large increases in Chinese and Indian cereal imports without huge price consequences. Although China in particular is already a significant player in world food markets and is likely to become increasingly important, it does not represent a major threat to the long-term stability of global markets. Global supply response will maintain considerable flexibility.

TABLE 6.5 Meat prices under the baseline and India and China slow-growth scenarios in 2020

Commodity	**Baseline**	**Slow-growth scenario**
	(US$/metric ton)	
Beef	1,740	1,739
Pork	2,239	2,263
Sheep and goat	2,832	2,811
Poultry	703	704

Source: IMPACT projections, June 2001.

High Asian Feed Ratios

The future of feed efficiency trends will depend significantly on the pace of commercialization in the Asian livestock sector. Industrial systems, mainly in the developed world, currently produce more than half of all poultry and pork products, raising them on well-balanced mixtures of prepared commercial feeds. Livestock systems in the developed world, which mainly produce for slowly growing domestic markets and neither produce their own feed products nor utilize nitrogenous wastes, are concerned mainly with raising efficiencies to maintain profits. Grazing/mixed-

TABLE 6.4 Meat production under the baseline and India and China slow-growth scenarios in 2020

	India		**China**	
Commodity	**Baseline**	**Slow-growth scenario**	**Baseline**	**Slow-growth scenario**
		(million metric tons)		
Beef	5.3	4.9	10.4	8.9
Pork	1.0	0.9	60.0	54.3
Sheep and goat	1.4	1.2	3.2	3.0
Poultry	1.5	1.2	26.4	21.7
All meat	9.2	8.2	100.0	88.0

Source: IMPACT projections, June 2001.

farming systems, where farm households often produce their own feeds and reuse wastes, also face strong incentives to improve efficiencies, mainly because of the rapidly growing demand for pork, poultry, and dairy products in developing countries (Steinfeld 1998). Nevertheless, despite the incentives for higher feed efficiencies under both industrial and grazing/mixed-farming production systems, compelling evidence exists that the shift in livestock production from small-scale households and mixed-farming systems to large-scale commercial facilities throughout much of Asia—the major ongoing and future trend in the regional livestock sector—is leading to significantly higher feed ratios (Steinfeld 1998). Other trends act to offset the impact on feed ratios of the shift from backyard to commercial production, particularly the ongoing improvement in feeding efficiency within the commercial sector and the shift to less feed-intensive poultry production.

The baseline scenario incorporates a moderate shift in the livestock production structure, but it is possible that the pace of the transition could proceed more rapidly than anticipated. Notably, while Asian feed demand growth at 2.7 percent annually is still expected to be higher than meat production growth at 2.6 percent annually during 1997–2020 under the baseline, this differential is rather small, and Southeast Asian meat production growth at 2.9 percent annually is significantly higher than annual feed demand growth of 2.4 percent. Rising feed ratios in East Asia, particularly China, are in large part responsible for the overall Asian trend, with cereal feed demand growth averaging 2.7 percent annually and meat production growth averaging 2.5 percent.

The faster growth in meat demand relative to feed demand in Southeast Asia stems from a number of factors. First, relatively more efficient poultry production is projected to account for 42 percent (4 million tons) of meat demand growth in Southeast Asia in 1997– 2020, compared with China's share of 34 percent (16 million tons) over the same period. Structural changes in livestock production have also progressed more rapidly in Southeast Asia than in East Asia, so a significant structural shift from backyard to commercial feeding ratios has already occurred. Both Indonesia and Thailand have undergone significant poultry production industrialization over the last 30 years—Indonesia since the mid 1970s, spurred by government production intensification programs such as BIMAS (Indonesia's Agricultural Services and Intensification Agency), and Thailand through production expansion and technology development led by the private sector. Thailand's poultry sector is now highly capital intensive and productive, and its poultry exports are significant (Soedjana 1999; Ranong 1999).[28] The rapid development of Southeast Asia's industrial livestock sector is indicative of the general trend of industrialization of the poultry sector preceding industrialization of the pork and dairy sectors (Steinfeld and Kamakawa 1999). The pork sector represented 69 percent of total agricultural production in East Asia in 1997, with less than 20 percent of the sector characterized by intensive production (Bingsheng 1997).[29] The greater importance of poultry to regional meat production led Southeast Asia to user fewer cereals per kilogram of meat production than East Asia in 1997, with Southeast Asia requiring 15 million tons of cereals to produce 9 million tons of meat (a ratio of 1.7), while East Asia required 119 million tons of cereals to produce 55 million tons of meat (a ratio of 2.2). Nevertheless, East Asian smallholders—especially pork producers—use more alternative feed crops than relatively more industrialized Southeast Asia, consuming 74 million tons of roots and tubers for feed purposes (a ratio of 1.4), compared with Southeast Asian consumption of only 2 million tons (a ratio of 0.2). While

TABLE 6.6 Meat production under the baseline and high Asian feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Region	**Base year**	**Baseline**	**High Asian feed ratio**
		(million metric tons)	
South Asia	8	15	15
Southeast Asia	9	18	19
East Asia	55	103	107
All Asia	72	137	142

Source: IMPACT projections, June 2001.

smallholder livestock production will not disappear in East Asia over the next two decades, it will undergo significant pressures from demand, population, and income growth.

Because the transition to higher feed ratios in this alternative scenario represents an increase in the pace of commercialization in livestock production, rates of growth of livestock production in Asia should also increase along with any projected increase in feed ratios. To simulate the shift in technology toward higher feed ratios in Asia, we raised maize feed ratios by 10 percent and increased the production growth for poultry, pork, and eggs in all Asian countries by an additional 0.3 percent per year.

These modifications will lead to an increase in Asian livestock production of 4 percent (5 million tons) above levels predicted by the baseline scenario in 2020 (Table 6.6), as well as a decline of net livestock imports into Asia of 3.8 million tons, from 6.3 million tons. Production increases are fairly uniform across regions and commodities. Higher Asian livestock production will cause some movement in meat prices, with pork prices falling 3 percent ($72 per ton), poultry prices falling 1 percent ($10 per ton), and egg prices falling 4 percent ($49 per ton) (Table 6.7). Meat products that are not affected by higher rates of industrialization generally experience a slight price increase above baseline levels under the low feed ratio scenario, although generally less than 1 percent.

The important ramifications of higher Asian feed ratios manifest themselves in grain markets (Table 6.8). It is possible that the shift from traditional feeds—including household

TABLE 6.7 Meat and dairy prices under the baseline and high Asian feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**High Asian feed ratio**
		(US$/metric ton)	
Beef	1,808	1,740	1,750
Pork	2,304	2,239	2,167
Sheep and goat	2,918	2,832	2,845
Poultry	735	703	693
Eggs	1,231	1,191	1,142
Milk	318	289	292

Source: IMPACT projections, June 2001.

TABLE 6.8 Cereal prices under the baseline and high Asian feed ratio scenarios in 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**High Asian feed ratio**
		(US$/metric ton)	
Wheat	133	123	126
Maize	103	102	119
Other coarse grains	97	86	91
Rice	285	250	256

Source: IMPACT projections, June 2001.

and farm wastes and roots and tubers crops such as sweet potatoes—to a higher proportion of grain feeds in Asia will cause significant upward price pressure in world grain markets. Raising the feed ratio for maize does, as expected, raise the price of maize by 17 percent above the baseline level in 2020. The effect of this price increase on maize food consumption is proportionally smaller, with food consumption declining 7 percent in Latin America, 5 percent in Sub-Saharan Africa, 3 percent in East Asia, and by negligible amounts in other regions (Table 6.9). The increase in Asian feed demand that precipitated these maize price increases, however, leads to an increase in total maize demand of 25 percent in East Asia (63 million tons), 15 percent (6 million tons) in Southeast Asia, and a negligible amount in South Asia. Thus, as would be expected from its position as the main livestock producer in the world, the rates of technological and institutional change in the Chinese livestock sector do influence world markets.

Declining consumption of maize for food as a result of higher prices will have its main effects on the two regions most dependent on maize for food—Sub-Saharan Africa and Latin America—where lower cereal consumption leads to predicted increases in child malnutrition that are small but certainly not trivial, with the number of malnourished children under the age of five rising by half a million children for the two regions combined.

As these results indicate, technological change in the Asian livestock sector toward higher feed intensity is important, but the implications of this change for world cereal prices should not be overemphasized. Nevertheless, it is noteworthy that maize, by far the most important feed grain in Asia, is also an essential grain for food security in Latin America and Africa, and that rising demand for this crop in the Asian livestock sector could price some consumers in these countries out of the market.

TABLE 6.9 Maize food demand under the baseline and high Asian feed ratio scenarios in 2020

Region	Baseline	High Asian feed ratio
	(million metric tons)	
Latin America	29	27
Sub-Saharan Africa	39	37
West Asia/North Africa	8	8
South Asia	13	13
Southeast Asia	12	12
East Asia	37	36

Source: IMPACT projections, June 2001.

AFRICAN SCENARIOS

A Troubled Continent

The baseline scenario projects growing agricultural import needs for Sub-Saharan Africa in 2020. The region's $6.5 billion in projected 2020 agricultural imports represents 8.9 percent of projected regional agricultural production, a slight increase above an agricultural import burden of 7.8 percent of regional agricultural production in 1997. Even these increases, however, rest on a fairly optimistic set of assumptions, given the recent agricultural performance of the region. The baseline scenario projects an annual cereal production growth rate of 2.4 percent for maize, 2.8 percent for other grains, 2.9 percent for wheat, and 3.1 percent for rice, aggregating to a total annual cereal production growth rate of 2.5 percent. Roots and tubers production is more important to Sub-Saharan Africa than to any other region, and production growth rates of these crops are also projected to average a relatively high 2.4 percent annually between 1997 and 2020. The projected baseline rates of growth for cereal crops are slightly below the annual rate of increase in cereal production of 3.6 percent achieved in the region between 1982 and 1997. However, this rapid rate of growth coincided with the continent's recovery from dismal performance between 1967 and 1982, when cereal production grew at a rate of only 1.8 percent annually. Projected annual roots and tubers production growth rates also represent a decline from growth rates averaging 4.3 percent between 1982 and 1997, and the trend of recovery from previous slow growth is even more extreme than for cereals, since roots and tubers production only grew at a rate of 1.8 percent between 1967 and 1982.

As was shown in the earlier historical section, the sources of past growth in African cereal production cause some concern for the future, since area expansion has driven production growth in the context of stagnant yields for most cereals in recent years. While the area under cereal production in Sub-Saharan Africa expanded by 1.9 percent per year over the period 1967–97, and by a rapid 3.5 percent per year between 1982 and 1997, cereal yield growth rates only averaged 0.8 percent per year during 1967–97 and a dismal 0.1 percent per year between 1982 and 1997. Part of the reason for poor yield performance in the past has been the fact that rapidly expanding area under cereal production—and the concomitant ability to practice low-intensity cultivation—obviated the need for rapid yield improvements. Area under crop production increased 63 percent during 1967–97. Between 1982 and 1997 alone, it surged from 94 million hectares to 153 million hectares. Regional growth in cropped area was fastest in Northern Sub-Saharan Africa with an increase of 93 percent during 1967–97 to 45 million hectares and slowest in Southern Sub-Saharan Africa with an increase of only 30 percent to 16 million hectares. Increases in cropped area over the 30-year period are not, however, a good indicator of current levels of land scarcity, since the ratio of arable and permanent cropland to total agricultural land is particularly high in Nigeria, Central and Western Sub-Saharan Africa, and Eastern Sub-Saharan Africa, and particularly low in Southern and Northern Sub-Saharan Africa.

Under the baseline, crop production in Sub-Saharan Africa will continue to expand onto previously unused land, although at a slower rate than in the past. The increase in the area under cereal and roots and tubers cultivation ranges from 21 percent in Nigeria to 38 percent in Central and Western Sub-Saharan Africa. Nevertheless, while Africa was a land surplus continent in the 1960s, with agricultural production mainly limited by sources of labor and capital, rapid population growth has raised population densities significantly across many regions, thus circumscribing the opportunities for further area expansion. Per capita arable area regionwide has declined from 0.48 hectares per capita in 1967 to 0.25 hectares in 1997. Cleaver and Schreiber (1994) point out that the figures for per capita arable area may even overstate the land available for cultivation because the figures may include land with very poor agroclimactic and soil conditions. Despite the increasing pressure, a detailed FAO (1994) study, summarized in Table 6.10, reveals that there is room for some additional area expansion into land of varying quality in many countries across the region, perhaps with the exception of water-constrained parts of Northern Sub-Saharan Africa. Nevertheless, proper technologies and investment would enable some land expansion even in the north, where the

TABLE 6.10 Countries in Sub-Saharan Africa with significant amounts of remaining high-potential arable land

Northern	Central and Western	Southern	Eastern
Chad	Benin	Angola	Tanzania
Ethiopia	Cameroon	Lesotho	Uganda
Mali	Central African Republic	Madagascar	
Sudan	Congo Republic	Malawai	
	Ivory Coast	Mozambique	
	Democratic Republic of Congo	Swaziland	
		Zambia	
	Gabon	Zimbabwe	
	Ghana		
	Guinea		
	Liberia		
	Nigeria		
	Togo		

Source: FAO 1994.

area under cereal and roots and tubers production almost doubled between 1974 and 1997.

The IMPACT baseline projects relatively strong yield growth averaging 1.5 percent for cereals in Sub-Saharan Africa, essentially doubling the yield growth achieved between 1967 and 1997. Despite the pessimism that prevails about the future of agricultural productivity growth in Sub-Saharan African and the dismal historical record, such strong cereal yield growth vindicates our belief that current trends in the region portend modest improvement over past performance. African yields are very low even by other developing country standards, indicating that significant growth should be possible if countries in the region move toward appropriate technologies, policies, and programs. Although economic liberalization has had mixed results, the policy environment is now more favorable to agriculture than it was in the 1970s and 1980s, with price discrimination reduced in many countries and market liberalization providing the necessary incentives for private-sector participation in the agricultural sector. Most African governments seem to have realized that agricultural growth will be the key to economic development in the region in the medium term and have embarked their countries upon development paths that support the increased productivity of the sector (World Bank 2000a).

As described above, theories of induced technological innovation predict that growing population pressure will lead to higher yield growth rates as low-input agriculture increasingly ceases to be a viable option (Boserup 1981). Increased population pressure in Sub-Saharan Africa is shown by the decline in total per capita cropped area from 0.40 hectares per capita in 1967 to 0.27 hectares per capita in 1997.[30] However, population-induced innovation requires access of land-constrained populations to technologies and inputs. Cleaver and Schreiber (1994) point out that even as populations throughout Sub-Saharan Africa are losing their ability to practice shifting cultivation due to high population densities, they continue to practice other elements of extensive cultivation, including low levels of technological and capital inputs, traditional land tenure and land husbandry practices, and traditional methods of resource acquisition. Various structural factors mentioned earlier have hindered the uptake of the methods necessary for agricultural intensification by local farmers. Exchange rate, tax, trade, and pricing policies in the context of strict government control have squeezed out the private sector and stifled farmer investment in agricultural land (Cleaver and Schreiber 1994).

Despite the crucial importance of an improved policy framework that allows the market to operate freely, it will not launch Sub-Saharan African agriculture on a strong and sustainable growth path without proactive measures at the national and international level to ensure more widespread diffusion of technological solutions and more intensive input application across the region. For instance, Sub-Saharan African governments must continue to focus substantial and well-planned effort on stimulating much higher levels of fertilizer use. While some researchers (Versteeg, Adegbola, and Koudokpon 1993; Janssen 1993) have pointed to the suitability of labor-intensive techniques such as legume rotations, animal manures, and alley cropping as potential short-term fertilizer substitutes in cases of labor surplus, the conclusion that chemical fertilizer use must increase rapidly if regional agricultural production is to respond to technological innovation is unavoidable (Byerlee and Heisey 1996). Unwise fertilizer subsidies in the 1970s and early 1980s brought high-cost marketing and limited choice, spurring increased use only among politically powerful farmers. Subsidy reform in the 1980s—along with currency devaluation and high world prices—led to significant local price increases and reduced consumption from 3.7 million tons in 1988/89 to 3.5 million tons in 1994/95, with more than half of the countries in the region depending on foreign aid to supply their fertilizer needs (Bumb and Baanante 1996).

While the removal of subsidies is necessary to stimulate private-sector participation in the market, the benefits have not yet been realized due to a variety of factors, including trade barriers, political indifference, foreign exchange shortages, low crop prices, and a lack of institutional and physical infrastructure (World Bank 2000a). A significant level of public-sector commitment will be necessary to achieve higher fertilizer use, with areas in need of focus including macroeconomic stability, price incentives, credit support, organizational efficiency, and much higher investment in infrastructure. Governments must encourage fertilizer use in high-potential areas, put in place proper measures to ensure environmental sustainability, and address the high cost of fertilizers by lowering transport costs and raising scale-economies of international purchasing and shipment (Byerlee and Heisey 1996; Bumb and Baanante 1996). Given that the regional supply potential is only 8.4 million tons, Sub-Saharan Africa will have to import large quantities of fertilizer over the foreseeable future if it is to dramatically increase consumption, thus necessitating stable and timely supplies of foreign exchange (Bumb and Baanante 1996).

The IMPACT baseline projections require large investments in roads, irrigation, clean water, and education in Sub-Saharan Africa (see Chapter 7). Because private-sector research in Africa is relatively undeveloped, the public sector is likely to be responsible for the vast majority of innovation over the next 20 years (Byerlee and Heisey 1996). Areas in need of attention include the development of nutrient management systems for specific soils, low-cost soil rehabilitation techniques, methods for incorporating perennial crops in farming landscapes, and innovative incentive structures to encourage long-term conservation of forest and grazing land (Scherr 1999). Byerlee and Heisey (1996) point out that the record of high-yielding maize research in Sub-Saharan Africa offers some hope for the future—with great potential for raising food crop production, particularly in the savanna and mid- and high-altitude areas—although "successful maize research programs in Eastern and Southern Africa required a decade or more of sustained effort to produce varieties and hybrids that were widely adopted." Lack of staff continuity and breeding strategies in many national programs have been mainly responsible for the widespread perception that local research efforts have not been successful, although Alston et al. (2000) calculated the mean rate of return to local research at a very respectable 49.6 percent.

