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,

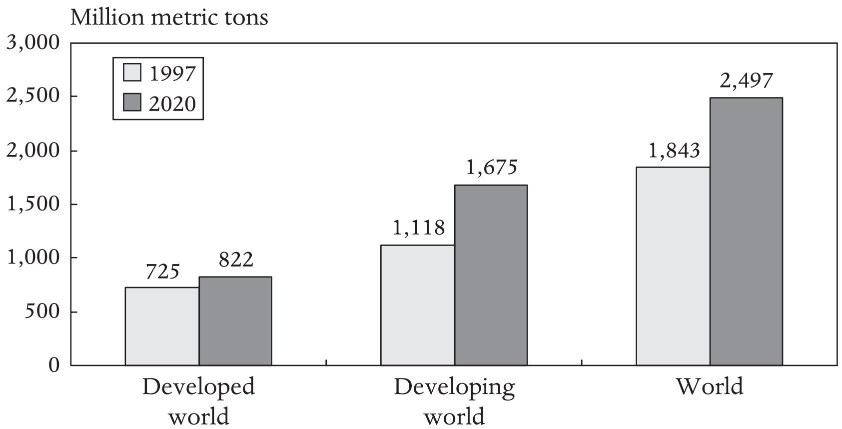

FIGURE 4.1 Total cereal demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

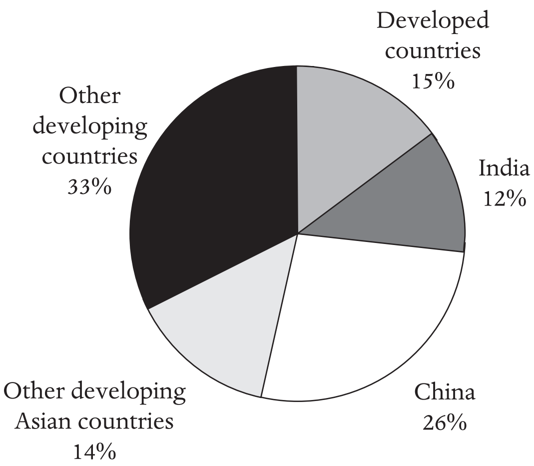

FIGURE 4.2 Share of regions in cereal demand increase, 1997–2020

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-

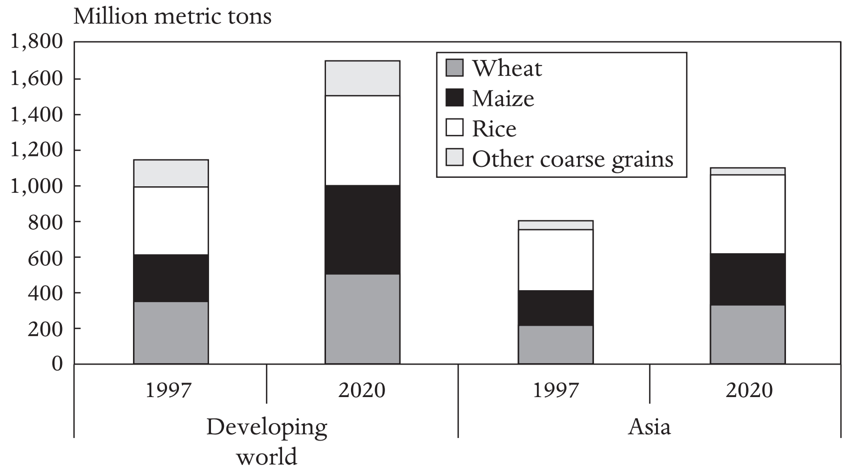

FIGURE 4.3 Cereal demand composition by crop, 1997 and 2020

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.

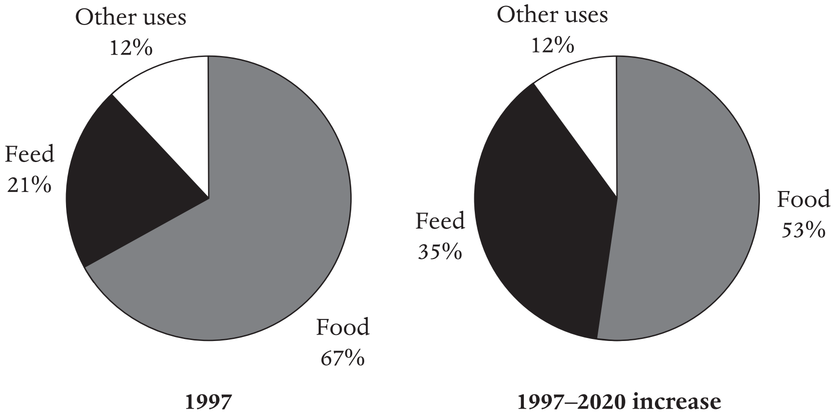

FIGURE 4.4 Share of food, feed, and other uses in total cereal demand of developing countries, 1997 and 1997–2020 increase

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

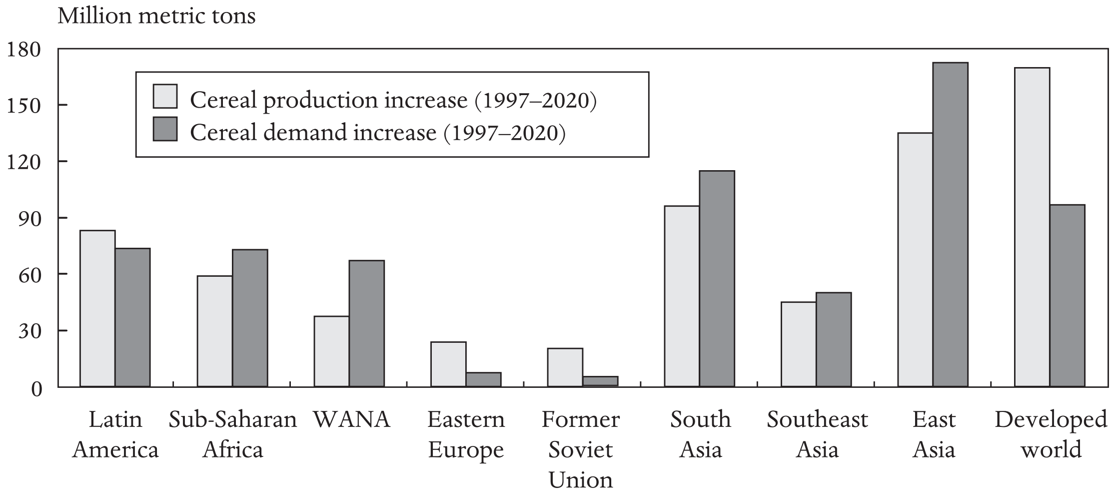

FIGURE 4.5 Cereal production and demand increases by region, 1997–2020

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.

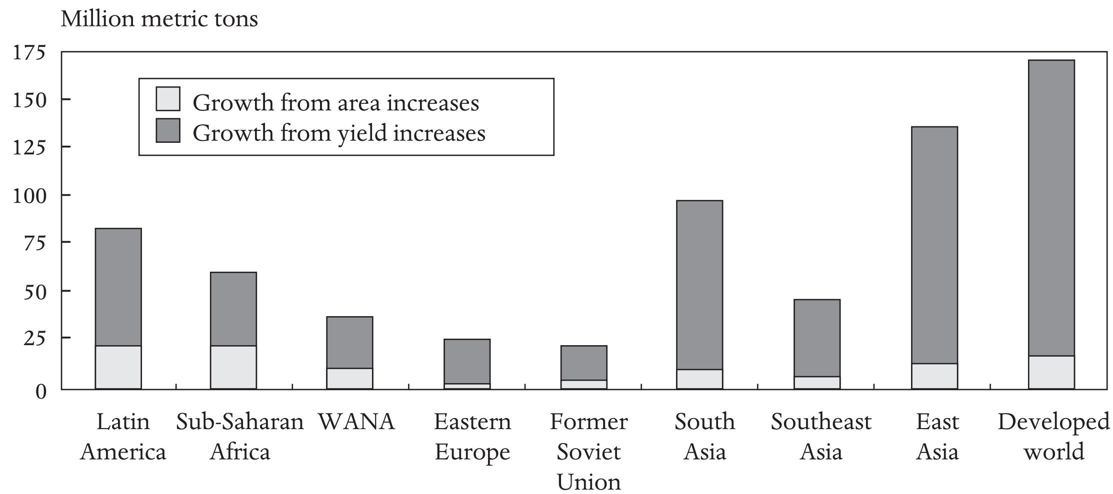

FIGURE 4.6 Share of area and yield increase in regional cereal production growth, 1997–2020

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.