Future research efforts may require a greater diversification from a focus on maize and explore opportunities for alternative crops such as cassava and rice that have particular problems associated with African agroecological conditions. Technological diffusion has proven a major problem in Sub-Saharan Africa, with Goldman and Block (1993) identifying a number of commodities for which high-yielding varieties exist but are underutilized, including cassava (with potential yield increases of 50 percent on half of currently planted area), sweet potato, and rice (irrigated and mangrove environments) (cited in Spencer 1994). Nevertheless, the experience with maize in Sub-Saharan Africa shows that small farmers will make use of improved seeds and complementary inputs provided the technology, infrastructure, and overall macroeconomic environment are appropriate. In order to address the conditions particular to the region, the development of improved technology packages for all crops needs to place a premium on efficient input use and maximizing returns to labor and cash during early adoption. Above all, effective research must be embedded within an overall framework for agricultural development that emphasizes smallholder commercialization, private-sector initiative at all levels, decentralized public participation, trade, and poverty alleviation (World Bank 2000a).

Underlying the baseline IMPACT projections is the implicit assumption that current developments on the continent offer the prospect of some amelioration of past trends. We take hope in the reformist currents evident during the 1990s throughout much of the region and note that agriculture became far more of a priority than it was during the import-substituting, industry-centered days of the 1960s, 1970s, and early 1980s. Agriculture has responded to macroeconomic reform and export crop liberalization in the 1990s, with 12 countries reporting agricultural GDP growth rates of 4 percent or more between 1990 and 1997, and 5 more countries added after 1993 (Table 6.11) (World Bank 2000a). Agricultural value-added per worker also increased in 19 out of 31 countries between 1979–81 and 1995–97, with West Africa showing particularly strong growth as the use of bovine animal traction spread (World Bank 2000a). It is our contention that as the general environment continues to improve—with policymakers still dedicated to improving policies and institutions—agricultural productivity will continue to improve moderately as well.

TABLE 6.11 Number of countries achieving agricultural GDP growth of 4 percent or more in Sub-Saharan Africa, 1980–97

Region	*1980–90*	*1990–97*	*1993–97*
Northern	0	2	4
Central and Western	3	6	7
Southern	0	4	6
Eastern	0	0	0

Source: World Bank (2000a).

Despite these optimistic signs, there is arguably a very real possibility of agricultural stagnation and deepening poverty in Sub-Saharan Africa. And recognition of a problem does not inevitably lead to effective action. Despite some successes, many countries in Sub-Saharan Africa have struggled with the transition to private-sector input provision and output markets, and uncertainty in input supply and producer prices remains a major factor limiting the ability of smallholders to plan investments with long time horizons (Byerlee and Eicher 1997). A number of factors lead to concern over the ability of regional production systems to even maintain the gains that have been made over the last 30 years, including severe soil fertility depletion and erosion in many areas farmed without appropriate nutrient replacement or conservationist practices, pest problems, overdependence on maize monoculture, and highly variable water availability. Worldwide, the decline of funding for international agricultural research has placed increasing responsibility for technological breakthroughs in agriculture on the private sector, and it is likely that the great majority of these advances will be unsuited to the agroclimatic environment of Sub-Saharan Africa. A long record of failure and concern over the availability of exploitable water supplies indicates that the potential for irrigation expansion in Sub-Saharan Africa is limited, at least over the medium term.

The environmental consequences of population growth and agricultural intensification under conditions of low input application and technology dissemination deserve further attention, given their centrality to the prospects for realization of the IMPACT baseline assumptions. Soil degradation—particularly erosion and nutrient depletion—has become a severe threat on both marginal lands undergoing population-induced permanent cropping and high-quality rainfed lands with high population densities. A Global Assessment of Soil Degradation (GLASOD) study found that water and wind erosion and chemicals had degraded 65 percent of soils on agricultural land in Sub-Saharan Africa since the 1950s, with serious degradation affecting 19 percent of all land (Oldeman et al. 1991). Supporting the need for far higher rates of fertilizer application, Stoorvogel et al. (1993) extrapolated in a continent-wide study of soil nutrient depletion that average annual nutrient losses over the last 30 years equaled 1.4 tons per hectare of urea fertilizer, 375 kilograms per hectare of triple superphosphate, and 896 kilograms per hectare of potassium chloride (Scherr 1999). A variety of studies consistent with these figures indicate that productivity losses from soil degradation since World War II have amounted to 25 percent for cropland, with African farm survey data showing declines in grain yields from 2–4 tons per hectare to 1 ton per hectare on originally fertile land (Oldeman 1998; Sanchez et al. 1997, as cited in Scherr 1999). Crop yield losses from past erosion show cumulative crop yield reductions that range from 2 to 40 percent across all Sub-Saharan African countries, with a mean of 6.2 percent for the region (Scherr and Yadav 1996). Bojo (1996) estimates that economic loss

TABLE 6.12 Production assumptions for Sub-Saharan Africa under the optimistic and pessimistic scenarios

Growth rate	Optimistic	Pessimistic
Cereal and oilcrop yield	Add 100%	Subtract 50%
Cereal and oilcrop area	No change	Subtract 50%
Roots and tubers yield	Add 50%	Subtract 50%
Roots and tubers area	No change	Subtract 50%
Livestock yield	No change	Subtract 30%
Livestock area	Add 30%	Subtract 30%

Source: Authors.

from soil degradation ranges from less than 1 percent of agricultural GDP in Madagascar, Mali, and South Africa to 2 to 5 percent of agricultural GDP in Ethiopia and Ghana to more than 8 percent in Zimbabwe.

Soil degradation may indeed remain a serious problem during the IMPACT projections period, particularly on marginal lands with rapidly growing populations in parts of the Sahel, mountainous East Africa, and the dry belt stretching from the coast of Angola to Southern Mozambique (Cleaver and Schreiber 1994). For instance, Lal (1995) predicts that water erosion alone will reduce crop productivity in Sub-Saharan Africa by 14.5 percent between 1997 and 2020 (Scherr 1999).

Pessimistic Africa Scenario

Given the downside risks for agriculture, it is important to assess the implications of an alternative, pessimistic scenario for Sub-Saharan Africa. In order to quantify a pessimistic scenario for Africa in the IMPACT model, we cut projected crop area and yield growth by 50 percent and reduced the growth in livestock, milk, and egg numbers by 30 percent (Table 6.12). Additionally, because agricultural production is so important to African

TABLE 6.13 GDP growth rates in Sub-Saharan Africa under the baseline, optimistic, and pessimistic scenarios, 1997–2020

Region	Baseline	Optimistic	Pessimistic
		(percent/year)	
Nigeria	3.8	8.0	1.9
Northern	3.3	8.0	1.7
Central and Western	3.8	8.0	1.9
Southern	3.2	8.0	1.6
Eastern	3.5	8.0	1.8

Source: IMPACT projections, June 2001.

TABLE 6.14 Cereal production and growth rates in Sub-Saharan Africa under the baseline, optimistic, and pessimistic scenarios in 2020

Region	Baseline	Optimistic	Pessimistic
		(million metric tons)	
Cereal production			
Nigeria	37	54	28
Northern	38	55	28
Central and Western	20	31	14
Southern	18	24	13
East	16	23	12
All Sub-Saharan Africa	129	187	96
Cereal growth rates		*(percent/year)*	
Nigeria	2.4	3.9	1.3
Northern	2.5	4.0	1.3
Central and Western	3.0	4.8	1.5
Southern	2.4	3.7	1.3
Eastern	2.4	3.9	1.3
All Sub-Saharan Africa	2.5	4.1	1.3

Source: IMPACT projections, June 2001.

economies, GDP growth rate assumptions between 3.2 and 3.8 percent annually are cut by 50 percent (Table 6.13). Last, a variety of social indicators are also expected to worsen, with national schooling and sanitation falling by 10 percent and the life expectancy ratio falling by 4 percent from baseline levels. With population growth projected at the UN's medium variant level (UN 1998), regional per capita GDP in the pessimistic Africa scenario will decline from $339 in 1997 to $297 in 2020, representing a reversal of the increase in per capita GDP growth of 1.2 percent a year projected under the baseline scenario.

The pessimistic Africa scenario naturally will adversely affect overall agricultural production, reducing cereal output in 2020 to 96 million tons, or 26 percent below the baseline level, as cereal production growth declines to 1.3 percent annually (Table 6.14). Roots and tubers production will only reach 201 million tons, or 20 percent below the baseline level (Table 6.15). The total agricultural production value of all IMPACT commodities, estimated under the baseline scenario to increase 79 percent above 1997 values to reach $73 billion in 2020, will fall to $66 billion under the pessimistic Africa scenario. Slowing area and yield growth will share responsibility for the shortfall in agricultural production, although both cereal and roots and tubers area growth will remain slightly positive throughout the region at 0.5 percent annually (Table 6.16).

These rates of area growth represent sharp declines from 1.9 percent annual cereal area growth and 2.2 percent annual roots and tubers area growth achieved between 1967 and 1997, and reflect rising land scarcity and degradation

TABLE 6.15 Roots and tubers production in Sub-Saharan Africa under the baseline, optimistic, and pessimistic scenarios in 2020

Region	Baseline	Optimistic	Pessimistic
		(million metric tons)	
Nigeria	102	126	82
Northern	10	12	8
Central and Western	85	103	67
Southern	24	29	21
East	30	37	23
All Sub-Saharan Africa	252	307	201

Source: IMPACT projections, June 2001.

under the pessimistic Africa scenario. Cereal yield growth will drop to 0.8 to 1.0 percent annually in all regions under the pessimistic Africa scenario, commensurate with the 0.8 percent annual yield growth rate achieved regionwide during 1967–97 (Table 6.17). Sharply lower area growth and yield growth similar to the historical average represent a plausible pessimistic scenario for Sub-Saharan Africa.

On the trade side, Sub-Saharan Africa's net cereal imports of $3.9 billion (27 million tons) in 2020 under the baseline scenario will increase to $5.4 billion (39 million tons) under the pessimistic Africa scenario, reaching a level that may not be sustainable given foreign exchange constraints (Table 6.18). Sub-Saharan Africa's food imports will expand precipitously to $11 billion of net agricultural imports in 2020, representing 17 percent of the value of agricultural production in that year.

The pessimistic Africa assumptions would lead to significantly worse malnutrition in Sub-Saharan Africa (Table 6.19). Overall, per capita kilocalorie availability would decline from 2,232 kilocalories in 1997 to 2,162 kilocalories in 2020, reversing the slight improvement of

TABLE 6.16 Sum of cereal and roots and tubers area cropped in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios, 1997 and 2020

Region	1997	Baseline	Optimistic	Pessimistic
			(million hectares)	
Nigeria	24	29	29	27
Northern	30	37	37	34
Central and Western	16	22	21	19
Southern	11	14	14	13
Eastern	9	12	12	11

Source: IMPACT projections, June 2001.

TABLE 6.17 Cereal yield growth rates in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios, 1997–2020

Region/Country	Baseline	Optimistic	Pessimistic
		(percent/year)	
Nigeria	1.6	3.3	0.8
Northern	1.7	3.4	0.9
Central and Western	1.9	3.9	1.0
Southern	1.4	2.9	0.8
East	1.5	3.1	0.8
All Sub-Saharan Africa	1.9	3.4	0.9

Source: IMPACT projections, June 2001.

TABLE 6.18 Agricultural trade balances in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios in 2020

Commodity	Baseline	Optimistic	Pessimistic
		(US$ billion)	
Wheat	−1.7	−3.0	−1.5
Maize	−0.7	−0.3	−1.1
Rice	−1.4	−1.5	−1.9
Other coarse grains	−0.1	1.0	−0.9
Potatoes	0.0	−0.4	−0.1
Sweet potatoes and yams	0.0	0.2	−1.2
Cassava and other roots and tubers	0.0	0.3	−1.8
Soybeans	−0.1	−0.2	0.0
Oils	−1.0	−1.6	−1.2
Meals	0.0	0.4	−0.1
Beef	−0.1	−7.4	0.3
Pork	−0.2	−2.2	−0.1
Sheep	0.2	−0.1	−0.4
Poultry	−0.2	−1.2	−0.1
Milk	−1.3	−8.0	−1.2
Eggs	0.0	−0.5	−0.1
Total	−6.5	−25.0	−11.0

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE 6.19 Kilocalorie consumption in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios in 2020

Scenario	Northern	Central and Western	Southern	Eastern	Nigeria	All Sub-Saharan Africa
			(kilocalories per capita)			
Baseline	2,317	2,370	2,219	2,170	3,168	2,442
Optimistic	3,012	2,976	3,207	2,838	4,323	3,232
Pessimistic	2,090	2,117	1,946	1,933	2,721	2,162

Source: IMPACT projections, June 2001.

210 kilocalories achieved between 1997 and 2020 under the baseline scenario. The number of malnourished children in Africa would also increase from 33 million in 1997 under the baseline scenario to 49 million children (Table 6.20). If budgetary and foreign exchange constraints rendered Sub-Saharan Africa unable to increase food imports to the high levels generated under the pessimistic scenario, the number of malnourished children in the region would increase still further.

A high level of food insecurity and heavy dependence on food aid characterizes Africa today. The region can ill afford further declines in per capita income and simply does not possess the necessary foreign exchange to satisfy its food needs through imports. While the assumptions of the pessimistic Africa scenario do result in a substantial increase in net imports of agricultural commodities, especially cereals, to help mitigate the projected production gap, the region still will experience a significant decline in per capita kilocalorie availability and a significant increase in child malnourishment even at these high and potentially economically unsustainable import levels.

An assessment of the investment requirements under the pessimistic Africa scenario is presented in Chapter 7 of this volume.

TABLE 6.20 Numbers of malnourished children in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios in 2020

Scenario	Nigeria	Northern	Central and Western	Southern	Eastern	All Sub-Saharan Africa
			(millions)			
Baseline	7.5	13.7	8.6	4.3	5.2	39.3
Optimistic	4.4	9.0	4.5	1.4	2.5	22.0
Pessimistic	9.3	16.0	11.9	5.7	6.6	48.6

Source: IMPACT projections, June 2001.

Optimistic Africa Scenario

While IMPACT baseline results predict an increase in the number of malnourished children in Sub-Saharan Africa from 33 million children in 1997 to 39 million in 2020, the developing world, excluding Sub-Saharan Africa, will achieve a decline in the absolute number of malnourished children of 31 percent, from 134 million children in 1997 to 92 million children in 2020. What kind of transformations in terms of economic and agricultural growth, education, and health will be necessary for Sub-Saharan Africa to battle childhood malnutrition as effectively as the rest of the developing world? Is it feasible to hope that even a major economic transformation on the continent could lead to real inroads against childhood malnutrition?

In order to provide a sense of the magnitude of the challenges facing Sub-Saharan Africa and the necessity for national governments and international organizations to pay concerted attention to these challenges, we present the following scenario as representative of what will be needed to achieve a 33 percent reduction in the number of malnourished children in Sub-Saharan Africa, that is, to go from 33 million children in 1997 to 22 million in 2020 (Tables 6.19 and 6.20). Such a reduction would bring malnutrition trends in Sub-Saharan Africa more in line with those projected elsewhere in the developing world. To achieve such a dramatic improvement in childhood malnutrition, total GDP growth in the five Sub-Saharan African subregions in IMPACT (Nigeria, Northern, Central and Western, Eastern, and Southern) would have to increase from the baseline-estimated range of 3.2 to 3.8 percent per year during 1997–2020 to an annualized rate of growth of 8 percent. Realized crop yield growth rates regionwide would have to rise from between 1.3 and 1.8 percent per year under the baseline to an annualized rate of 2.7 to 3.6 percent in 1997–2020.[31] Yield growth rates of this magnitude would be necessary to satisfy rising cereal demand on the continent without increasing the level of cereal imports. If yield growth rates were lower, higher cereal imports could meet the deficit between regional demand and supply, although it is difficult to see how the region could achieve 8 percent GDP growth without tremendous growth in agricultural productivity. Foreign exchange constraints, of concern in the baseline and pessimistic Sub-Saharan Africa scenarios, would probably not restrict moderate levels of net cereal imports if the economies of the region were growing at a rate of 8 percent per year.

The high yield rates (and high investment requirements presented in Chapter 7) needed to generate an optimistic Africa scenario serve as a caution against assuming that agriculture will take off in Sub-Saharan Africa the same as it did during the Green Revolution in Asia. Various authors have argued the necessity of seeking different paths to rapid and sustainable agricultural productivity growth. Spencer (1994) points to higher seasonal labor productivity, new production technologies relying minimally on transported inputs, new technologies for disease and pest resistance, and a focus on rainfed systems as keys to overcoming the unique challenges that Sub-Saharan agriculture poses. A perfect example of the type of low-cost technology that can play a role in overcoming seemingly daunting obstacles is the bicycle. In the Asian countryside, ownership of bicycles often approaches 40 percent. Bicycle ownership rates in Sub-Saharan Africa are only about 3.5 percent due to the paucity of local production and various government import impediments in the form of taxes and surcharges (Hayami and Platteau 1997).

Growing evidence has accumulated in recent years indicating that GDP and agricultural production growth alone are not sufficient to drive significant improvements in childhood malnutrition (Smith and Haddad 2000). A variety of additional variables concerning the status and education of women and the access of the general population to clean water have proven crucial determinants of childhood well-being, and these would have to improve drastically in Africa to significantly improve malnutrition. Under the optimistic Africa scenario, rates of female schooling are projected to increase by 20 percent, compared with the baseline, with clean water access and female life expectancy both increasing by 10 percent. Achievement of the impressive advances in quality-of-life indicators represented by the optimistic Africa scenario would require a tremendous level of commitment and investment at all levels, and a major effort to focus on the status, education, and health of women. Neither African governments nor the international community have yet displayed a willingness to provide the investments that would be necessary to establish a decent life for the great many impoverished and malnourished children in the region. Tragically, the rapidly increasing costs of HIV/AIDS in most of Sub-Saharan Africa will only raise the challenges impeding improved human development in the region. Brown (1996) presents the remarkable finding that while HIV/AIDS does not impact overall population growth rates to a significant degree, the disease could lower per capita GDP growth rates in severely affected Sub-Saharan Africa by 0.6 to 1.4 percent annually. Any outcome in this range would obviously represent a huge blow to the prospects for sustainable economic development.