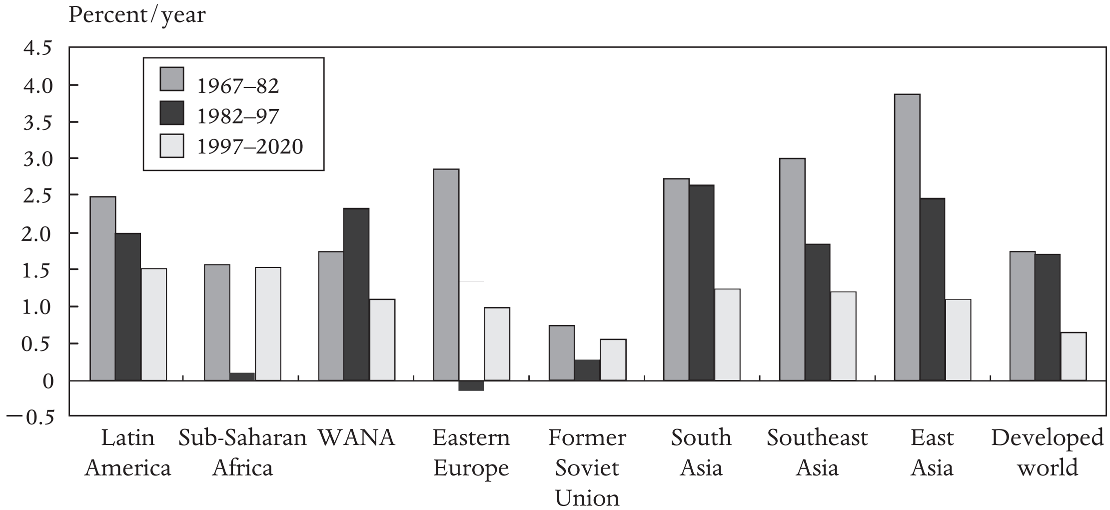

FIGURE 4.7 Yield growth rates by region, all cereals, 1967–82, 1982–97, and 1997–2020

Source: IMPACT projections, June 2001.

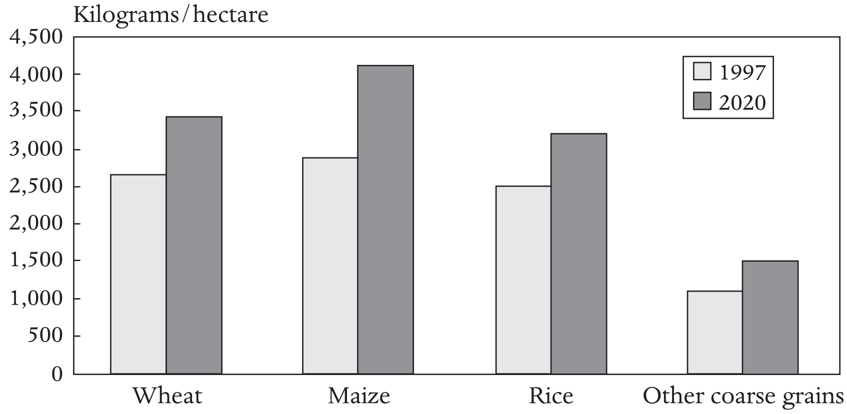

FIGURE 4.8 Cereal yields by crop in developing countries, 1997 and 2020

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.