The optimistic Africa scenario shows that significant poverty alleviation in Sub-Saharan Africa is an immense task that will require an equally immense level of commitment on both the national and international levels. East and Southeast Asia have realized impressive gains over the last three decades in combating poverty and generating economic growth, and a similarly remarkable transformation will be necessary for real improvements in childhood malnutrition to take place in Sub-Saharan Africa. For example, substantial crop yield growth at the level indicated by the optimistic Africa scenario would require an estimated 8 to 10 percent annual growth in fertilizer use across the region, a level commensurate with the 9 percent annual growth achieved in Asia between 1959/60 and 1994/95 (Bumb and Baanante 1996).[32] For an idea of what will be required in the way of investments under the optimistic Africa scenario, see Chapter 7.

HIGH MEAT DEMAND IN INDIA—TURMOIL IN WORLD MARKETS?

Many have voiced concern that revolutionary growth in meat demand in India over the coming decades could lead to massive Indian imports of meat or cereals (for feed), with resultant upward pressure on world prices (see, for example, Bhalla, Hazell, and Kerr 1999). Current levels of meat and egg consumption in India are quite low, even taking into account the country's low per capita incomes. Indians consumed only 4 million tons of meat and 1 million ton of eggs in 1997, translating into annual per capita consumption of 4.4 kilograms of meat and 1.6 kilograms of eggs. By contrast, Pakistanis consumed 13.6 kilograms per capita of meat per year and 2.1 kilograms per capita of eggs in 1997, and the Chinese consumed 38.6 kilograms of meat per year and 5.6 kilograms of eggs, albeit at a significantly higher level of per capita income. On the other hand, per capita consumption of milk in India is high at 71.2 kilograms, with only Pakistani consumption higher in Asia at 139.8 kilograms.

The IMPACT baseline predicts significant increases in Indian meat and dairy demand, with income elasticities of demand comparable to those in other Asian countries. However, because meat consumption levels will be low initially, total Indian meat demand will only increase to 9 million tons in 2020, which translates into per capita demand of 7.1 kilograms—still very low. By contrast, per capita meat demand will reach 17.3 kilograms in Pakistan and 64.4 kilograms in China by 2020. Indian egg demand will also increase under the baseline, reaching 2.5 kilograms per capita in 2020. This figure will be higher than in Pakistan, where per capita egg demand will only increase to 2.5 kilograms per capita, but significantly lower than per capita egg demand of 8.5 kilograms per capita in China in 2020.

But a more extreme change in the Indian dietary pattern than foreseen in the baseline scenario is possible (Bhalla, Hazell, and Kerr 1999). Meat demand in India (and South Asia generally) differs from that in the rest of Asia in being lower and heavily weighted toward ruminant meat, mainly because beef is widely available and lower priced than other meats (Rutherford 1999).[33] Nevertheless, urban consumers in India do consume significantly more meat than rural consumers, and urbanization is expected to rise over the projections period (Abdulai 1999).[34] In addition, Bhalla, Hazell, and Kerr (1999) report that income elasticities for meat and egg products in India have increased over time in rural areas. It is possible that as Indian consumers become richer, better integrated into the world economy, and more aware of the dietary options available to them, they will abandon their traditional vegetarianism and shift demand preferences toward animal protein. Bhalla, Hazell, and Kerr (1999) report some evidence that this shift has occurred already, with 44 percent of urban and 32 percent of rural households consuming meat products in 1987/88 and 50 percent of both doing so in 1993/94. Similarly, average budget shares for meat increased by 19 percent

TABLE 6.21 Livestock production and demand assumptions underlying the high India meat demand and baseline scenarios, including comparison with historical growth in China

	Income elasticity		Production growth		
Commodity	Baseline	High India meat demand	Baseline (1997–2020)	High India meat demand (1997–2020)	China (1967–97)
			(percent/year)		
Beef	0.63	1.25	2.9	6.6	11.1
Pork	0.58	1.50	2.9	6.9	6.1
Sheep and goat	0.58	1.50	3.0	7.2	8.2
Poultry	0.96	1.50	4.8	8.3	8.6
Milk	0.58	1.00	3.2	5.5	5.7
Eggs	0.55	1.50	3.4	7.3	8.4

Source: FAO (2000a) for China and expert estimates for all other data.

in rural areas between 1987/88 and 1993/94, despite a minimal increase in incomes and rising relative prices for these goods, compared with the consumer price index (National Sample Survey, as reported in Bhalla, Hazell, and Kerr 1999).

Under the high India meat demand scenario, the income elasticities of Indian meat demand, feed ratios, and rates of growth in livestock production are increased (Tables 6.21 and 6.22). The income elasticities of demand for pork, sheep and goats, poultry, and eggs are all increased to 1.50, the income elasticity of demand for beef is increased to 1.25, and that for milk is increased to 1.00, with all kept constant for the entire projections period. Rates of growth in livestock numbers and feed ratios for wheat, maize, and other grains are also raised, reflecting demand-induced increases in livestock production and the rapid shift from backyard to commercial production that would have to accompany rising livestock production. The rate of growth of total meat production of 3.1 percent under the baseline scenario increases to 6.4 percent under the high India meat demand scenario during 1997–2020. Such production growth rates are much higher than the annual projected rates of growth of 2.6 percent in East Asia and 3.0 percent in Southeast Asia, but comparable to annual production growth rates in Asia of 5.1 percent in temperate and highland zones and 7.2 percent in the humid and subhumid tropics between 1985 and 1997 (Hoffman 1999). China set an historical precedent of 7.4 percent annual meat production growth between 1967 and 1997.

TABLE 6.22 Ratio of cereal feed demand to livestock production (not including milk) under the high India meat demand scenario, 1997 and 2020

Region/Country	1997	High India meat demand, 2020
China	2.1	2.2
Developed world	4.3	4.2
India	0.3	1.2
Indonesia	0.7	0.5
Latin America	2.2	2.1
Pakistan	0.4	0.4
Philippines	2.2	2.2
Thailand	2.7	2.4

Source: IMPACT projections, June 2001.

A massive increase in Indian meat demand and production under the high meat demand scenario would have a major impact on Indian trade balances for meats and cereals. World meat and cereal prices would also be affected to varying degrees. Total meat demand in India is projected to rise to 23 million tons, or 18.0 kilograms per capita (Table 6.23). This level of per capita meat demand is comparable to the Pakistani projected per capita demand of 18.2 kilograms per capita and the Indonesian of 16.0 kilograms per capita in 2020, but it is significantly higher than per capita demand in other South Asian countries such as Bangladesh (Table 6.24). We assume that Indian meat production will have to rise sufficiently to cover most massive quantities of meat products. Therefore we estimate net meat imports of 1.8 million tons as necessary to cover excess demand. Egg demand under the high India meat demand scenario will increase to a projected 10 million tons, representing per capita consumption of 7.6 kilograms. Such a level of per capita egg consumption would place India's projected per capita egg consumption on a par with WANA's (7.0 kilograms) and Southeast Asia's (6.7 kilograms).

Higher meat production, through its effects on feed demand, will place a significant strain on Indian agriculture. With meat production increasing to 20.9 million tons, Indian cereal

TABLE 6.23 Total and per capita meat demand in India under high India meat demand and baseline scenarios, 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**High India meat demand**
		(million metric tons)	
Meat demand			
Beef	2.6	5.4	12.5
Pork	0.5	1.0	3.1
Sheep and goat	0.7	1.4	4.0
Poultry	0.5	1.5	3.2
Total meat demand	4.3	9.4	22.7
Milk	71.4	147.5	246.8
Eggs	1.6	3.4	9.6
Per capita demand		*(kilograms/capita)*	
Beef	2.7	4.3	9.9
Pork	0.5	0.8	2.4
Sheep and goat	0.7	1.1	3.2
Poultry	0.5	1.2	2.5
Milk	74.3	116.5	195.0
Eggs	1.7	2.7	7.6

Source: IMPACT projections, June 2001.

demand will increase from 181 million tons in 1997 to 281 million tons in 2020, with 25 million tons of 2020 demand accounted for by feed demand. The baseline scenario projected total Indian cereal demand in 2020 at only 260 million tons, with 4 million tons accounted for by feed demand. Cereal production shortfalls under the high India meat demand scenario will necessitate cereal imports of 26 million tons ($3.1 billion in value) in 2020 (Table 6.25). Meal demand will also increase significantly over the projections period, rising from 11 million tons in 1997 to 58 million tons in 2020, while production will only increase to 27 million tons, thus necessitating imports of 31.4

TABLE 6.24 Per capita meat demand in various countries under the high India meat demand scenario, 1997 and 2020

Country	*1997*	*2020*
	(kilograms/capita)	
Bangladesh	3.3	5.0
China	42.8	70.7
India	4.5	18.0
Indonesia	9.9	16.0
Pakistan	14.7	18.2
Thailand	28.9	49.5

Source: IMPACT projections, June 2001.

TABLE 6.25 Net Indian cereal and meal trade under high India meat demand and baseline scenarios, 1997 and 2020

	1997	*2020*	
Commodity	**Base year**	**Baseline**	**High India meat demand**
		(million metric tons)	
Wheat	−0.8	−6.7	−15.7
Maize	0.0	0.2	−5.5
Other coarse grains	0.0	0.5	−4.7
Rice	2.6	−0.3	−0.3
All cereals	1.8	−6.4	−26.2
Meals	4.2	1.8	−31.4

Source: IMPACT projections, June 2001.
Note: Positive figures indicate net exports; negative figures indicate net imports.

million tons ($5.6 billion) in 2020. Total projected meal demand in 2020 under the baseline scenario is only 24 million tons.

Higher meat demand in India will affect world meat and cereal prices, but the impacts are rather small. Table 6.26 shows meat and cereal prices under the baseline and high India meat demand scenarios. Meat prices will be only slightly higher in 2020 under the high India meat demand scenario than under the baseline scenario. Under the high demand scenario, beef prices will be 1 percent higher in 2020 and poultry prices 3 percent higher. Price changes among the cereals will also be small, with wheat prices 5 percent higher in 2020 than under the baseline scenario, rice prices 2 percent higher, and maize prices 6 percent higher. High Indian meat demand will have the largest impact on international meals prices, raising them 28 percent above the baseline 2020 values.

Higher meat consumption in India will lead to higher kilocalorie consumption and lower childhood malnutrition. Per capita kilocalorie consumption in 2020 will rise from 2,868 kilocalories under the baseline to 3,060 kilocalories under the high India meat demand scenario, and the projected number of malnourished children under the age of five in 2020 will decline from 44 million children under the baseline to 42 million children under the high India meat demand scenario. This positive shift, however, will be highly dependent on the ability of Indian livestock producers and farmers to meet the production targets that our scenario assumes. Indian livestock will have to undergo a significant commercial transformation if it is to satisfy a significant proportion of projected demand under the high India meat demand scenario. India already faces significant land and water shortages, rendering the feasibility of the projected 6.2 percent growth in livestock numbers highly questionable. While higher meat imports could presumably take pressure off the Indian

TABLE 6.26 Prices under the baseline and high India meat demand scenarios, 1997 and 2020

	1997		*2020*	
Commodity	**Base year**	**Baseline**	**High India meat demand**	**Price change over baseline**
		(US$/metric ton)		*(percent)*
Beef	1,808	1,740	1,772	2
Pork	2,304	2,239	2,289	2
Sheep and goat	2,918	2,832	3,043	7
Poultry	735	703	723	3
Milk	318	289	294	2
Eggs	1,231	1,191	1,262	6
Wheat	133	123	129	5
Maize	103	102	108	6
Other coarse grains	97	86	93	8
Rice	285	250	254	2
Meals	199	191	244	28

Source: IMPACT projections, June 2001.

livestock sector to meet domestic demand, India's projected agricultural trade deficit under current assumptions of high feed imports for domestic production already reaches $17 billion in 2020, representing 8.9 percent of total agricultural production.[35] Should domestic Indian production prove unable to supply a rapidly expanding domestic market, Indian consumers would turn to the international market, resulting in a further increase in livestock prices, thus precipitating a move back down the demand curve to lower levels of meat consumption. We have not modeled this scenario, however.

7

INVESTMENT REQUIREMENTS: WHAT WILL THE COSTS BE?

IMPACT projections of agricultural production and malnourishment depend on assumptions regarding investment expenditures on a variety of sectors generally considered important for agricultural development. The most important investment drivers in the IMPACT model are irrigation, rural roads, education, clean water provision, and agricultural research. In this chapter we attempt to place dollar values on the assumptions embedded in the various scenarios: the baseline, the global pessimistic and optimistic scenarios, and the regional pessimistic and optimistic scenarios for Sub-Saharan Africa.

REQUIREMENTS FOR THE BASELINE SCENARIO

For the baseline scenario, the cost of improvements in the five sectors during 1997–2020 are evaluated and aggregated into total investment costs for each region of the developing world. The dollar values thus represent what will have to be spent in each of the five sectors between 1997 and 2020 if the baseline projections are to become a reality. Table 7.1 summarizes investments across the five sectors.

Any comprehensive investment assessment on a global basis requires synthesis of sparse data and many simplifying assumptions. When reliable, disaggregated country-level data are not available, we have chosen to employ global averages as a second-best approximation of real costs. The analysis presented here should thus be viewed as a guide to the level of investment effort required to generate baseline outcomes on a regional and large-country basis, and the following figures are intended as ballpark estimates of total costs and a basis for regional comparisons. Additional analysis will be required to synthesize and prioritize investment decisions in individual countries.

Total Investments

As the estimates in this chapter make clear, the developing nations and international donors face major challenges in order to achieve even the modest levels of agricultural production growth and human welfare improvement envisioned in the IMPACT baseline scenario. Projected expenditures on the five categories of investment total $578.9 billion between 1997 and 2020. This translates on an annual basis to

3.6 percent of 1997 developing-world government spending of $706.1 billion (World Bank 2000b). Projected spending by South Asia is highest at $148.2 billion, followed by Latin America at $140.4 billion. This represents 11 percent per year of total government expenditures of $58.1 billion for South Asia, and 2.2 percent of $272.7 billion in government expenditures for Latin America. Sub-Saharan Africa will face investment requirements totaling $106.9 billion, representing a sizeable 19 percent a year of government expenditures of $25.0 billion in 1997. China, despite doomsayers' frequent warnings of impending agricultural disaster, will only require investments totaling $41.4 billion to achieve baseline results.

Different regions face different challenges. Overall, irrigation will represent 30 percent of total investment in the five sectors, with agricultural research and rural roads accounting for 21 percent each. Education receives the lowest investment at 13 percent of the total. While irrigation expansion—particularly dam construction—has been much maligned in recent years for its possibly adverse impacts on the environment and local populations, it is projected that investment in irrigation will remain a large item, especially in India and Latin America; India mainly because of the high rate of increase in irrigated area, and Latin America because costs of irrigation development are relatively high there.

Rural road construction will be particularly important in Sub-Saharan Africa and Latin America, where it will represent 35 and 26 percent of total investment in the five investment sectors, respectively, because new roads are needed to support relatively rapid area and crop yield growth in those regions. Despite high levels of investment, Sub-Saharan Africa will still have an extremely underdeveloped transportation system, and further improvements in this sector are essential.

Because of rapid population growth, education will represent 27 percent of total investment expenditures in WANA. Clean water, representing 15 percent of total investment expenditures across the developing world, is projected to account for 35 percent of China's expenditures in 1997–2020. Agricultural research will account for particularly large shares of China's and WANA's total investment expenditures, at 35 percent and 31 percent, respectively. Public agricultural research will account for only 7 percent of Sub-Saharan Africa's total investment expenditures between 1997 and 2020.

Irrigation

Methodology. Total irrigation investments are calculated by multiplying the estimated area increases in irrigation in 1997–2020 projected in the IMPACT baseline by the cost of irrigation per hectare (Jones 1995; Rosegrant and Svendsen 1993; Rosegrant et al. 1997). Total irrigated area data are adjusted for cropping intensity (FAO 2000a), because the IMPACT model data include multiple cropping seasons. Investment costs per hectare are on a 1997 real basis, with data from other years adjusted to 1997 real dollars, utilizing the manufacturing unit value (MUV) index (World Bank 1998).

Projected Investment. Irrigation investments in developing countries between 1997 and 2020 are projected to total $175 billion under the baseline scenario (Table 7.1). South Asia will account for a significant share of this investment, accounting for 35 percent of total irrigation investment in the developing world; India alone will account for 24 percent of this share. Latin America's share is 26 percent, Sub-Saharan Africa's 16 percent, and WANA and East Asia's approximately 10 percent each. India has the lowest estimated costs per hectare of irrigation development in the developing

TABLE 7.1 Total projected investments, baseline scenario, 1997–2020

Region/Country	Irrigation	Rural roads	Education	Clean water	National agricutural research[a]	Total investments
			(US$ billion)			
Latin America	44.8	36.7	12.1	9.8	37.0	140.4
West Asia/North Africa	17.9	7.3	21.5	8.5	25.3	80.5
Sub-Saharan Africa	28.1	37.9	15.7	17.3	8.0	106.9
South Asia	61.3	27.4	14.5	27.0	18.0	148.2
India	42.5	23.5	10.5	18.4	15.6	110.5
Southeast Asia	18.6	3.9	6.8	9.4	14.1	52.6
China	3.2	6.8	2.4	14.4	14.6	41.4
Developing world	174.6	120.3	75.9	86.5	121.7	578.9

Source: IMPACT projections, June 2001.

[a]In addition, international agricultural research expenditures by the CGIAR centers are projected to be US$9.7 billion.

world at $3,074, indicating the extent to which large projected total expenditures can be attributed to massive increases in irrigated area. India is projected to expand physical irrigated area by 13.8 million hectares during 1997–2020, almost twice the projected expansion of 7.0 million hectares in Latin America over this period, despite the roughly equal projected total costs in these two regions. China, which had the largest irrigated area in the world in 1997, will only spend $3.2 billion on 0.5 million hectares of irrigation expansion between 1997 and 2020, accounting for 1.8 percent of the developing world total. India is projected to surpass China as the most heavily irrigated country in the world by 2020, with 63.3 million hectares under irrigation, compared with China's 57.6 million hectares.

Rural Roads

Methodology. Rural road investments are calculated by multiplying the incremental road length required in 1997–2020 by road investment costs per kilometer, with the latter costs estimated by Spencer (1994). Unfortunately, a lack of country-level data on this variable requires application of the world average of $50,000 per kilometer to all regions. Rural road length data are available for 1997 (International Road Federation 1999). The increase in rural road length required under the baseline scenario is composed of two components. First, the road length is assumed to increase at the rate necessary to maintain the same density of roads for new cropland as exists for present cropland. Second, the additional road length required to generate the crop yield increase attributable to road investment is estimated and added to the road length required for cropland expansion. The contribution of road investment to yield growth is estimated based on the projected proportion of future yield growth attributable to road expansion and the elasticity of productivity growth with respect to road investment (the latter is based on Fan, Hazell, and Thorat 1999).

Projected Investment. Cumulative rural road investments in the developing world are projected to total $120.3 billion between 1997 and 2020 (Table 7.1). Sub-Saharan Africa and Latin America together account for more than 60 percent of total expenditures in developing countries over the projections period. These two regions account for most of the projected expansion in crop area harvested, as well as relatively rapid crop yield growth, with significant requirements for investments in roads underlying both of these developments. India alone would have to invest $23.5 billion of South Asia's $27.4 billion investment in rural roads. Southeast Asia, China, and WANA are projected to have much lower road investments.

Public Agricultural Research

Methodology. Both national research expenditures and international expenditures of the CGIAR are estimated and summed to produce total public agricultural research expenditures. Data on annual agricultural research expenditures are not available for the year 1997 (Tabor, Janssen, and Bruneau 1998). Therefore, the most recent data available (for the period 1991–96, depending on the country), together with growth rates in agricultural research expenditures for recent periods, are used to interpolate forward to estimate 1997 real agricultural research expenditures. Because the original national level data were standardized on a 1993 purchasing power parity basis, they were inflated with the MUV index (World Bank 1998) to obtain 1997 values. The data were then converted from purchasing power parity basis to market prices (World Bank 2000b) to maintain comparability with the other investment data. In order to project annual expenditures on agricultural research to 2020, future rates of growth in agricultural research expenditures are then estimated based on recent past trends in research expenditures and crop yields, the projected contribution of research to future crop yield growth, and elasticities of productivity with respect to agricultural research expenditures. All expenditures between 1997 and 2020 are subsequently summed to obtain total agricultural research expenditures over the projections period.

Projected Investment. Public national agricultural research expenditures in the developing world are projected to total $121.7 billion during 1997–2020 (Table 7.1). Expenditures in Latin America will total $37.0 billion, representing 30 percent of total expenditures in the developing world and far outstripping the second highest region, WANA. The large expenditures in Latin America are mainly due to remarkably high agricultural research expenditures in Brazil, which are estimated to account for $22.7 billion. Sub-Saharan Africa is expected to invest only $8.0 billion in research between 1997 and 2020, signaling continued underinvestment in agricultural research in that region. Moderate agricultural research expenditures are projected in India ($15.6 billion) and China ($14.6 billion).

In addition to national agricultural research, the international research conducted by the CGIAR system has played a key role in crop productivity growth (Evenson, Pray, and Rosegrant 1999; Pardey et al. 1996). The research conducted in the CGIAR is not included in the estimates above for public agricultural research expenditures or total national investment expenditures, so these are estimated separately. Expenditures by the CGIAR system for international agricultural research were $319.2 million in 1997, with an annual rate of real expenditure growth of 3.8 percent between 1990 and 1997. On the assumption that rates of funding growth for international agricultural research will continue to decline over the projections period, we used an estimated annual growth rate of 1.9 percent to project that expenditures for international agricultural research will reach $9.7 billion under the baseline scenario in 1997–2020. Thus, combined international and national agricultural research will total $131.4 billion over the projections period.

Education

Methodology. The estimated incremental investments in education are based on the cumulated annual costs of the additional number of female students required to improve the percentage of females with access to secondary education to the levels projected in the baseline. In order to calculate education investment costs, it is first necessary to obtain estimates of the additional number of students that will enroll for secondary school education between 1997 and 2020. This value is calculated by multiplying the number of females of secondary school age in 1997 (UN 1998) by the percentage of females enrolled in secondary school in 1997, and subtracting that number from the number of females of secondary school age in 2020 (UN 1998), multiplied by projected enrollment in the IMPACT baseline for 2020. Assuming a constant rate of growth in school enrollment, the annual increment in enrollment necessary to achieve the projected enrollment in 2020 is computed. The annual increase in enrollment is subsequently multiplied by the annual cost of secondary school education per student (UNESCO 2000; Sayed 1996) and cumulated over the period to generate the total incremental costs for secondary school education.

Projected Investment. Under the baseline scenario, incremental expenditures on educating women in the developing world will total $75.9 billion during 1997–2000 (Table 7.1). WANA's secondary school education costs per student—ranging from $132 to $327—and the need to educate 73.2 million women between 1997 and 2020 will cause the region to have the highest projected education costs, representing 28 percent of the developing world total. India's costs per student are relatively low at $74, but India will have to educate an estimated 142.4 million women between 1997 and 2020. China's projected education investment is very low at only $2.4 billion to educate an additional 32.9 million women, an indication of both the relatively good performance in female education achieved to this point and the low education costs per student in China.

Clean Water

Methodology. Incremental investment costs for clean water are based on the investment required to increase the percentage of people having access to clean water to the levels projected under the baseline scenario. These investment costs are calculated by multiplying the number of people gaining access to clean water between 1997 and 2020 by the investment costs per person of providing clean water. Per capita costs of providing clean water (WSSCC 2000) and estimates of the number of people gaining access to clean water are disaggregated by urban and rural components (UN 1998). The per capita unit cost of providing water is estimated at $75 for urban areas and $25 for rural areas (WSSCC 2000).

Projected Investment. The baseline scenario will require a projected $86.5 billion investment in clean water provision, with 1.8 billion additional people gaining access to clean water throughout the developing world, as the percentage of those in the developing world who have access to clean water rises from 69 percent in 1997 to 79 percent in 2020. South Asia's required investment will be the highest at $27.0 billion, representing 31 percent of total expenditures in the developing world; India will account for

$18.4 billion of that investment, as an additional 387 million people gain access to clean water (an increase from 81 percent of the total population to 92 percent). Sub-Saharan Africa's projected expenditures for clean water are also large at $17.3 billion, with an additional 359 million people gaining access to clean water. Nevertheless, only 65 percent of the population of Sub-Saharan Africa will have access to clean water in 2020. China will also have significant expenditures of $14.4 billion on clean water provision, reaching an additional 303 million people, with coverage extending to 78 percent of the population by 2020.

REQUIREMENTS FOR OPTIMISTIC AND PESSIMISTIC SCENARIOS

As expected, the optimistic scenario requires large increases in investment in the key drivers, while the pessimistic scenario envisions significant reductions in investment. In this section, we summarize the major changes in investment required: Table 7.2 gives projected investments for the optimistic scenario, and Table 7.3 for the pessimistic. Under the optimistic scenario, increases in irrigated area cause projected irrigation expenditures in the developing world to nearly double between 1997 and 2020. South Asia's irrigation investment costs rise to $101 billion, compared with the baseline of $61 billion. Chinese irrigation investments increase explosively in both absolute and relative terms vis-à-vis the baseline, rising from $3.2 to $37.3 billion, or from 1.8 to 10.9 percent of developing world expenditures. Latin America's share is 19 percent; Sub-Saharan Africa's, 14 percent; WANA's, 13 percent; and Southeast Asia's, 9 percent. With no expansion in irrigation assumed under the pessimistic scenario, the projected increase in irrigation expenditures is zero.

The optimistic scenario projects total rural road expenditures in the developing countries to rise 7 percent above the baseline level to $128.5 billion. China's expenditures will rise 6

TABLE 7.2 Total projected investments under the optimistic scenario, 1997–2020

Region/Country	Irrigation	Rural roads	Education	Clean water	National agricultural research[a]	Total investments
			(US$ billion)			
Latin America	66.4	37.9	24.3	11.1	39.5	179.1
West Asia/North Africa	42.9	7.6	26.2	9.4	26.2	112.3
Sub-Saharan Africa	47.2	41.3	17.7	18.8	8.2	133.3
South Asia	101.0	29.9	17.1	30.0	20.4	198.4
India	61.0	25.6	12.7	20.4	17.8	137.8
Southeast Asia	30.9	4.2	9.2	10.2	15.2	69.7
China	37.3	7.2	5.0	17.5	16.4	83.5
Developing world	342.7	128.5	102.9	97.5	130.7	802.4

Source: IMPACT projections, June 2001.

[a]In addition, international agricultural research investment of the CGIAR centers is projected to be US$10.4 billion.

TABLE 7.3 Total projected investments under the pessimistic scenario, 1997–2020

Region/Country	Irrigation	Rural roads	Education	Clean water	National agricultural research[a]	Total investments
			(US$ billion)			
Latin America	0	33.5	6.0	8.2	27.4	75.0
West Asia/North Africa	0	6.5	16.4	7.4	21.6	52.0
Sub-Saharan Africa	0	28.6	13.6	14.9	6.8	63.9
South Asia	0	22.4	11.6	23.2	13.2	70.3
India	0	19.3	8.2	15.7	11.3	54.5
Southeast Asia	0	3.2	4.6	8.2	11.1	27.1
China	0	5.6	0	10.2	11.0	26.8
Developing world	0	100.2	54.6	72.6	95.4	322.7

Source: IMPACT projections, June 2001.

[a]In addition, international agricultural research investment of the CGIAR centers is projected to be US$7.5 billion.

percent above baseline levels, while Sub-Saharan Africa, South Asia, and Southeast Asia are all projected to increase their expenditures by approximately 9 percent. Under the pessimistic scenario, rural road investments in the developing world are projected to decline 17 percent below baseline levels. Investments in Sub-Saharan Africa will fall particularly sharply by 24 percent, from $37.9 to $28.6 billion, while investments in WANA and Latin America will only fall 11 and 9 percent from the baseline, respectively.

Total education costs rise 36 percent above the baseline level to $102.9 under the optimistic scenario. Increases will be particularly high in Latin America, with projected expenditures rising 101 percent, and China, at 105 percent. Expenditure increases for education under the optimistic scenario will be rather low in South Asia and WANA, and extremely low in Sub-Saharan Africa, where educational expenditures are projected to increase by only 13 percent. WANA's share of the developing world's total education investment falls to 25 percent under the optimistic scenario.

Total projected education investment in the developing world declines 28 percent from the baseline to $54.6 billion under the pessimistic scenario. Declines are generally symmetrical to the increases generated by the optimistic scenario, with the notable exceptions of Latin America and China. In Latin America expenditures will decline 50 percent from the baseline to $6 billion (whereas investments double under the optimistic scenario). In China, expenditures will decline to 0, compared with the baseline of $2.4 billion because the number of children of secondary school age will be greatly reduced.

Projected expenditures on clean water provision in the developing world between 1997 and 2020 rise 13 percent above baseline levels to $97.5 billion under the optimistic scenario, as 183.6 million additional people gain access to clean water. The percentage of the developing world population with access to clean water in 2020 rises to 87 percent from 79 percent in the baseline scenario. Additional expenditures are particularly large in China, with an increase of 22 percent; Latin America, with an increase of 14 percent; and India, with an increase of 11 percent. The population with access to clean water in 2020 increases by 57.8 million people above the baseline level in China (from 78 to 86 percent), 18.4 million people above the baseline in Latin America (from 81 to 89 percent), and 32.7 million people above the baseline in India (from 92 percent to full coverage).

Expenditure shifts for clean water provision under the pessimistic scenario are approximately 3 to 4 percent lower than the corresponding increases under the optimistic scenario, with the exception of China, where clean water expenditures decline by 29 percent to $10.2 billion.

During 1997–2020, agricultural research expenditures in the developing world will rise 7.4 percent above baseline levels under the optimistic scenario (to $130.7 billion). Increases are pronounced in India, rising 14 percent, and China, with an increase of 12 percent. Increases in all other regions remain below 10 percent.

Declines under the pessimistic scenario are more dramatic, indicating the unfortunate reality that the scope for cutting public agricultural research budgets remains greater than the scope for increasing them. Overall expenditures on public agricultural research between 1997 and 2020 are projected to decline 22 percent from baseline levels under the pessimistic scenario. Declines are again particularly pronounced in Asia, with expenditure in India falling 28 percent and expenditures in China falling 25 percent. Declines are also quite large in Latin America, with expenditures falling 26 percent.

In terms of international agricultural research, CGIAR expenditures during 1997–2020 are projected to increase 7 percent under the optimistic scenario ($10.4 billion) and decline 22 percent under the pessimistic scenario ($7.5 billion) (CGIAR 1999).

Total investment expenditures for the optimistic and pessimistic scenarios show both the promising future that could result from higher investment in agricultural production and human health as well as the depressing reality of a more likely future of serious underinvestment in these sectors. Total investment in the optimistic scenario increases to $802.4 billion, 39 percent higher than under the baseline scenario. However, $168.1 billion of the $223.5 billion investment increase under the optimistic scenario is devoted to expansion of irrigated area. The other four categories of investment go up by only $55.4 billion, an increase of 14 percent over the cumulative level of investment for these expenditures under the baseline. Total investment under the pessimistic scenario declines to $322.7 billion, a decrease of 44 percent from the baseline level. Irrigation again accounts for the largest shift, falling by $174.6 billion, while other investments combined fall by $81.8 billion, or 20 percent.

REGIONAL INVESTMENT REQUIREMENTS

The Pessimistic Scenario for Africa

The development challenges facing Sub-Saharan Africa are clearly the most daunting of those facing any region in the world. Concerted investment in agricultural and human development will be necessary to overcome these challenges over the next two decades, but pervasive poverty, mismanagement, and corruption in the region have limited the scope for internally generated investment, while donor fatigue and the perceived failures of much of past multilateral lending and bilateral aid may limit the availability of external funds. The baseline scenario requires total regional investment expenditures for Sub-Saharan Africa of about $107 billion during the period 1997–2020, which on an annual basis represents a sizeable 19 percent of total government consumption in the region in 1997 (Table 7.4). Rural roads will account for projected spending of $38 billion, irrigation for $28 billion, provision of access to clean water for $17 billion, education for $16 billion, and agricultural research for $8 billion. Southern Sub-Saharan Africa is projected to have the largest expenditures in the region at $27 bil-

TABLE 7.4 Total projected investment in Sub-Saharan Africa under the baseline, pessimistic, and optimistic scenarios, 1997–2020

Investment scenario	Nigeria	Northern	Central and Western	Southern	Eastern	All Africa
			(US$ billion)			
Irrigation						
Baseline	7.4	13.2	0.3	6.1	1.2	28.1
Optimistic	18.3	21.2	1.8	11.6	2.1	54.4
Pessimistic	0	0	0	0	0	0
Rural roads						
Baseline	4.6	3.1	16.2	9.1	4.9	37.9
Optimistic	6.7	4.6	25.2	12.8	7.0	56.3
Pessimistic	2.7	1.8	9.0	5.4	2.9	21.8
Agricultural research						
Baseline	0.8	0.7	1.5	2.2	2.7	8.0
Optimistic	1.4	1.3	2.9	3.7	4.7	14.1
Pessimistic	0.6	0.5	1.1	1.6	2.0	5.8
Education						
Baseline	3.4	1.7	1.7	6.5	2.5	15.7
Optimistic	6.4	6.0	4.5	12.7	7.5	37.2
Pessimistic	2.7	1.4	1.3	5.4	2.1	12.9
Access to clean water						
Baseline	3.1	4.1	4.7	2.6	2.8	17.3
Optimistic	3.8	5.1	5.6	3.0	3.2	20.7
Pessimistic	2.8	3.6	4.2	2.3	2.5	15.3
Total Investments						
Baseline	19.2	22.7	24.3	26.5	14.2	106.9
Optimistic	36.6	38.7	39.4	44.0	24.5	182.8
Pessimistic	8.8	7.9	15.6	14.7	9.4	55.8

Source: IMPACT projections, June 2001.

lion, followed by Central and Western Sub-Saharan Africa at $24 billion and Northern Sub-Saharan Africa at $23 billion. Eastern Sub-Saharan Africa will have the lowest projected investment expenditures under the baseline at $14 billion.

Investment expenditures are sharply lower under the pessimistic Sub-Saharan Africa scenario, declining 48 percent to $56 billion, which on an annual basis represents 10 percent of total government consumption in the region in 1997. Rural road investment declines 42 percent from the baseline level; irrigation investment, 100 percent to zero; investment in clean water provision, 12 percent; education investment, 18 percent; and agricultural research investment, 28 percent. Investment expenditures decline in all regions under the pessimistic scenario, with Central and Western Africa investing the most at $16 billion, followed by Southern Africa at $15 billion and Eastern Africa at $9 billion. Northern Sub-Saharan Africa's investment decline will be particularly precipitous under the pessimistic scenario, with total expenditures falling 65 percent to $8 billion, while Nigeria's expenditures fall 54 percent to $9 billion.

The Optimistic Scenario for Africa

Unfortunately the obstacles to achieving the optimistic Africa vision are in many ways more daunting than those facing Asia in the 1950s. The optimistic Africa scenario requires a 71 percent increase in projected investment across the region between 1997 and 2020 to reach $183 billion, which on an annual basis represents 32 percent of total government consumption in the region in 1997 (Table 7.4). Under the optimistic Africa scenario, rural road investment jumps 49 percent above the baseline level, irrigation investment jumps 94 percent, investment in provision of clean water rises 20 percent, and agricultural research investment increases 77 percent. Southern Sub-Saharan Africa will have the highest investment expenditures in the region, followed by Central and Western Sub-Saharan Africa.

These results show that far higher investments will be necessary under the optimistic Africa scenario to secure significant improvements in agricultural productivity and human well-being. The optimistic Africa scenario represents a self-reinforcing, virtuous cycle of higher growth and higher investment, which Africa has been unable to initiate up to this point. The destructive cycle of declining investment and stagnating GDP growth outlined in the pessimistic Africa scenario, with per capita GDP actually declining due to rapid population growth, may turn out to be just as self-reinforcing as the virtuous cycle outlined in the optimistic Africa scenario. The poor prospects for Sub-Saharan Africa under the baseline scenario show that more aggressive policy actions on multiple fronts are needed to improve food security prospects in this region, and the optimistic scenario for Africa confirms that massive increases in investment will be necessary to achieve serious inroads against child malnutrition.