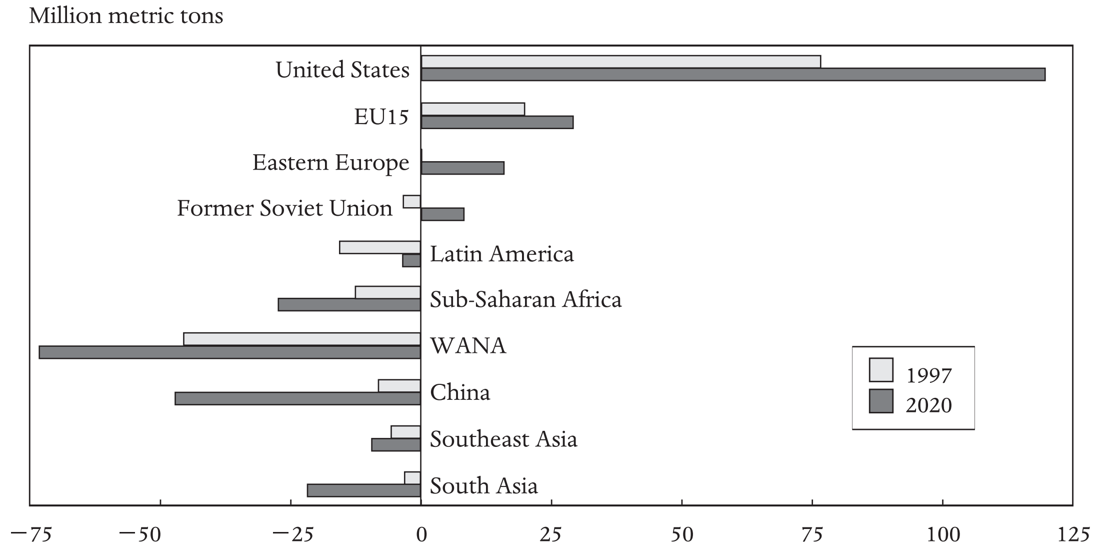

FIGURE 4.9 Net cereal trade by region, 1997 and 2020

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-

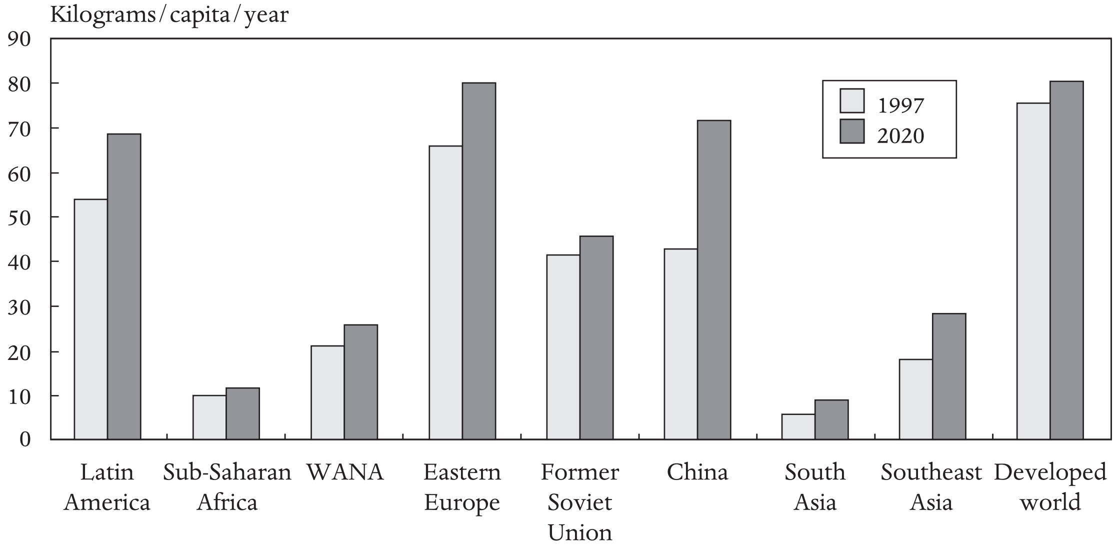

FIGURE 4.10 Per capita meat demand by region, 1997 and 2020

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-

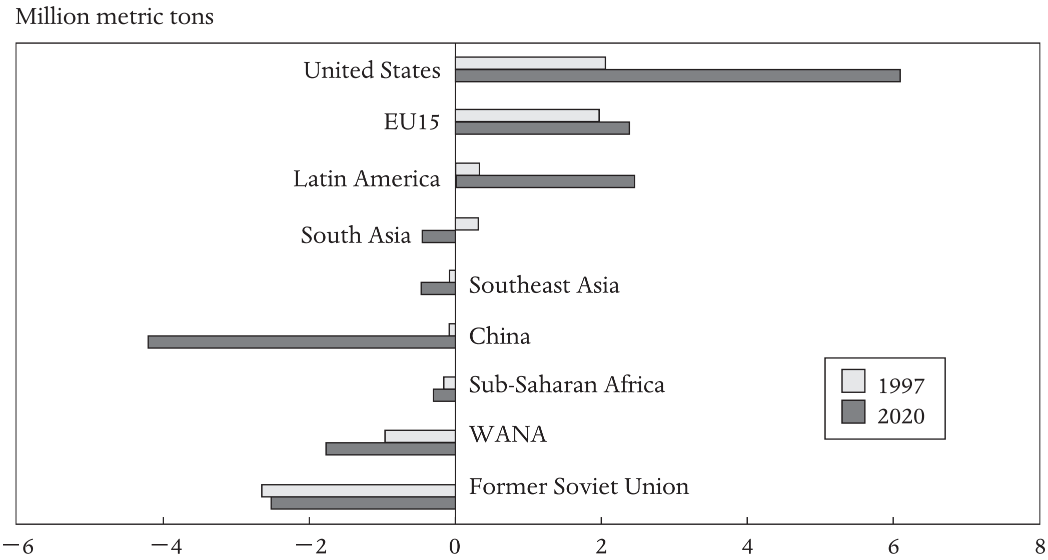

FIGURE 4.11 Net meat trade by region, 1997 and 2020

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

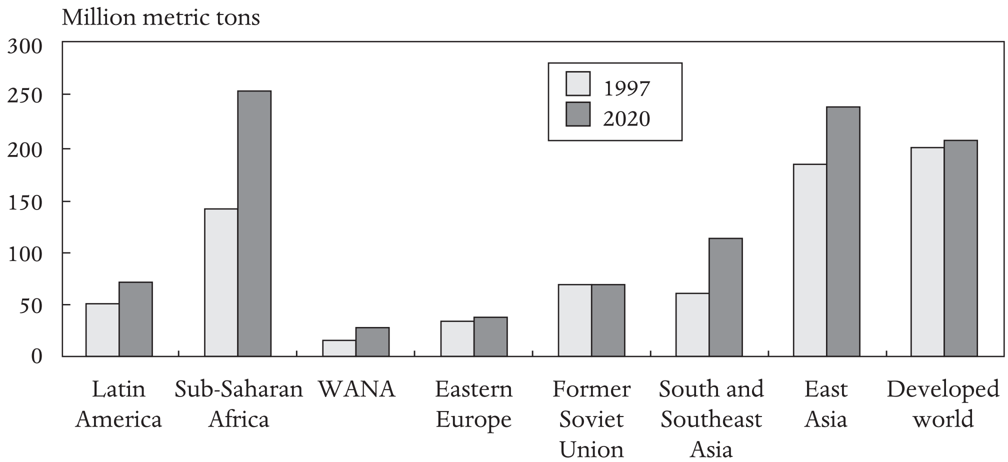

FIGURE 4.12 Roots and tubers demand by region, 1997 and 2020

Source: IMPACT projections, June 2001.