8

SUMMARY AND CONCLUSIONS

LESSONS FROM THE BASELINE SCENARIO

Fundamental changes are occurring in the global structure of food demand, driven in large part by economic growth, rising incomes, and rapid urbanization in the developing economies. As population growth rates in developing countries decline over the next 20 years, rising incomes and rapid urbanization, particularly in Asia, will change the composition of demand.[36] World cereal markets will strengthen from historical levels under the IMPACT baseline, with real international cereal prices declining only slowly. The stronger price picture results in significant part from the continued gradual slowing of the rate of cereal production growth: with the exception of Latin America and Sub-Saharan Africa, cereal area will grow but little. Cereal yield growth will thus account for the preponderance of production growth. However, in most countries and regions—Sub-Saharan Africa being the notable exception—the gradual slowdown in growth of crop yields that began in much of the world during the early 1980s will persist. Livestock production will grow considerably faster than crop production but will also slow relative to recent production growth.

Direct per capita consumption of maize and coarse grains for food will decline as rising incomes lead consumers to shift to wheat and rice. As incomes rise further and lifestyles change with urbanization, a continued gradual shift in demand from rice to wheat will continue. Increasing incomes in developing countries will also drive strong growth in per capita and total meat consumption, which will in turn induce strong growth in consumption of cereals for feed, particularly maize. In contrast, per capita meat consumption in developed countries will remain nearly constant, with small declines in beef and pork consumption offset by growth in poultry consumption. These trends will lead to an increase in the importance of developing countries in global food markets. Thus, even with continued slowing of population growth rates, urbanization and rising incomes in the developing world will drive food demand growth higher than production growth in most regions over the next two decades. Greater regional disparities between supply and demand will result in more agricultural trade, with developing countries playing an increasingly significant role in global food markets. East and South Asia will fuel the boom in cereal import demand, although other regions will be important growth centers for imports of certain cereal crops (WANA for wheat, for example). On the export side, the United States will benefit more from future export opportunities than the EU15. Indeed, China, South Asia, and WANA will become much more dependent on cereal imports, with South Asia shifting to a cereal trade deficit in 2020 from near trade balance in 1997. Meat demand in China will also help drive increased world meat trade, with the United States, EU15, and Latin America the primary exporters of meat products. Several individual commodities are the force behind higher agricultural trade volumes: wheat will lead the upward trend in cereal trade and poultry will do the same for livestock trade.

Concurrently with overall expanding trade volumes, projected trade patterns will enlarge existing trade surpluses and deficits at the regional level. On the surplus side, the exports of the United States, Latin America, and Southeast Asia will account for the highest net values of agricultural exports. More dramatic increases are in store for the net agricultural importers, however. WANA will continue to post the highest import bill as a percentage of the total value of agricultural production (at 34 percent in 2020), although China will easily move past WANA as the primary importer of agricultural goods in absolute terms. Nevertheless, China's imports will remain a modest 6 percent of the total value of agricultural production because of the tremendous size of the Chinese agricultural sector. Overall, China's import bill will increase more than threefold, and WANA's will rise slightly more than 50 percent. Sub-Saharan Africa's import bill will grow to 9 percent of agricultural production in value terms by 2020. In general, although trade volumes and values will be higher, regional differences—in dietary patterns, income, population growth, and production possibilities—will persist.

Despite declining real food prices and expanding world trade, food security for the poor will only improve slowly in many regions. Sub-Saharan Africa, for example, will experience little improvement in per capita calorie availability, and the region's number of malnourished children will increase by 9 million children. Thus, even with relatively abundant food in the world, there will not be enough growth in effective per capita demand for food in Sub-Saharan Africa to improve its food security situation. More progress can be seen for South Asia, home to more than one-half of the world's malnourished children, but some 64 million children will still be malnourished in the region in 2020, down from 85 million in 1997. Slowly declining world food prices and buoyant international trade will coexist with continuing—and even rising—malnutrition throughout much of the world.

LESSONS FROM ALTERNATIVE SCENARIOS

The IMPACT baseline scenario presents food security outcomes based on our best estimates of a large number of underlying drivers of world food markets. Complex interactions among technology, policy, investments, environment, and human behavior in turn influence them. The alternative scenarios presented in this volume show that plausible changes in these drivers, and the influences underlying them, can have dramatic effects on food supply, demand, prices, trade, and malnutrition, although the good news is that international agricultural markets have proven quite successful in dampening the effects of even significant shocks to the system.

The global scenarios show that no single phenomenon at the global level can, in and of itself, determine the world food picture in 2020. Much public attention over the last several decades has focused on population growth in the developing world as the "fundamental" global problem in need of immediate attention, and indeed the low population growth scenario shows that slower population growth over the next two decades would indeed have substantial, beneficial effects on levels of child malnutrition in the developing world. Nevertheless, while slower population growth will reduce overall food demand and alleviate stress on fragile production systems, it cannot fix the deeply rooted structural and technological challenges that confront the poor—the rural poor in particular—even in the present day.

The future of trade liberalization has been another area of recent public focus, with disagreements over globalization stalling the millennium round of trade negotiations. The trade liberalization scenario shows small-to-moderate increases in world prices, compared with the baseline in 2020. Changes in supply and demand in most of the developing regions are small, with the exception of Sub-Saharan Africa. More important, trade liberalization would generate significant net economic benefits for developing countries. Taking into account the benefits to producers and consumers and the tax savings due to removals of subsidies, liberalization of trade for the 16 IMPACT commodities would generate global benefits of $35.7 billion in 2020, including $21.5 billion for developing countries. Sub-Saharan Africa would get the highest benefits of any region, $4.4 billion, or 10 percent of the value of domestic production of the IMPACT commodities.

Perhaps the most surprising results are those for the low feed ratio scenario, which indicate that improvements in feeding efficiency could have a substantial impact on child malnutrition by lowering international cereal prices, particularly maize and other grain prices, and raising food consumption of these crops in the developing world. Sub-Saharan Africa benefits greatly under this scenario, with the number of malnourished children in the region falling by 1.6 million children—an improvement of 4 percent from the baseline number of 39.3 million children. As these results show, the integration of world agricultural markets means that broad trends at the global level can have important secondary effects, both for good and ill, on individual regions that are relatively unaffected by the original trends themselves.

The wide price swings associated with the alternative yield scenarios show that yield growth will be a key determinant in ensuring that food is available at affordable prices to the world's poor over the next several decades. The yield scenarios assume that the downside potential is greatest in the developed world and the upside potential is greatest in the developing world. However, the developing world is characterized by both greater uncertainty about ultimate productivity gains and a greater stake in outperforming expectations, particularly in high-poverty regions such as South Asia and Sub-Saharan Africa. Should rising productivity in the more advanced developing and developed countries leave less-developed regions behind, international cereal prices will fall and poor net cereal consumers will benefit, but the net cereal producers who comprise much of the rural population in poor countries will see their incomes decline. Greater attention to the needs of producers in difficult agroclimatic and low-potential production systems is urgently needed.

The regional Asian scenarios provide insight into the ability of world markets, particularly grain markets, to respond flexibly to local production shocks. For India and China both, the slow-growth scenarios as well as the high Asian feed ratio scenario have significant impacts on various measures of local agricultural production, demand, trade, and food security but only modest effects on international prices. This result points to the need to react sensibly to the prospect that both India and China could become much larger net cereal-importing countries over the coming decades than is projected in the baseline. Far more important than the simple fact that these countries are placing significant demands on world markets should be the underlying reasons behind such a development. Clearly, production shortfalls due to disappointing yield performance and widespread degradation would be cause for concern in the two Asian giants. But rising import dependence can be a positive development if it results from a reduction in trade distortions and a realignment of domestic incentives toward sectors in which these countries possess a comparative advantage. If India and China welcome the benefits of supplying their domestic food needs through global markets, the rest of the world should certainly be able to supply these needs without major dislocations.

Intense concern over the future prospects for Sub-Saharan Africa is a theme echoed throughout this volume. It reflects the unavoidable expectation that worsening food insecurity in the region will continue over the coming decades. Many experts see the pessimistic scenario as the most likely outcome for Sub-Saharan Africa. Deteriorating natural resources, stagnant technologies, and rising population densities remain common features of the rural landscape throughout much of Sub-Saharan Africa. These problems will only be alleviated with the advent of a major structural transformation from subsistence agriculture to a commercialized and highly productive agricultural economy, capable of supporting a large urban population. The optimistic scenario—comprising an admittedly highly stylized set of hypothetical assumptions that lead to rather modest declines in child malnutrition—invokes a rate of productivity growth that in itself would represent a remarkable transformation. Nevertheless, while the ability of African production systems to produce the hypothesized levels of agricultural production in the time frame of the optimistic scenario remains questionable, surely financial and political commitment to this goal should remain at the forefront of the development agenda. In light of the ominous threats that confront the health and well-being of its children, Africa cannot afford to fall further behind, but a sense of urgency and commitment to the challenge of rural development has been lacking.

The broader global optimistic and pessimistic scenarios show that better policy and more rapid economic and agricultural growth can lead to substantial food security improvements, but significantly worse outcomes are also possible if key drivers perform even slightly worse. As investment calculations show, food security is vulnerable to relatively small declines in policy efforts relative to the baseline. Conversely, the developing countries can achieve significant reductions in childhood malnutrition within the boundaries of plausible long-term economic performance. It is projected that an increase in investment of $224 billion—about 40 percent above the baseline projection—in irrigation, agricultural research, rural roads, female education, and development of clean water would be required to reduce the number of malnourished children in 2020 by 38 million children (29 percent), compared with the baseline projection for 2020. A concerted effort to eliminate childhood malnutrition will require policy reform and greater public investment, producing dramatic long-term gains in income growth, agricultural productivity, and social indicators.

LESSONS FOR INVESTMENT

Irrigation, agricultural research, and rural roads are the three main investments that will drive agricultural production growth in the model, and it is projected that together these three areas will require $416.6 billion of investment between 1997 and 2020 to achieve baseline agricultural production growth rates. Irrigation is projected to account for 42 percent of investment in these three areas under the baseline and nearly 60 percent of productivity-enhancing investments under the optimistic scenario, not taking into account the costs of operating and maintaining existing systems. Given the relatively low rates of return achieved on many recent irrigation projects (Jones 1995), the extent to which governments may be overinvesting in irrigation projects at the expense of other worthwhile productive investments remains unclear. Cutbacks on irrigation investment under the pessimistic scenario, however, impose significant reductions in crop yield and area growth. Moreover, initial results from a prototype model linking the IMPACT model to a global water simulation model support the assessment that the downside impacts on food production of cutbacks in irrigation investment—and more broadly in water supply, demand management, and water infrastructure—can be very large (Rosegrant and Cai 2000). Given the aggregate level of the global analysis here, more detailed analyses of country-specific opportunities in irrigation and water infrastructure are required to further prioritize irrigation and water investments.

Ultimately, it will be up to individual policymakers at specific moments in time to determine whether scarce public resources are better spent on expanding or repairing irrigation infrastructure, investing in agricultural research to develop locally appropriate crop varieties, or providing farmers with better extension services. Recent studies (Alston et al. 2000) have shown the high returns that accrue to investments in agricultural research, underpinning a strong case that national governments are underinvesting. Additionally, national expenditures have only increased in importance as funding for international agricultural research declines, and the private sector increasingly serves as the engine driving technological change in agriculture. The developing countries will lose out on the tremendous benefits from emerging advances if they do not commit enough of their own funds to adapting these technologies to their specific needs. While private investment in agricultural research in developed countries is likely to grow significantly, an important, and probably dominant, role for public investment will remain because of incentive problems that discourage private investment in research oriented to the crops and agroclimatic conditions of developing countries.

New research on India (Fan, Hazell, and Thorat 1999) and China (Fan, Zhang, and Zhang 2000) shows that investments in rural roads have large impacts on productivity and poverty alleviation. The baseline projections indicate that the construction of rural roads in Sub-Saharan Africa necessary to support crop yield growth and area expansion will require massive investments, accounting for 35 percent of total projected investments in the region. Failure to invest heavily in rural roads would make it difficult for the region to move beyond subsistence agriculture to a more commercialized system, with all the dynamic effects that agricultural commercialization could have on rural incomes.

Together with Sub-Saharan Africa, South Asia faces the biggest challenges in improving food security and reducing malnutrition. South Asia, with the largest projected investment expenditures of any region, will also have to make difficult allocation decisions, especially given the projected need to invest heavily in irrigation infrastructure, rural roads, and clean water provision. Policymakers in Sub-Saharan Africa and South Asia—and throughout the developing world—must carefully assess investment options, and they will require the political will and foresight necessary to make the appropriate allocation decisions among competing sectors.

Given the key roles played by female education and clean water provision in reducing childhood malnutrition, it is essential that developing countries reinvigorate their commitments to these spending areas. The baseline scenario projects cumulative spending of $75.9 billion on female education and $86.5 on clean water provision. Additional investment of $27 billion for education and $11 billion in clean water provision contributes a large share of the reduction in childhood malnutrition realized under the optimistic scenario. While these investments have value beyond their contribution to reducing childhood malnutrition, it is important to note that increased food production alone will not lead to major improvements in food security in the absence of such complementary investments. WANA and Sub-Saharan Africa in particular will require significant investments in the education of women, even under the baseline scenario.

Finally, economic growth will be an essential component of all investment decisions, both because it can provide the resources necessary to make investments, and because only through economic growth can employment opportunities expand for those leaving agriculture and taking advantage of expanding educational opportunities. Although the precise set of policy reforms and the priorities and magnitudes of increases in investment required to eliminate childhood malnutrition need to be determined in detail for each country, IMPACT results confirm that the three foundations for success are broad-based economic growth, growth in agricultural production, and investment in social services, including education and health. Failure in any of these three areas will severely hamper efforts to eliminate childhood malnutrition.

The challenges to improving food security worldwide are not intractable. As the baseline and alternative scenarios presented here demonstrate, considerable flexibility in world food markets provides a substantial buffer against catastrophic downside outcomes. Scope exists for national and international policy to improve regional outcomes while adding to the worldwide buffer. Taking advantage of the opportunities available and delivering on the possibility of a more food-secure world in 2020 will remain the primary challenge for policymakers at all levels over the next 20 years.

Appendix A

COUNTRIES AND COMMODITIES INCLUDED IN THE IMPACT MODEL

Definitions of IMPACT Regions and Countries

Developed regions/countries

Australia

European Union (EU 15): Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom

Japan

United States

Other developed countries: Canada, Iceland, Israel, Malta, New Zealand, Norway, South Africa, and Switzerland

Former Soviet Union (FSU) Regions/Countries

Eastern Europe: Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia, and Yugoslavia

Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan

Rest of the Former Soviet Union: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova, Russian Federation, and Ukraine

Developing regions/countries

Central and Latin America

Argentina

Brazil

Colombia

Mexico

Other Latin America: Antigua and Barbuda, Bahamas, Barbados, Belize, Bolivia, Chile, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent, Suriname, Trinidad and Tobago, Uruguay, and Venezuela

Sub-Saharan Africa

Central and Western Sub-Saharan Africa: Benin, Cameroon, Central African Republic, Comoros Island, Congo Democratic Republic, Congo Republic, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Sao Tome and Principe, Senegal, Sierra Leone, and Togo

Eastern Sub-Saharan Africa: Burundi, Kenya, Rwanda, Tanzania, and Uganda

Nigeria

Northern Sub-Saharan Africa: Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Somalia, and Sudan

Southern Sub-Saharan Africa: Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Réunion, Swaziland, Zambia, and Zimbabwe

West Asia/North Africa (WANA)

Egypt

Turkey

Other West Asian/North African countries: Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen

South Asia

Bangladesh

India

Pakistan

Other South Asian countries: Afghanistan, Maldives, Nepal, and Sri Lanka

Southeast Asia

Indonesia

Malaysia

Myanmar

Philippines

Thailand

Viet Nam

Other Southeast Asian countries: Brunei, Cambodia, and Laos

East Asia

China (including Taiwan and Hong Kong)

Korea, Republic of

Other East Asian countries: Democratic People's Republic of Korea; Macao; and Mongolia

Rest of the world: Cape Verde, Fiji, French Polynesia, Kiribati, New Caledonia, Papua New Guinea, Seychelles, and Vanuatu

Definitions of IMPACT Commodities

Beef (beef and buffalo meat)

Pork (pig meat)

Sheep/goat (sheep and goat meat)

Poultry (chicken meat)

Eggs

Milk (raw milk containing all its constituents: not concentrated, pasteurized, sterilized or otherwise preserved, homogenized, or peptonized)

Wheat

Maize

Rice

Other coarse grains (barley, millet, oats, rye, and sorghum)

Potatoes

Sweet potatoes and yams

Cassava and other roots and tubers (cassava and other tubers, roots or rhizomes)

Soybeans

Meals (copra cake, cottonseed cake, groundnut cake, other oilseed cakes, palm kernel cake, rape and mustard seed cake, sesame seed cake, soybean cake, sunflower seed cake, fish meal, meat and blood meal)

Oils (vegetable oils and products, animal fats and products)

Appendix B

SUPPLEMENTARY PRODUCTION, DEMAND, AND TRADE DATA

TABLE B.1 Net maize and wheat trade, selected countries, 1967 and 1997

	Wheat		Maize	
Region/Country	*1967*	*1997*	*1967*	*1997*
		(million metric tons)		
Asia	–12.3	–21.7	0.3	–13.9
China	−5.5	−4.6	−0.4	−2.0
Indonesia	−0.3	−3.7	0.1	−0.5
Japan	−4.0	−5.8	−4.2	−16.1
Korea, Republic of	−0.7	−3.4	0.0	−8.0
Malaysia	−0.3	−0.8	−0.2	−2.3
Philippines	−0.6	−2.1	0.0	−0.4
Latin America	–3.9	–7.8	5.6	−2.3
Brazil	−2.5	−6.7	0.7	−0.6
Colombia	−0.2	−1.0	0.0	−1.8
Mexico	0.1	−1.8	1.0	−4.4
Other Latin American	−3.4	−6.2	−0.4	−5.0
West Asia/North Africa	–5.8	–25.9	–0.4	–9.7
Egypt	−2.3	−6.8	−0.2	−2.9
Other West Asia/North Africa	−3.1	−18.2	−0.2	−5.8
Sub-Saharan Africa	−1.2	−6.1	0.7	−1.8

Source: Based on FAOSTAT data (FAO 2000a).

Note: Positive figures indicate net exports; negative figures indicate net imports.

TABLE B.2 Growth rates of demand for various cereals, 1967–97

Region	Wheat demand			Maize demand			Other coarse grains demand			Rice demand		
	1967–82	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*	*1967–82*	*1982–90*	*1990–97*
	(percent/year)											
Latin America	3.4	0.8	2.3	3.6	2.3	4.0	7.1	–0.7	1.9	3.5	2.0	1.7
Sub-Saharan Africa	6.2	1.7	5.6	2.9	5.3	2.7	1.4	2.8	3.6	5.1	3.3	2.9
West Asia/North Africa	4.6	3.1	1.9	6.1	4.7	3.9	2.7	4.5	0.6	4.6	3.3	4.6
Asia	5.8	3.6	2.3	3.1	1.7	–3.5	–0.0	–2.6	–2.3	3.3	2.6	1.5
South Asia	4.9	3.8	3.4	1.3	3.1	2.5	0.6	–0.8	–0.5	2.8	3.4	1.8
Southeast Asia	6.2	3.2	6.9	4.4	6.4	4.7	8.1	6.5	4.7	3.6	2.6	2.1
East Asia	6.5	3.5	1.3	6.1	4.1	4.3	–1.2	–3.3	0.1	3.5	1.8	1.0
Developed world	1.6	1.5	–0.9	2.8	0.8	1.1	1.3	–0.2	–3.3	0.7	0.5	0.6
Developing world	5.2	3.1	2.3	4.5	3.8	4.0	1.4	0.7	1.3	3.4	2.5	1.6

Source: Based on FAOSTAT data (FAO 2000a).

TABLE B.3 Global meat trade, 1967 and 1997

Meat	1967	1997
	(milion metric tons)	
Beef	2.4	6.9
Pork	1.6	6.7
Sheep and goat	0.6	0.9
Poultry	0.4	6.4
Total	5.0	20.9

Source: Based on FAOSTAT data (FAO 2000a).

TABLE B.4 Roots and tubers demand, 1967–97

Region	1967	1982	1990	1997
		(milion metric tons)		
Latin America	44.2	44.7	47.0	49.5
Sub-Saharan Africa	56.2	73.5	110.6	148.8
West Asia/North Africa	3.4	8.4	12.8	15.6
Asia	145.7	188.6	197.9	242.8
South Asia	11.5	20.6	25.4	32.2
Southeast Asia	18.6	25.0	26.0	28.4
East Asia	115.6	143.0	146.5	182.2
Developing world	251.1	316.7	370.9	449.1
Developed world	258.7	226.8	219.7	195.0

Source: Based on FAOSTAT data (FAO 2000a).

TABLE B.5 Cereal yields, Sub-Saharan Africa, 1967–97

Cereal	1967	1982	1990	1997
		(kilograms/hectare)		
Maize	945	1,158	1,201	1,267
Wheat	928	1,394	1,589	1,655
Other coarse grains	633	809	712	751
Rice	877	916	1,107	1,074

Source: Based on FAOSTAT data (FAO 2000a).

TABLE B.6 Income demand elasticities, 1997 and 2020

Commodity	Year	South Asia	East Asia	Southeast Asia	WANA	Sub-Saharan Africa	Latin America	Developed countries
Beef	1997	0.57	0.82	0.81	0.45	0.84	0.38	0.17
	2020	0.39	0.63	0.69	0.35	0.72	0.28	0.05
Pork	1997	0.28	0.61	0.64	0.33	0.64	0.41	0.27
	2020	0.12	0.52	0.46	0.16	0.56	0.35	0.09
Sheep and goat meat	1997	0.42	0.54	0.33	0.40	0.33	0.48	0.24
	2020	0.25	0.37	0.17	0.23	0.21	0.32	0.16
Poultry	1997	0.91	0.91	0.81	0.72	0.72	0.81	0.64
	2020	0.77	0.82	0.66	0.59	0.64	0.70	0.51
Eggs	1997	0.56	0.51	0.51	0.41	0.46	0.21	0.03
	2020	0.47	0.36	0.35	0.21	0.34	0.12	–0.09
Milk	1997	0.50	0.63	0.59	0.32	0.73	0.30	0.27
	2020	0.40	0.46	0.42	0.20	0.61	0.20	0.12
Wheat	1997	0.18	0.26	0.32	0.10	0.50	0.09	0.17
	2020	0.13	0.13	0.28	–0.01	0.49	0.03	0.11
Rice	1997	0.18	0.05	0.14	0.20	0.38	0.22	0.33
	2020	0.04	–0.20	0.01	0.13	0.38	0.19	0.22
Maize	1997	0.02	–0.16	0.04	–0.14	0.30	0.05	–0.05
	2020	–0.03	–0.26	–0.07	–0.22	0.26	–0.02	–0.15
Other coarse grains	1997	0.01	–0.09	–0.04	–0.12	0.33	–0.10	–0.18
	2020	–0.06	–0.15	–0.12	–0.24	0.26	–0.21	–0.24
Potatoes	1997	0.56	0.42	0.45	0.45	0.42	0.31	0.21
	2020	0.45	0.30	0.36	0.34	0.40	0.23	0.14
Sweet potatoes and yams	1997	–0.08	–0.06	0.00	0.10	0.26	–0.05	–0.10
	2020	–0.18	–0.16	–0.10	0.02	0.18	–0.15	–0.20
Cassava and other roots	1997	0.06	–0.05	0.04	0.08	0.31	–0.06	–0.18
and tubers	2020	–0.08	–0.14	–0.06	–0.09	0.19	–0.16	–0.27

Source: Expert estimates.

TABLE B.7 Crop area (or animal slaughter numbers) elasticity with respect to own-crop price, average by region

Commodity	South Asia	East Asia	Southeast Asia	WANA	Sub-Saharan Africa	Latin America	Developed countries
Beef	0.27	0.35	0.26	0.26	0.29	0.39	0.34
Pork	0.23	0.36	0.45	0.13	0.25	0.42	0.35
Sheep and goat meat	0.26	0.22	0.24	0.26	0.22	0.20	0.29
Poultry	0.38	0.37	0.36	0.38	0.30	0.35	0.35
Eggs	0.28	0.38	0.35	0.37	0.28	0.28	0.23
Milk	0.34	0.37	0.34	0.40	0.38	0.32	0.31
Wheat	0.10	0.15	0.02	0.20	0.21	0.21	0.23
Rice	0.12	0.10	0.10	0.16	0.15	0.15	0.12
Maize	0.13	0.12	0.12	0.20	0.19	0.17	0.19
Other coarse grains	0.13	0.13	0.11	0.21	0.26	0.22	0.19
Potatoes	0.15	0.14	0.10	0.15	0.15	0.15	0.16
Sweet potatoes and yams	0.09	0.08	0.10	0.08	0.12	0.10	0.11
Cassava and other roots and tubers	0.09	0.07	0.11	0.08	0.15	0.09	0.08
Soybeans	0.16	0.15	0.13	0.12	0.10	0.18	0.14

Source: Expert estimates.

TABLE B.8 Crop yield elasticity with respect to own-crop price, average by region

Crop	South Asia	East Asia	Southeast Asia	WANA	Sub-Saharan Africa	Latin America	Developed countries
Wheat	0.18	0.16	0.13	0.14	0.19	0.15	0.12
Rice	0.12	0.13	0.10	0.13	0.18	0.15	0.11
Maize	0.15	0.14	0.11	0.13	0.17	0.13	0.14
Other coarse grains	0.12	0.11	0.09	0.10	0.14	0.10	0.10
Potatoes	0.14	0.12	0.10	0.12	0.16	0.12	0.11
Sweet potatoes and yams	0.11	0.09	0.08	0.08	0.14	0.09	0.09
Cassava and other roots and tubers	0.11	0.09	0.08	0.08	0.14	0.09	0.09
Soybeans	0.14	0.12	0.10	0.11	0.16	0.12	0.11

Source: Expert estimates.

TABLE B.9 Crop yield elasticity with respect to wage of labor, average by region

Crop	South Asia	East Asia	Southeast Asia	WANA	Sub-Saharan Africa	Latin America	Developed countries
Wheat	–0.11	–0.07	–0.08	–0.07	–0.17	–0.09	–0.04
Rice	–0.07	–0.05	–0.06	–0.07	–0.15	–0.09	–0.03
Maize	–0.11	–0.06	–0.07	–0.06	–0.15	–0.07	–0.04
Other coarse grains	–0.09	–0.05	–0.06	–0.05	–0.12	–0.06	–0.03
Potatoes	–0.10	–0.06	–0.07	–0.07	–0.15	–0.08	–0.04
Sweet potatoes and yams	–0.09	–0.05	–0.06	–0.06	–0.13	–0.07	–0.04
Cassava and other roots and tubers	–0.09	–0.05	–0.06	–0.06	–0.13	–0.07	–0.04
Soybeans	–0.09	–0.06	–0.07	–0.06	–0.14	–0.08	–0.04

Source: Expert estimates.

TABLE B.10 Crop yield elasticity with respect to price of capital, average by region

Crop	South Asia	East Asia	Southeast Asia	WANA	Sub-Saharan Africa	Latin America	Developed countries
Wheat	–0.06	–0.09	–0.05	–0.07	–0.02	–0.06	–0.09
Rice	–0.05	–0.07	–0.04	–0.07	–0.03	–0.06	–0.08
Maize	–0.05	–0.08	–0.04	–0.07	–0.02	–0.05	–0.10
Other coarse grains	–0.04	–0.06	–0.03	–0.05	–0.01	–0.04	–0.07
Potatoes	–0.04	–0.06	–0.03	–0.05	–0.02	–0.04	–0.07
Sweet potatoes and yams	–0.02	–0.04	–0.02	–0.03	–0.01	–0.03	–0.06
Cassava and other roots and tubers	–0.02	–0.04	–0.02	–0.03	–0.01	–0.02	–0.06
Soybeans	–0.04	–0.06	–0.03	–0.05	–0.02	–0.05	–0.07

Source: Expert estimates.

TABLE B.11 Baseline IMPACT PSE estimates, livestock products

Region/Country	Beef	Pork	Sheep and goat	Poultry	Eggs	Milk
Developed countries						
United States	0.04	0.03	0.04	0.03	0.00	0.60
EU15	0.63	0.10	0.63	0.19	0.00	0.57
Japan	0.32	0.34	0.32	0.34	0.00	0.80
Australia	0.04	0.03	0.04	0.03	0.00	0.31
Other developed countries	0.12	0.13	0.14	0.15	0.00	0.47
Eastern Europe	0.14	0.10	0.06	0.21	0.00	0.29
Central Asia	0.23	0.22	0.21	0.24	0.00	0.37
Other Former Soviet Union	0.39	0.38	0.38	0.38	0.00	0.45
Latin America						
Mexico	0.04	0.05	0.04	0.05	0.00	0.44
Brazil	0.12	0.12	0.12	0.12	0.00	0.20
Argentina	0.07	0.04	0.07	0.04	0.00	0.10
Colombia	0.08	0.06	0.06	0.06	0.00	0.20
Other Latin America	0.06	0.06	0.06	0.06	0.00	0.18
Sub-Saharan Africa						
Nigeria	0.25	0.25	0.25	0.25	0.00	0.00
Northern	0.28	0.08	0.16	0.08	0.00	0.00
Central and Western	0.43	0.28	0.28	0.10	0.00	0.00
Southern	0.24	0.10	0.20	0.05	0.00	−0.29
Eastern	0.50	0.30	0.50	0.30	0.00	−0.10
West Asia/North Africa						
Egypt	0.15	0.15	0.15	0.15	0.00	0.30
Turkey	0.34	0.28	0.34	0.28	0.00	0.54
Other West Asia/North Africa	0.12	0.12	0.12	0.12	0.00	0.23
Asia						
India	0.29	0.29	0.29	0.29	0.00	0.26
Pakistan	0.10	0.10	0.10	0.10	0.00	0.22
Bangladesh	0.10	0.10	0.10	0.10	0.00	0.22
Other South Asia	0.05	0.05	0.05	0.05	0.00	0.19
Indonesia	0.11	0.18	0.13	0.20	0.00	0.15
Thailand	0.13	0.13	0.13	0.13	0.00	0.50
Malaysia	0.13	0.40	0.13	0.35	0.00	0.50
Philippines	0.25	0.30	0.25	0.25	0.00	0.50
Viet Nam	0.27	0.22	0.27	0.15	0.00	0.27
Myanmar	0.15	0.16	0.15	0.16	0.00	0.08
Other Southeast Asia	0.15	0.16	0.15	0.16	0.00	0.08
China	0.22	0.10	0.22	0.10	0.00	0.25

Source: See note 16.

TABLE B.12 Baseline IMPACT PSE estimates, cereals and roots and tubers

Region/Country	Wheat	Maize	Rice	Other grains	Potatoes	Sweet potatoes and yams	Cassava and other roots and tubers	Soybeans	Meals	Oils
Developed countries										
United States	0.17	0.06	0.14	0.14	0.00	0.00	0.00	0.10	0.10	0.10
EU15	0.46	0.29	0.46	0.46	0.00	0.00	0.00	0.38	0.48	0.38
Japan	0.86	0.84	0.68	0.68	0.00	0.00	0.00	0.36	0.36	0.36
Australia	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02
Other developed countries	0.06	0.07	0.01	0.01	0.00	0.00	0.00	0.10	0.10	0.10
Eastern Europe	0.02	0.00	0.05	0.00	0.00	0.00	0.00	−0.09	−0.09	−0.09
Central Asia	−0.15	0.20	0.20	0.20	0.00	0.00	0.00	−0.04	−0.04	−0.04
Other Former Soviet Union	−0.15	−0.30	0.00	0.00	0.00	0.00	0.00	−0.04	−0.04	−0.04
Latin America										
Mexico	0.29	0.01	0.10	0.10	0.00	0.00	0.00	0.06	0.06	0.06
Brazil	0.24	0.20	0.05	0.05	0.00	0.00	0.00	0.09	0.05	0.05
Argentina	0.04	0.06	0.05	0.05	0.00	0.00	0.00	0.01	0.00	0.00
Colombia	0.21	0.28	0.05	0.05	0.00	0.00	0.00	0.11	−0.01	−0.01
Other Latin America	0.05	0.11	0.05	0.05	0.00	0.00	0.00	0.16	0.28	0.28
Sub-Saharan Africa										
Nigeria	−0.30	0.30	− 0.10	−0.10	0.00	0.00	0.00	−0.10	−0.10	−0.10
Northern	−0.29	−0.17	−0.17	−0.17	0.00	0.00	0.00	−0.03	−0.03	−0.03
Central and Western	−0.20	0.41	−0.23	−0.23	0.00	0.00	0.00	−0.07	−0.07	−0.07
Southern	−0.25	0.12	−0.20	−0.20	0.00	0.00	0.00	−0.07	−0.07	−0.07
Eastern	−0.23	0.30	−0.06	−0.06	0.00	0.00	0.00	−0.02	−0.02	−0.07

West Asia/North Africa										
Egypt	0.46	0.12	0.03	0.23	0.00	0.00	0.00	0.30	0.04	0.04
Turkey	0.42	0.05	0.46	0.46	0.00	0.00	0.00	0.45	0.23	0.45
Other West Asia/North Africa	0.07	0.07	0.13	0.07	0.00	0.00	0.00	0.18	0.18	0.18
India	0.10	0.18	0.02	0.02	0.00	0.00	0.00	0.30	0.20	0.20
Pakistan	0.15	0.10	0.28	0.26	0.00	0.00	0.00	0.30	0.18	0.18
Bangladesh	0.10	0.20	0.20	0.10	0.00	0.00	0.00	0.20	0.12	0.12
Other South Asia	0.05	0.10	0.10	0.06	0.00	0.00	0.00	0.25	0.20	0.20
Indonesia	0.10	0.09	0.04	0.04	0.00	0.00	0.00	0.38	0.19	0.19
Thailand	0.60	0.10	0.10	0.10	0.00	0.00	0.00	0.24	0.10	0.10
Malaysia	0.28	0.49	0.25	0.45	0.00	0.00	0.00	0.05	0.17	0.17
Philippines	0.28	0.27	0.60	0.32	0.00	0.00	0.00	0.29	0.10	0.10
Viet Nam	0.05	0.25	0.09	0.23	0.00	0.00	0.00	0.10	0.17	0.17
Myanmar	0.10	0.20	0.09	0.10	0.00	0.00	0.00	0.10	0.10	0.10
Other Southeast Asia	0.10	0.20	0.09	0.10	0.00	0.00	0.00	0.10	0.10	0.10
China	0.07	0.07	0.08	0.08	0.00	0.00	0.00	0.02	0.02	0.02
Republic of Korea	0.13	0.71	0.70	0.70	0.00	0.00	0.00	0.77	0.77	0.77
Other East Asia	0.05	0.20	0.10	0.38	0.00	0.00	0.00	0.10	0.20	0.20
Rest of the world	0.10	0.20	0.10	0.19	0.00	0.00	0.00	0.10	0.20	0.20

Source: See note 16.