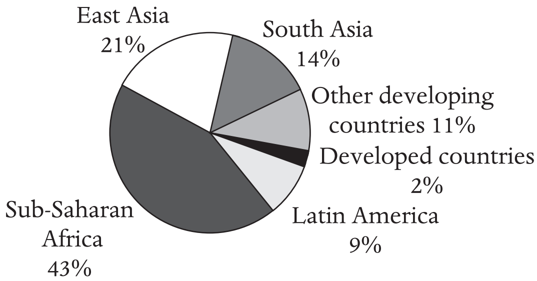

FIGURE 4.13 Share of roots and tubers demand increase by region, 1997–2020

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

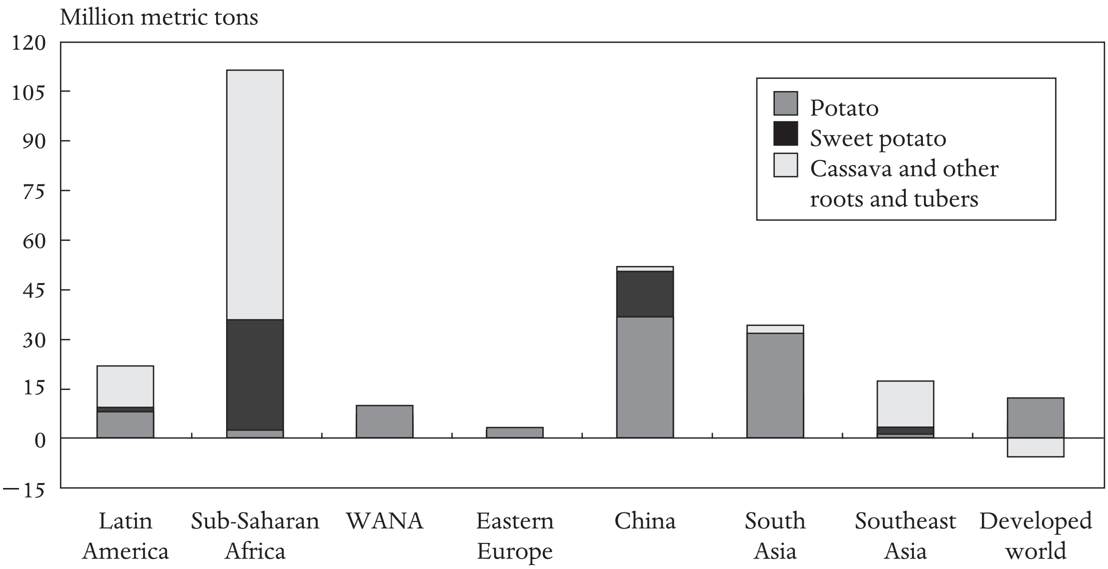

FIGURE 4.14 Increase in roots and tubers demand by crop and region, 1997–2020

Source: IMPACT projections, June 2001.