TABLE B.13 Baseline IMPACT CSE estimates, livestock products

Region/Country	Beef	Pork	Sheep and goat	Poultry	Eggs	Milk
Developed Countries						
United States	−0.01	0.00	−0.01	0.00	0.00	−0.57
EU15	−0.34	−0.08	−0.34	−0.21	0.00	−0.53
Japan	−0.29	−0.33	−0.29	−0.33	0.00	−0.71
Australia	0.00	0.00	0.00	0.00	0.00	−0.28
Other developed countries	−0.09	−0.11	−0.05	−0.13	0.00	−0.47
Eastern Europe	−0.05	−0.05	−0.01	−0.18	0.00	−0.26
Central Asia	−0.23	−0.22	−0.19	−0.23	0.00	−0.36
Rest of Former Soviet Union	−0.39	−0.38	−0.37	−0.37	0.00	−0.45
Latin America						
Mexico	−0.02	−0.04	−0.02	−0.04	0.00	−0.40
Brazil	−0.12	−0.12	−0.12	−0.12	0.00	−0.20
Argentina	−0.07	−0.04	−0.07	−0.04	0.00	−0.10
Colombia	−0.08	−0.06	−0.06	−0.06	0.00	−0.20
Other Latin America	−0.06	−0.06	−0.06	−0.06	0.00	−0.18
Sub-Saharan Africa						
Nigeria	−0.25	−0.25	−0.25	−0.25	0.00	0.00
Northern	−0.28	−0.08	−0.16	−0.08	0.00	0.00
Central and Western	−0.43	−0.28	−0.28	−0.10	0.00	0.00
West Asia	−0.24	−0.10	−0.20	−0.05	0.00	−0.09
North Africa	−0.50	−0.30	−0.50	−0.30	0.00	−0.15
Egypt	−0.15	−0.15	−0.15	−0.15	0.00	−0.30
Turkey	−0.25	−0.25	−0.25	−0.25	0.00	−0.50
Other West Asia / North Africa	−0.12	−0.12	−0.12	−0.12	0.00	−0.23

Asia						
India	−0.29	−0.29	−0.29	−0.29	0.00	−0.26
Pakistan	−0.05	−0.05	−0.05	−0.05	0.00	−0.22
Bangladesh	−0.05	−0.05	−0.05	−0.05	0.00	−0.22
Other South Asia	−0.05	−0.05	−0.05	−0.05	0.00	−0.19
Indonesia	−0.11	−0.15	−0.15	−0.20	0.00	−0.15
Thailand	−0.13	−0.13	−0.13	−0.13	0.00	−0.50
Malaysia	−0.13	−0.40	−0.13	−0.25	0.00	−0.50
Philippines	−0.25	−0.30	−0.25	−0.35	0.00	−0.50
Viet Nam	−0.27	−0.22	−0.27	−0.15	0.00	−0.27
Myanmar	−0.15	−0.16	−0.15	−0.16	0.00	−0.08
Other Southeast Asia	−0.15	−0.16	−0.15	−0.16	0.00	−0.08
China	−0.22	−0.10	−0.22	−0.10	0.00	−0.25
Republic of Korea	−0.38	−0.31	−0.38	−0.31	0.00	−0.20
Other East Asia	−0.20	−0.15	−0.18	−0.05	0.00	−0.64
Rest of the world	−0.20	−0.15	−0.15	−0.05	0.00	−0.40

Source: See note 16.

TABLE B.14 Baseline IMPACT CSE estimates, cereals and roots and tubers products

Region/Country	Wheat	Maize	Rice	Other coarse grains	Potatoes	Sweet potatoes and yams	Cassava and other roots and tubers	Soybeans	Meals	Oils
United States	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU15	−0.09	−0.25	−0.13	−0.13	0.00	0.00	0.00	0.00	0.00	0.00
Japan	−0.76	−0.74	−0.55	−0.55	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	−0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other developed countries	−0.03	−0.05	−0.05	−0.01	0.00	0.00	0.00	−0.07	−0.07	−0.07
Eastern Europe	0.01	0.00	−0.20	0.00	0.00	0.00	0.00	−0.05	−0.05	−0.05
Central Asia	0.15	−0.20	0.00	−0.20	0.00	0.00	0.00	−0.07	−0.07	−0.07
Rest of Former Soviet Union	0.15	−0.03	−0.09	0.00	0.00	0.00	0.00	−0.07	−0.07	−0.07
Mexico	−0.18	−0.01	−0.05	−0.09	0.00	0.00	0.00	−0.04	−0.04	−0.04
Brazil	−0.24	−0.20	−0.05	−0.05	0.00	0.00	0.00	−0.09	−0.10	−0.10
Argentina	−0.04	−0.06	−0.05	−0.05	0.00	0.00	0.00	−0.01	−0.02	−0.02
Colombia	−0.21	−0.28	−0.05	−0.05	0.00	0.00	0.00	−0.11	−0.01	−0.01
Other Latin America	−0.05	−0.11	−0.15	−0.15	0.00	0.00	0.00	−0.16	−0.28	−0.28
Nigeria	−0.30	−0.30	−0.25	−0.15	0.00	0.00	0.00	−0.10	−0.10	−0.10
Northern Sub-Saharan Africa	−0.20	−0.21	−0.28	−0.25	0.00	0.00	0.00	−0.07	−0.07	−0.07
Central & Western Sub-Saharan Africa	−0.10	−0.41	−0.20	−0.28	0.00	0.00	0.00	−0.22	−0.22	−0.22
Southern Sub-Saharan Africa	−0.15	−0.12	−0.18	−0.20	0.00	0.00	0.00	−0.22	−0.22	−0.22
Eastern Sub-Saharan Africa	−0.05	−0.30	−0.03	−0.18	0.00	0.00	0.00	−0.22	−0.22	−0.22
Egypt	−0.46	−0.12	−0.03	−0.23	0.00	0.00	0.00	−0.25	−0.04	−0.04
India	−0.10	−0.09	−0.02	−0.02	0.00	0.00	0.00	−0.30	−0.20	−0.20
Bangladesh	−0.05	−0.20	−0.20	−0.10	0.00	0.00	0.00	−0.20	−0.10	−0.10

Pakistan	−0.15	−0.10	−0.28	−0.26	0.00	0.00	0.00	−0.30	−0.16	−0.16
Turkey	−0.32	−0.01	−0.38	−0.38	0.00	0.00	0.00	−0.37	−0.21	−0.37
Other West Asia/North Africa	−0.06	−0.07	−0.14	−0.07	0.00	0.00	0.00	−0.15	−0.18	−0.18
India	−0.10	−0.09	−0.02	−0.02	0.00	0.00	0.00	−0.30	−0.20	−0.20
Pakistan	−0.15	−0.10	−0.28	−0.26	0.00	0.00	0.00	−0.30	−0.16	−0.16
Bangladesh	−0.05	−0.20	−0.20	−0.10	0.00	0.00	0.00	−0.20	−0.10	−0.10
Other Southeast Asia	−0.05	−0.17	−0.10	−0.05	0.00	0.00	0.00	−0.25	−0.20	−0.20
Indonesia	−0.10	−0.09	−0.04	−0.04	0.00	0.00	0.00	− 0.38	−0.12	−0.12
Thailand	−0.60	−0.05	−0.10	−0.10	0.00	0.00	0.00	−0.24	−0.10	−0.10
Malaysia	−0.28	−0.49	−0.25	−0.45	0.00	0.00	0.00	−0.05	−0.01	−0.01
Philippines	−0.28	−0.27	−0.60	−0.32	0.00	0.00	0.00	−0.29	−0.10	−0.10
Viet Nam	−0.05	−0.25	−0.09	−0.12	0.00	0.00	0.00	−0.10	−0.11	−0.11
Myanmar	−0.05	−0.20	−0.09	−0.10	0.00	0.00	0.00	−0.10	−0.17	−0.17
Other Southeast Asia	−0.05	−0.20	−0.08	−0.10	0.00	0.00	0.00	−0.10	−0.17	−0.17
China	−0.07	−0.07	−0.08	−0.08	0.00	0.00	0.00	−0.02	−0.02	−0.02
Republic of Korea	−0.13	−0.67	−0.67	−0.67	0.00	0.00	0.00	−0.38	−0.38	−0.38
Other East Asia	−0.05	−0.20	−0.09	−0.30	0.00	0.00	0.00	−0.10	−0.20	−0.20
Rest of the world	−0.10	−0.20	−0.09	−0.19	0.00	0.00	0.00	−0.10	−0.20	−0.20

Source: See note 16.

Appendix C

REGIONAL FOOD SUPPLY AND DEMAND DATA AND ANNUAL GROWTH RATES

ASIA

TABLE C.1 Food supply and demand indicators, East Asia, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	812.2	1,085.6	1,220.8	1,320.4
Per capita area harvested (hectares)	0.12	0.09	0.08	0.07
Cereal production (million metric tons)	153.9	271.3	339.1	391.0
Cereal yield (kilograms/hectare)	1,637	2,887	3,576	4,157
Per capita cereal production (kilograms)	191.9	268.9	293.9	314.0

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.2 Annual growth rates in East Asia, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.0	1.5	1.1
Per capita area harvested	−1.9	−1.3	−1.2
Cereal production	3.9	2.8	2.1
Cereal yield	3.9	2.7	2.2
Cereal imports	10.5	0.2	−3.2

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.3 Food supply and demand indicators, South Asia, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	663.7	935.6	1,117.1	1,288.5
Per capita area harvested (hectares)	0.177	0.139	0.116	0.101
Cereal production (million metric tons)	96.8	160.0	203.0	232.5
Cereal yield (kilograms/hectare)	827	1,235	1,574	1,816
Per capita cereal production (kilograms)	157.5	171.3	181.0	184.4

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.4 Annual growth rates in South Asia, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.3	2.2	1.9
Per capita area harvested	−1.6	−2.3	2.0
Cereal production	3.4	3.0	2.0
Cereal yield	2.7	3.1	2.1
Cereal imports	−8.9	1.3	−8.8

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.5 Food supply and demand indicators, Southeast Asia, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	263.2	372.8	436.9	492.4
Per capita area harvested (hectares)	0.143	0.117	0.106	0.101
Cereal production (million metric tons)	41.5	74.1	91.8	111.2
Cereal yield (kilograms/hectare)	1,100	1,705	1,982	2,238
Per capita cereal production (kilograms)	157.8	198.8	210.1	226.3

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.6 Annual growth rates in Southeast Asia, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.3	2.0	1.7
Per capita area harvested	−1.4	−1.2	−0.7
Cereal production	3.9	2.7	2.8
Cereal yield	3.0	1.9	1.8
Per capita cereal production	1.6	0.7	1.1

Source: Based on FAOSTAT data (FAO 2000a).

LATIN AMERICA

TABLE C.7 Food supply and demand indicators, Latin America, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	263.9	377.2	440.5	495.7
Per capita area harvested (hectares)	0.172	0.139	0.111	0.100
Cereal production (million metric tons)	58.5	97.5	96.6	124.6
Cereal yield (kilograms/hectare)	1,308	1,888	2,009	2,531
Per capita cereal production (kilograms)	225	262	222	253

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.8 Annual growth rates in Latin America, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.4	2.0	1.7
Per capita area harvested	−1.4	−2.8	−1.4
Cereal production	3.5	−0.1	3.7
Cereal yield	2.5	0.8	3.4
Cereal imports	n.a.	15.8	3.5

Source: Based on FAOSTAT data (FAO 2000a).

SUB-SAHARAN AFRICA

TABLE C.9 Food supply and demand indicators, Sub-Saharan Africa, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	243.4	368.3	463.0	560.9
Per capita area harvested (hectares)	0.172	0.118	0.132	0.132
Cereal production (million metric tons)	31.2	40.9	56.8	69.3
Cereal yield (kilograms/hectare)	746	937	924	948
Per capita cereal production (kilograms)	128.2	111.0	122.7	124.4

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.10 Annual growth rates in Sub-Saharan Africa, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.8	2.9	2.6
Per capita area harvested	−2.5	1.4	−0.1
Cereal production	1.8	4.2	2.9
Cereal yield	1.5	−0.2	0.3

Source: Based on FAOSTAT data (FAO 2000a).

WEST ASIA/NORTH AFRICA

TABLE C.11 Food supply and demand indicators, West Asia/North Africa, 1967–97

Indicator	*1967*	*1982*	*1990*	*1997*
Population (millions)	155.3	236.7	298.8	338.8
Per capita area harvested (hectares)	0.236	0.166	0.146	0.124
Cereal production (million metric tons)	39.7	54.9	74.1	85.5
Cereal yield (kilograms/hectare)	1,080	1,394	1,672	1,973
Per capita cereal production (kilograms)	286.4	351.5	366.9	366.8

Source: Based on FAOSTAT data (FAO 2000a).

TABLE C.12 Annual growth rates, West Asia/North Africa, 1967–97

Indicator	*1967–82*	*1982–90*	*1990–97*
		(percent/year)	
Population	2.8	3.0	2.2
Per capita area harvested	−2.3	−1.6	−2.3
Cereal production	2.2	3.8	2.0
Cereal yield	1.7	2.3	2.4
Cereal imports	3.4	3.7	2.0

Source: Based on FAOSTAT data (FAO 2000a).

Appendix D

PRODUCTION, DEMAND, AND TRADE DATA BY COMMODITY, 1997 AND 2020

TABLE D.1 Beef production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	30,682	30,198	152	34,887	33,731	1,156
United States	11,755	11,928	−167	14,363	14,125	238
EU15	7,860	7,237	503	7,844	7,506	339
Former Soviet Union	4,872	5,578	−731	5,293	5,920	−628
Developing world	27,000	27,037	−152	50,529	51,685	−1,156
Latin America	13,013	12,450	500	21,192	19,369	1,823
Sub-Saharan Africa	2,470	2,452	11	5,148	5,212	−63
West Asia/North Africa	1,388	1,747	−377	2,352	3,095	−744
South Asia	4,125	3,953	158	8,040	8,241	−201
Southeast and East Asia	5,984	6,398	−425	13,771	15,696	−1,926
World	57,681	57,235	0	85,415	85,415	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.2 Pork production, demand, and trade data, 1997 and 2020

Region/Country	1997 Production	1997 Demand	1997 Net trade	2020 Production	2020 Demand	2020 Net trade
			(1,000 metric tons)			
Developed world	36,331	36,171	7	40,612	39,210	1,402
United States	8,074	7,943	156	10,132	9,057	1,074
EU15	16,818	15,704	992	17,786	16,441	1,345
Former Soviet Union	3,025	3,689	−646	3,411	3,882	−471
Developing world	46,740	46,676	−7	78,698	80,101	−1,402
Latin America	3,798	3,878	−105	6,488	6,439	49
Sub-Saharan Africa	775	804	−43	1,553	1,645	−92
West Asia/North Africa	60	66	−6	89	105	−16
South Asia	520	520	0	996	1,066	−70
Southeast and East Asia	41,531	41,344	157	69,495	70,703	−1,208
World	83,071	82,846	0	119,311	119,311	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.3 Sheep and goat production, demand, and trade data, 1997 and 2020

Region/Country	1997 Production	1997 Demand	1997 Net trade	2020 Production	2020 Demand	2020 Net trade
			(1,000 metric tons)			
Developed world	3,366	3,147	211	4,207	3,725	482
United States	118	157	−39	153	189	−36
EU15	1,139	1,365	−222	1,278	1,467	−189
Former Soviet Union	606	635	−21	885	863	22
Developing world	7,578	7,758	−211	12,982	13,465	−482
Latin America	436	454	−24	708	731	−23
Sub-Saharan Africa	1,205	1,197	6	2,292	2,216	76
West Asia/North Africa	1,769	1,845	−104	2,990	3,092	−102
South Asia	1,767	1,760	7	3,363	3,413	−50
Southeast and East Asia	2,399	2,453	−48	3,626	3,914	−289
World	10,944	10,906	0	17,189	17,189	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.4 Poultry production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed countries	29,665	28,150	701	40,748	37,593	3,155
United States	14,913	12,423	2,109	21,882	17,063	4,819
EU15	8,399	7,574	689	10,158	9,271	887
Former Soviet Union	1,070	2,154	−1,251	1,359	2,807	−1,449
Developing countries	28,838	29,197	−701	64,238	67,393	−3,155
Latin America	9,363	9,261	−60	18,983	18,395	588
Sub-Saharan Africa	957	1,052	−127	1,965	2,179	−214
West Asia/North Africa	3,151	3,482	−459	5,765	6,670	−905
South Asia	1,109	1,110	−1	2,935	3,064	−129
Southeast and East Asia	14,240	14,258	−35	34,557	37,012	−2,453
World	58,503	57,347	0	104,986	104,986	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.5 All meats production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	100,044	97,666	1,071	120,454	114,259	6,195
United States	34,860	32,451	2,059	46,530	40,434	6,095
EU15	34,216	31,880	1,962	37,066	34,685	2,382
Former Soviet Union	9,573	12,056	−2,649	10,948	13,472	−2,526
Developing world	110,156	110,668	−1,071	206,447	212,644	−6,195
Latin America	26,610	26,043	311	47,371	44,934	2,437
Sub-Saharan Africa	5,407	5,505	−153	10,958	11,252	−293
West Asia/North Africa	6,368	7,140	−946	11,196	12,962	−1,767
South Asia	7,521	7,343	164	15,334	15,784	−450
Southeast and East Asia	64,154	64,453	−351	121,449	127,325	−5,876
World	210,199	208,334	0	326,901	326,901	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.6 Wheat production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	2,581	316,698	244,781	62,318	2,990	374,099	268,155	105,944
United States	2,661	66,283	35,309	26,135	3,326	85,955	44,771	41,184
EU15	5,793	99,424	80,578	12,996	6,134	103,185	84,911	18,274
Former Soviet Union	1,445	68,195	73,010	−2,747	1,674	81,308	75,303	6,005
Developing world	2,657	280,002	340,138	−62,318	3,411	385,737	491,681	−105,944
Latin America	2,439	23,094	29,635	−7,845	3,357	39,285	41,273	−1,988
Sub-Saharan Africa	1,655	2,633	9,411	−6,580	2,266	5,081	19,060	−13,980
West Asia/North Africa	1,915	50,487	75,109	−25,908	2,541	73,194	110,967	−37,773
South Asia	2,358	88,829	93,473	−5,261	3,172	127,373	147,057	−19,684
Southeast and East Asia	4,733	114,959	132,210	−16,430	5,735	140,804	172,789	−31,985
World	2,616	596,700	584,919	0	3,190	759,836	759,836	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.7 Rice production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	4,015	17,025	17,204	54	4,626	18,124	18,790	−666
United States	4,396	5,470	3,533	2,203	5,551	7,133	4,666	2,467
EU15	4,271	1,796	2,105	−396	4,940	2,147	2,512	−365
Former Soviet Union	1,557	781	1,264	−523	1,874	970	1,565	−595
Developing world	2,494	367,053	363,623	−54	3,202	485,088	484,422	666
Latin America	2,144	13,089	14,751	−1,357	3,199	20,941	21,709	−768
Sub-Saharan Africa	1,074	7,466	10,932	−3,798	1,660	15,185	20,943	−5,758
West Asia/North Africa	3,993	5,453	8,151	−3,069	5,479	8,275	13,418	−5,143
South Asia	1,896	111,003	108,386	2,931	2,611	157,942	158,711	−769
Southeast and East Asia	6,388	230,030	221,172	5,517	7,967	282,732	269,251	13,481
World	2,536	384,078	380,827	0	3,238	503,212	503,212	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.8 Maize production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	6,825	329,357	290,528	27,507	8,145	410,648	343,677	66,971
United States	8,123	238,759	183,057	44,810	9,673	297,186	227,330	69,856
EU15	8,722	36,947	37,633	−1,166	9,586	39,129	40,021	−891
Former Soviet Union	2,649	7,086	7,464	−303	3,631	10,351	7,571	2,780
Developing world	2,881	266,347	294,985	−27,507	4,109	440,979	507,950	−66,971
Latin America	2,639	74,093	75,562	−2,304	3,880	123,197	118,116	5,081
Sub-Saharan Africa	1,267	26,218	28,650	−1,578	1,764	45,564	52,107	−6,543
West Asia/North Africa	4,806	9,488	18,296	−9,703	5,785	13,413	27,777	−14,364
South Asia	1,645	13,222	13,716	−102	2,115	18,759	18,965	−206
Southeast and East Asia	7,270	143,307	158,687	−13,765	10,529	240,024	290,877	−50,853
World	4,233	595,704	585,513	0	5,399	851,627	851,627	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.9 Other coarse grains production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)	*(1,000 metric tons)*			*(kilograms/capita)*	*(1,000 metric tons)*		
Developed world	2,457	190,916	172,467	14,455	2,833	221,521	191,637	29,884
United States	3,507	27,317	22,531	3,616	4,406	34,207	28,425	5,783
EU15	4,386	65,733	52,283	8,608	4,774	68,066	55,594	12,471
Former Soviet Union	1,361	48,202	49,549	668	1,449	51,851	51,780	71
Developing world	1,101	103,653	119,256	−14,455	1,482	161,031	190,914	−29,884
Latin America	2,572	14,308	18,122	−3,756	3,546	23,977	29,809	−5,832
Sub-Saharan Africa	751	32,986	33,512	−418	1,121	62,698	63,762	−1,065
West Asia/North Africa	1,475	20,025	27,435	−6,400	1,846	27,592	43,423	−15,831
South Asia	878	22,423	22,750	−588	1,092	27,723	28,565	−842
Southeast and East Asia	3,568	13,908	17,379	−3,277	4,769	19,037	25,271	−6,233
World	1,714	294,569	291,724	0	2,048	382,552	382,552	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.10 All cereals production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	3,377	853,996	724,980	104,334	3,976	1,024,392	822,259	202,133
United States	5,334	337,829	244,430	76,764	6,469	424,481	305,192	119,290
EU15	5,540	203,900	172,599	20,042	5,970	212,527	183,038	29,489
Former Soviet Union	1,448	124,264	131,287	−2,905	1,647	144,480	136,219	8,261
Developing world	2,316	1,017,055	1,118,002	−104,334	3,065	1,472,835	1,674,967	−202,133
Latin America	2,531	124,584	138,070	−15,262	3,654	207,400	210,907	−3,507
Sub-Saharan Africa	948	69,303	82,505	−12,374	1,380	128,528	155,872	−27,346
West Asia/North Africa	1,975	85,453	128,991	−45,080	2,574	122,474	195,585	−73,111
South Asia	1,814	235,477	238,325	−3,020	2,460	331,797	353,298	−21,501
Southeast and East Asia	6,395	502,204	529,448	−27,955	8,480	682,597	758,188	−75,590
World	2,703	1,871,051	1,842,983	0	3,383	2,497,227	2,497,227	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.11 Potatoes production, demand, and trade data, 1997 and 2020