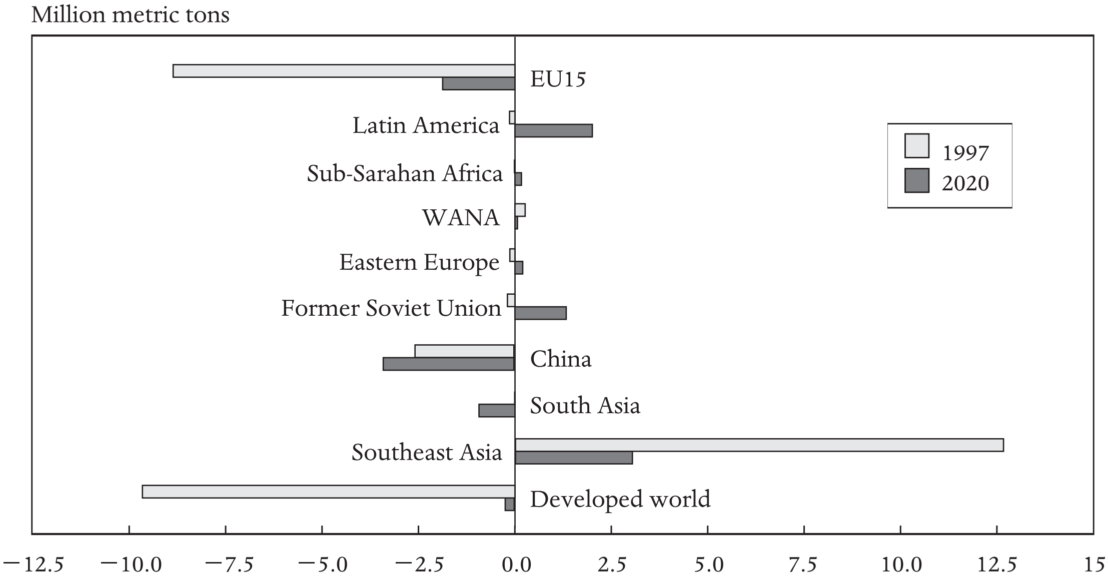

FIGURE 4.15 Net roots and tubers trade by region, 1997 and 2020

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.

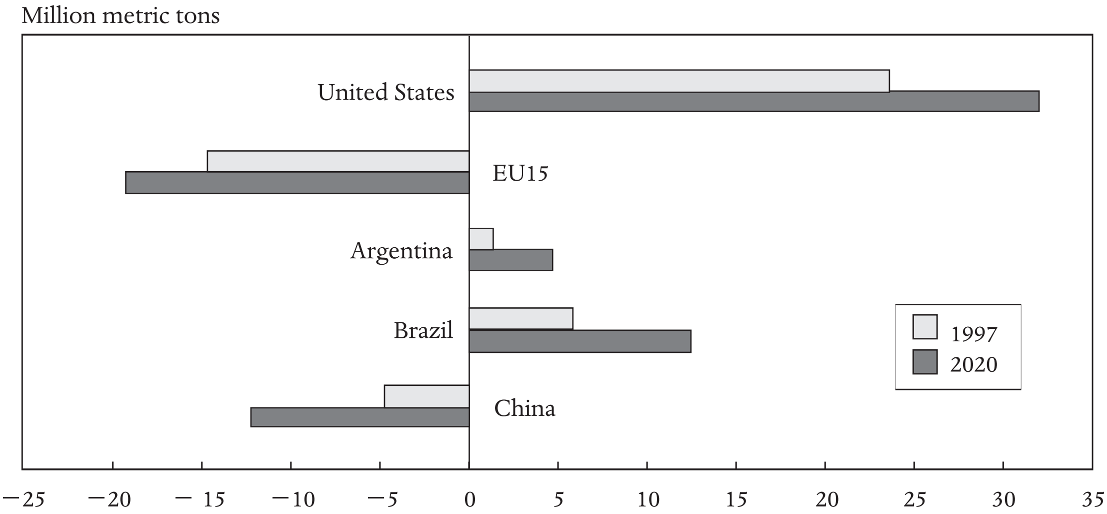

FIGURE 4.16 Net soybean trade by selected countries, 1997 and 2020

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

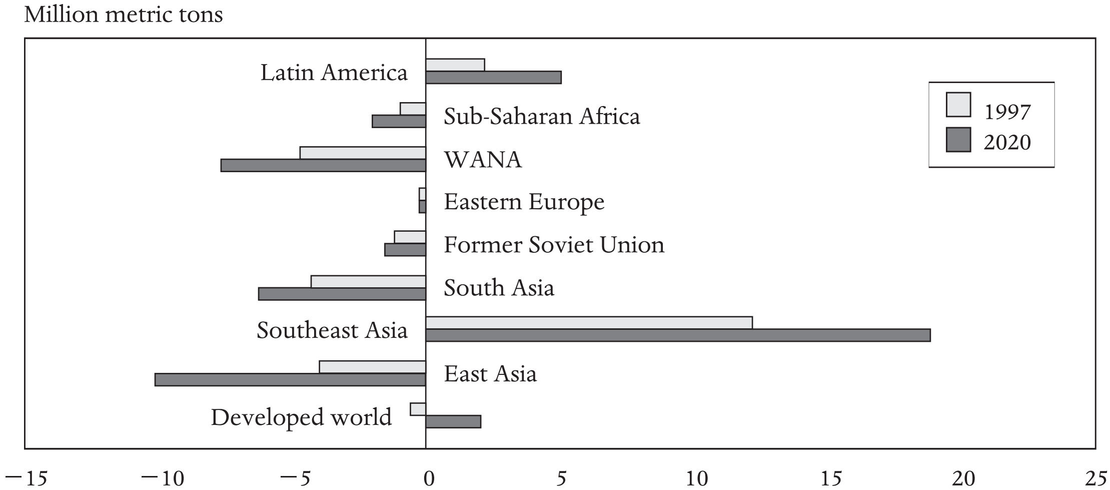

FIGURE 4.17 Net trade in edible oils by region, 1997 and 2020

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.