Region/Country	Yield (1997)	Production (1997)	Demand (1997)	Net trade (1997)	Yield (2020)	Production (2020)	Demand (2020)	Net trade (2020)
	(kilograms/capita)	*(1,000 metric tons)*			*(kilograms/capita)*	*(1,000 metric tons)*		
Developed world	17,222	184,708	185,458	1,052	19,729	201,098	197,379	3,720
United States	38,815	21,772	21,655	82	48,434	27,713	27,253	460
EU15	33,535	47,872	47,933	847	38,607	50,563	49,026	1,537
Former Soviet Union	10,922	68,555	69,293	−184	11,862	70,449	69,070	1,379
Developing world	15,279	117,185	119,101	−1,052	23,004	206,558	210,278	−3,720
Latin America	13,877	15,206	15,821	−394	19,291	23,943	23,970	−27
Sub-Saharan Africa	5,922	2,650	2,719	−69	8,644	4,889	5,094	−205
West Asia/North Africa	20,028	15,189	15,056	345	29,062	24,829	24,817	12
South Asia	15,628	24,280	24,317	−4	26,024	55,599	56,352	−752
Southeast and East Asia	29,147	59,851	61,142	−901	42,628	97,283	99,973	−2,690
World	16,412	301,892	304,559	0	21,263	407,656	407,656	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.12 Sweet potatoes and yams production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	18,665	2,033	2,138	−68	22,116	2,332	2,266	66
United States	17,480	589	607	−15	22,910	734	695	40
EU15	10,921	54	85	−12	13,500	66	92	−26
Former Soviet Union	0	0	0	0	0	0	0	0
Developing world	12,963	165,485	165,506	68	16,292	216,437	216,503	−66
Latin America	7,848	2,672	2,685	30	11,283	3,985	3,762	223
Sub-Saharan Africa	7,751	39,911	39,940	6	11,806	73,547	73,418	129
West Asia/North Africa	22,729	202	198	4	35,197	321	302	19
South Asia	8,499	1,662	1,661	1	10,158	2,007	1,958	49
Southeast and East Asia	25,183	120,347	120,331	28	32,232	135,629	136,086	−458
World	13,011	167,518	167,644	0	16,338	218,769	218,769	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.13 Cassava and other roots and tubers production, demand, and trade data, 1997 and 2020

Region/Country	1997 Yield	1997 Production	1997 Demand	1997 Net trade	2020 Yield	2020 Production	2020 Demand	2020 Net trade
	(kilograms/capita)	*(1,000 metric tons)*			*(kilograms/capita)*	*(1,000 metric tons)*		
Developed world	12,432	338	10,354	−10,624	16,793	441	4,465	−4,024
United States	13,000	3	245	−257	18,926	4	274	−270
EU15	16,308	6	9,111	−9,655	20,226	8	3,349	−3,342
Former Soviet Union	0	0	1	−1	0	0	0	0
Developing world	9,539	178,981	165,232	10,624	13,077	274,806	270,782	4,024
Latin America	11,384	31,176	30,996	221	16,822	45,223	43,402	1,822
Sub-Saharan Africa	8,000	97,385	97,336	49	11,691	173,523	173,312	211
West Asia/North Africa	57,665	198	209	−59	79,230	268	276	−8
South Asia	19,907	6,575	6,599	−23	24,453	8,440	8,644	−203
Southeast and East Asia	28,309	42,953	29,410	10,429	36,254	46,325	44,183	2,141
World	9,543	179,319	175,587	0	13,081	275,248	275,248	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.14 All roots and tubers production, demand, and trade data, 1997 and 2020

	1997				*2020*			
Region/Country	**Yield**	**Production**	**Demand**	**Net trade**	**Yield**	**Production**	**Demand**	**Net trade**
	(kilograms/capita)		*(1,000 metric tons)*		*(kilograms/capita)*		*(1,000 metric tons)*	
Developed world	17,225	187,079	197,950	−9,640	19,747	203,871	204,110	−238
United States	37,587	22,364	22,507	−190	47,104	28,451	28,222	230
EU15	33,449	47,932	57,129	−8,820	38,507	50,637	52,467	−1,831
Former Soviet Union	10,922	68,555	69,294	−185	11,862	70,449	69,070	1,379
Developing world	11,777	461,651	449,839	9,640	16,124	697,801	697,563	238
Latin America	11,749	49,054	49,502	−143	17,083	73,151	71,134	2,018
Sub-Saharan Africa	7,876	139,946	139,995	−14	11,645	251,959	251,824	135
West Asia/North Africa	20,245	15,589	15,463	290	29,351	25,418	25,395	23
South Asia	15,633	32,517	32,577	−26	24,653	66,046	66,954	−906
Southeast and East Asia	28,631	223,151	210,883	9,556	36,610	279,237	280,242	−1,007
World	12,959	648,729	647,790	0	16,821	901,673	901,673	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.15 Eggs production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	17,890	17,827	74	17,860	17,726	134
United States	4,615	4,495	122	4,929	4,784	145
EU15	5,354	5,262	90	4,942	4,812	130
Former Soviet Union	2,853	2,875	−13	2,785	2,832	−47
Developing world	32,884	32,955	−74	48,805	48,939	−134
Latin America	4,445	4,462	−19	6,395	6,357	38
Sub-Saharan Africa	901	905	−9	1,727	1,723	4
West Asia/North Africa	2,215	2,227	−10	3,507	3,574	−67
South Asia	2,142	2,134	11	4,560	4,551	9
Southeast and East Asia	23,166	23,212	−46	32,588	32,702	−113
World	50,773	50,782	0	66,666	66,666	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.16 Milk production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	338,719	317,630	20,014	382,284	348,585	33,699
United States	70,690	73,933	−3,269	86,087	89,477	−3,390
EU15	125,354	114,196	10,639	138,771	117,575	21,197
Former Soviet Union	66,620	65,866	733	69,507	69,925	−419
Developing world	207,963	227,675	−20,014	386,015	419,714	−33,699
Latin America	55,670	61,332	−5,767	87,367	91,906	−4,539
Sub-Saharan Africa	15,826	18,135	−2,279	33,519	38,115	−4,596
West Asia/North Africa	25,467	30,167	−4,885	41,424	49,289	−7,864
South Asia	96,356	97,097	−711	194,208	198,332	−4,123
Southeast and East Asia	14,569	20,729	−6,227	29,367	41,674	−12,308
World	546,682	545,305	0	768,299	768,299	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.17 Meals production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	71,735	83,702	−12,873	104,966	109,829	−4,863
United States	35,600	29,069	5,644	56,079	43,087	12,991
EU15	20,645	35,981	−15,094	28,371	43,268	−14,897
Former Soviet Union	2,832	2,890	−56	3,613	3,779	−165
Developing world	85,039	71,483	12,873	152,684	147,820	4,863
Latin America	34,550	15,596	18,770	60,966	29,191	31,775
Sub-Saharan Africa	2,963	2,497	469	5,645	5,410	235
West Asia/North Africa	2,742	6,024	−3,360	4,568	10,973	−6,405
South Asia	17,004	12,771	4,073	29,215	28,413	802
Southeast and East Asia	27,725	34,550	−7,090	52,207	73,751	−21,544
World	156,774	155,185	0	257,649	257,649	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.18 Oils production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	50,710	51,079	−604	61,525	59,530	1,995
United States	16,583	14,250	2,205	21,923	17,767	4,156
EU15	18,954	19,766	−1,147	20,837	21,618	−781
Former Soviet Union	4,178	5,646	−1,169	4,946	6,452	−1,506
Developing world	63,112	61,156	604	114,357	116,352	−1,995
Latin America	14,073	11,818	2,108	24,740	19,762	4,978
Sub-Saharan Africa	4,395	5,338	−916	8,857	10,868	−2,010
West Asia/North Africa	2,573	6,968	−4,722	4,274	11,938	−7,664
South Asia	10,297	13,824	−4,248	20,040	26,284	−6,245
Southeast and East Asia	31,428	23,119	8,124	55,922	47,314	8,608
World	113,822	112,235	0	175,882	175,882	0

Source: IMPACT projections, June 2001.

Note: For net trade, positive figures indicate exports, negative figures indicate imports.

TABLE D.19 Soybeans production, demand, and trade data, 1997 and 2020

	1997			*2020*		
Region/Country	**Production**	**Demand**	**Net trade**	**Production**	**Demand**	**Net trade**
			(1,000 metric tons)			
Developed world	75,847	71,949	3,117	101,683	96,709	4,974
United States	70,852	45,969	23,614	94,861	62,879	31,982
EU15	1,381	16,631	−14,676	1,862	21,326	−19,464
Former Soviet Union	316	395	−48	354	458	−104
Developing world	69,063	73,053	−3,117	125,031	130,006	−4,974
Latin America	45,140	40,791	5,151	81,832	67,823	14,009
Sub-Saharan Africa	642	667	−25	1,078	1,331	−252
West Asia/North Africa	239	863	−633	365	1,622	−1,258
South Asia	6,226	6,317	−22	12,394	13,017	−623
Southeast and East Asia	16,815	24,413	−7,586	29,362	46,208	−16,846
World	144,910	145,001	0	226,714	226,714	0

Source: IMPACT projections, June 2001.
Note: For net trade, positive figures indicate exports, negative figures indicate imports.

NOTES

1 Unless otherwise noted, figures in this section come from ACC/SCN (1992) and WHO (1997), as cited in Smith and Haddad (2000, Table 1).

2 Two standard deviations below a median value of weight-for-age is considered a sign of malnutrition, using U.S. National Center for Health Statistics/ World Health Organization standards.

3 Population statistics are calculated from FAO (2000a), with three-year averages centered on the end years used to calculate growth.

4 See Appendix A for a list of the countries included in each region in this study.

5 Although the 12-member European Community did not become the 15-member European Union until 1993, we will refer to the EU15 throughout this report. The member states are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

6 A revision of Chinese statistics would also lower growth rates of meat demand between 1990 and 1997. However, while China has certainly driven meat demand and production increases in recent years, other regions have also expanded demand rapidly, including Latin America and Southeast Asia. In any event, China's production growth rates are so high that even a revision downward would not change the overall picture. Nevertheless, we must await better data for a definitive answer.

7 However, Smil (2000) points out that much of the area removed from production is basically unsuited to agriculture and produces a very low-yielding crop.

8 Other grain per capita demand declined during this period, thus accounting for the fact that the sum of the wheat and maize increase is greater than the total of 23 kilograms per capita.

9 All dollar amounts in this volume refer to U.S. dollars.

10 Southern Africa, in particular Zimbabwe during the early 1980s, serves as a good example.

11 Coarse grains other than maize.

12 However, it should be noted that other grain yields in Nigeria were extraordinarily high in 1982.

13 The treatment of WANA in the IMPACT model is relatively aggregated. Other WANA includes Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen.

14 WANA actually had the fastest population growth rate of any region in the world between 1982 and 1990 at 3.0 percent.

15 All population projections are from UN (1998).

16 Sources include OECD (1999); Ingco and Ng (1998); Fan and Tuan (1998); Finger et al. (1996); McDougall et al. (1998); UNCTAD various years; Valdes (1996); Valdes and Schaeffer (1995a); Valdes and Schaeffer (1995b); Valdes and Schaeffer (1995c); Valdes and Schaeffer (1995d).

17 Calculations of value for total agricultural trade, total agricultural production, and so forth, refer only to the IMPACT commodities; they do not include the large number of agricultural products not subsumed within the IMPACT model. Calculations in value terms are produced by multiplying projected IMPACT volume by price.

18 The baseline irrigated area data were obtained from FAO (2000b) for all developing countries except China. For China, national data were used, and various sources were used for developed countries. All values are calibrated to IMPACT baseline harvested area and production.

19 The moral issues surrounding high population growth in food-insecure regions—including the difficult question of the intrinsic worth of life even under conditions of extreme poverty—lie outside the scope of this report. Nevertheless, the authors wish to recognize the importance of these issues.

20 An alternative specification for a low population growth scenario would maintain per capita income growth at the level projected under the baseline scenario, necessitating a decline in total income growth rates to compensate for slower population growth. This alternative scenario is somewhat more consistent with the dynamic view of population growth that emphasizes labor's role as a factor of production and source of additional knowledge. Under this scenario, per capita income in the developing world in 2020 declines to $2,458, from $2,599 under the standard low population growth scenario. This decline in per capita income corresponds in turn to an increase in the number of children under the age of five who are malnourished of 1 million children in the developing world in 2020. One other notable impact of this alternative low population growth scenario is a decline in net developing world meat imports of 1 million tons, from 7 million tons under the standard low population growth scenario to 6 million tons. Other elements of food consumption remain similar between these two scenarios.

21 It should be noted, however, that slower population growth rates in the developed world would intensify a host of nonagricultural problems in these countries related to the costs of an aging population at near zero growth. Measuring these effects is beyond the scope of this paper.

22 However, the sword cuts both ways: the base level for demand growth has also increased, and growth in total demand requirements is projected to be as high over the next 25 years as over the previous 25 years.

23 Also note that the 1997 base yield remains constant in all scenarios, so that the shock to yield growth rates only affects projected yield increases between 1997 and 2020.

24 Free-range chickens consume up to 20 percent more feed than their caged counterparts (Smil 2000).

25 It should be noted that the net effect on consumers of an increase in prices due to full trade liberalization depends on the level of distortions currently facing these consumers under the current trading regime. While international cereal and livestock prices will increase under trade liberalization, consumers living under particularly heavily taxed systems will pay lower prices overall.

26 The world price and global net benefits estimated here are similar in magnitude to those estimated by Diao, Somwaru, and Roe (2001) using a general equilibrium model for full agricultural trade liberalization including a few additional commodities such as sugar and fruits and vegetables. Diao, Somwaru, and Roe estimated static welfare net benefits of $31.1 billion, and an increase in the index of world agricultural prices by 11.6 percent.

27 For crops in which area actually declined during the projections period, a doubling of this decline was assumed.

28 For example, the average size of broiler production units grew from 345 animals in the mid-1970s to 14,000 animals in the mid-1990s (Steinfeld and Kamakawa 1999).

29 While the precise percentage of pork produced under intensive conditions is limited, the number of pig-holding households decreased from 1.076 million in 1975 to 0.636 million in 1995, while the total number of pigs increased by more than 100 percent (Riethmueller 1997, as quoted in Steinfeld and Kamakawa 1999).

30 Although Sub-Saharan Africa has the highest per capita cereal area harvested of any IMPACT region at 0.13 hectares per capita, this figure has actually increased from 0.12 hectares per capita in 1982.

31 Yield growth rates vary by crop.

32 Cleaver and Schreiber (1994), however, estimate that fertilizer use would have to rise 15 percent annually to achieve 3.5 percent annual yield growth.
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33 With per capita consumption in 1997 equal to 2.8 kilograms per capita for beef, 0.5 kilograms per capita for pork, 0.7 kilograms per capita for sheep and goat meat, and 0.5 kilograms per capita for poultry products.

34 India's urban population as a percentage of its total population is expected to rise from 26 percent in 1993 to 35 percent in 2020.

35 Importing livestock would be by definition more expensive than importing the feed necessary to domestically produce livestock, since the value-added would no longer occur domestically.

36 Even the East Asian economic crisis will not slow the pace of urbanization in Asia.

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