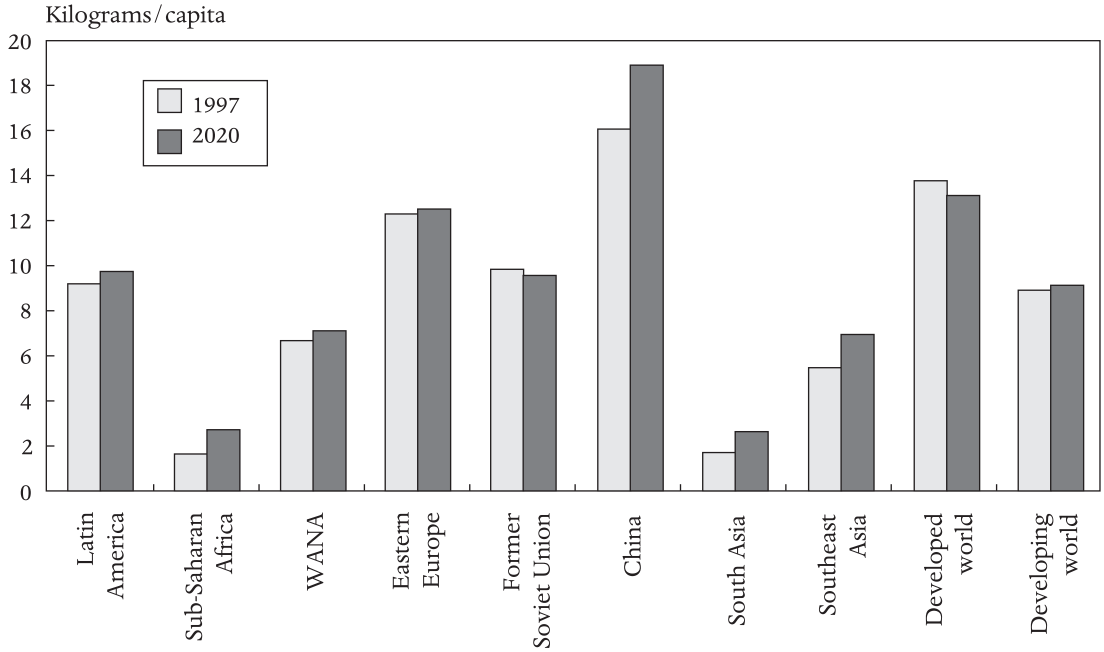

FIGURE 4.18 Per capita egg demand by region, 1997 and 2020

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

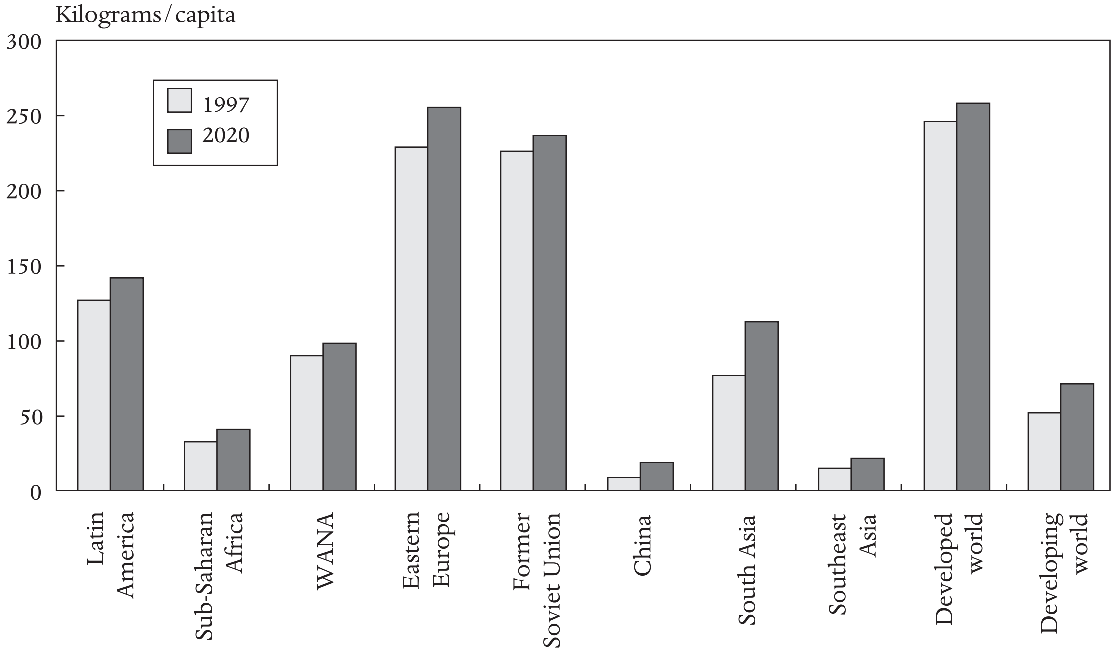

FIGURE 4.19 Per capita milk demand by region, 1997 and 2020

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-

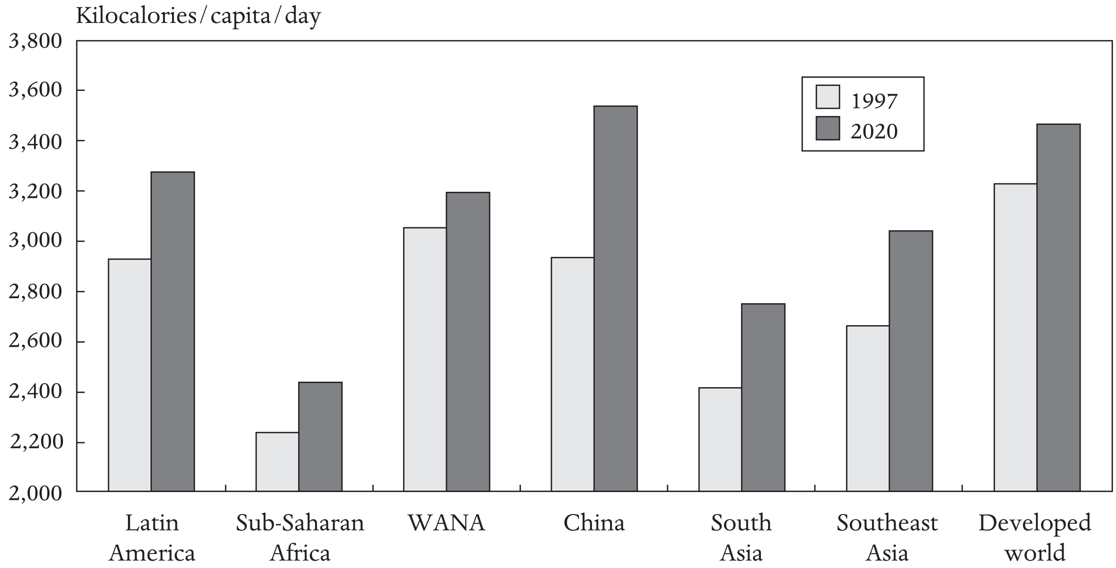

FIGURE 4.20 Daily per capita calorie consumption by region, 1997 and 2020

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

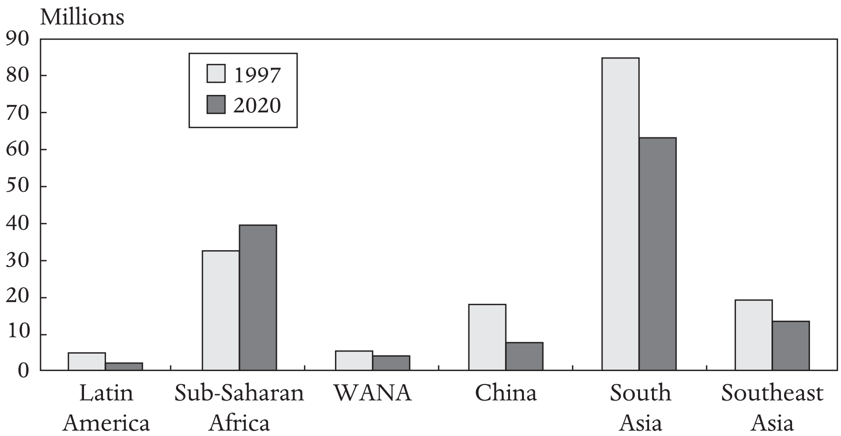

FIGURE 4.21 Number of malnourished children by region, 1997 and 2020

Source: IMPACT projections, June 2001.

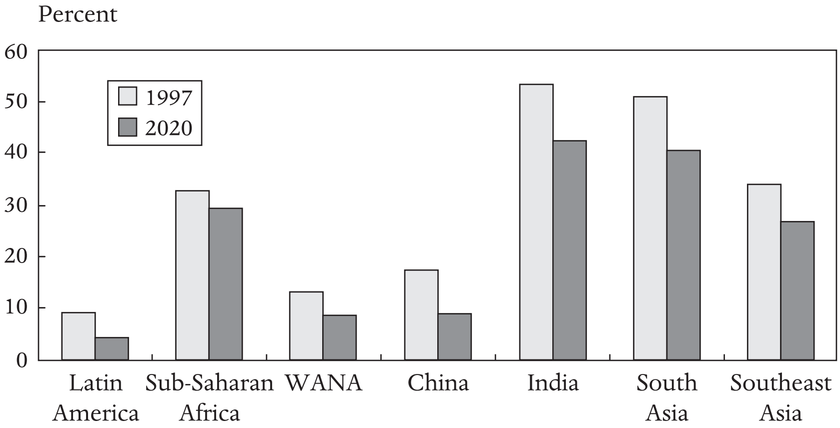

FIGURE 4.22 Malnourished children as a percentage of total children under five years by region, 1997 and 2020

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.