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New Risks and Opportunities for Food Security

Scenario Analyses for 2015 and 2050

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Contents

Tables

Figures

Boxes

Executive Summary

Given the number of undernourished people in the developing world and the increasingly complex risks to food security, policymakers are faced with an enormous agenda. Freeing people from hunger will require more and better-targeted investments, innovations, and policy actions, driven by a keen understanding of the dynamic risks and forces that shape the factors affecting people's access to food and the links with nutrition.

The International Food Policy Research Institute's (IFPRI's) International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) provides insight into the management of these risks through appropriate policy actions. By projecting future global food scenarios to 2050, IMPACT explores the potential implications of policy action and inaction in several main risk areas as well as the effects on child malnutrition in the developing world, commodity prices, demand, cereal yields, production, and net trade.

In the progressive policy actions scenario, which assumes increased investment in rural development, health, education, and agricultural research and development, developing-country governments and the international community are able to dramatically reduce the number of food-insecure people, leading to a worldwide decline in hunger. Under these conditions, Latin America and China are able to virtually eliminate child malnutrition by 2050. Bolstered by the development and dissemination of improved technologies and better infrastructure, crop production and yields increase in developing countries. Notably, the bulk of the growth in production is driven by yield increases rather than by expanding land area. Spurred by growth in the agricultural sector, average incomes in developing countries increase. Rising incomes bolster demand for high-value agricultural products, such as meat, dairy, and fruits and vegetables; global livestock production more than doubles, for example. Average per capita calorie supplies for developing countries exceed 3,400 per day, well in excess of minimum requirements.

The policy failure scenario assumes greater political discord and more extensive agricultural protectionism, together with the failure of policies to deal with food emergencies related to conflict. Slow growth and trade restrictions lead to stagnation in average per capita calorie availability, which remains only slightly above minimum requirements until after 2030, when availability increases. In addition, crucial investments in agriculture, rural development, and poverty reduction are forgone or displaced. Because of limited investment in agricultural research and technology, this scenario has a high level of crop area expansion as a result of relatively rapid population growth and slim yield improvements in developing countries. This scenario also results in flat maize prices, declining per capita cereal demand, falling beef prices, and relatively flat meat demand. As a result of the policies in this scenario, the number of malnourished children in developing countries rises between 1997 and 2015, after which there are only modest declines.

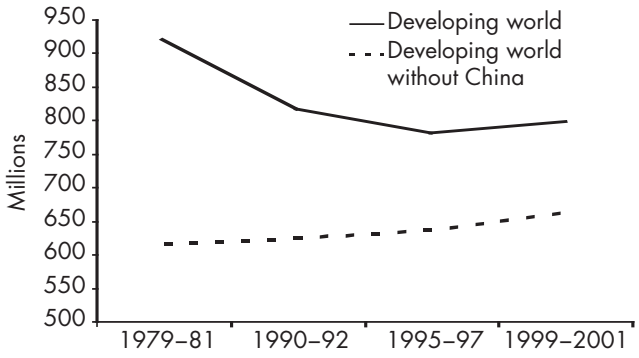
In the technology and natural resource management failure scenario, yield growth falls even more than under the preceding scenario, forcing farmers to move into marginal producing areas, which causes a more rapid expansion of cereal area into less productive land that does not compensate for the yield shortfalls (and causes environmental degradation). As a result, cereal prices rise substantially through 2030 and then fall off only gradually. Beef and other meat prices, which are affected by the price of feed, follow a similar pattern. Developing-country per capita calorie availability is essentially unchanged over 1997–2050 and remains at a barely adequate average level. Given unequal access to the food that is available, millions of people actually consume less than the minimum. The occurrence of child undernourishment is even higher than under the policy failure scenario in all developing-country regions. Overall, the technology and natural resource management failure scenario results in the worst impact on food security and child malnourishment in the developing world.

The progressive policy scenario outlines several of the most crucial positive steps. National governments and the international community must assume a new focus on agricultural growth and rural development, along with increasing their investments in education, social services, and health. Policies to encourage synergistic growth in the nonfarm sectors are also needed to spur broad-based economic growth. Underpinning these strategies and research agendas must be a firm commitment to reducing hunger and improving the welfare of the world's undernourished people.

1. Introduction

Over the past several decades, the world has made remarkable progress in reducing undernourishment as expressed by food energy deficiency, also referred to as hunger.[1] According to the Food and Agriculture Organization of the United Nations (FAO), the number of undernourished people in developing countries fell from 920 million in 1980 to 798 million in 2001, while the proportion of people living under such conditions dropped substantially, from 28 to 17 percent. Economic growth, along with programs targeted to the poor in some countries, contributed significantly to the progress. Increased investment in agricultural research and technological improvements has heavily supported this decline by catalyzing growth in per capita production of cereals—the most important source of calories—and lowering real cereal prices to the benefit of poor consumers. Between 1967 and 1997, global cereal production increased 84 percent, as per capita cereal production rose from 295 kilograms to 325 kilograms (Rosegrant, Paisner, and Meijer 2003). Food availability has increased by 26 percent over the past three decades to reach 2,667 calories per person per day (Rosegrant et al. 2001). Furthermore, real world prices of major cereals, such as rice and maize, declined by 29 percent and 30 percent, respectively, between 1982 and 1997.

Figure 1—Hunger in the developing world, 1980–2001



Source: FAO 2003.

However, there are concerns that water scarcity, soil depletion, the lack of technology adoption and dissemination, political and civil conflict, and the continued threat of disease epidemics such as HIV/AIDS pose a grave threat to the food security of growing populations in the developing world. There are ominous signs. Progress in hunger reduction slowed considerably during the late 1990s: between 1995 and 2001, the number of undernourished people in the developing world increased by more than 18 million. If China is excluded from consideration, the number of undernourished people in the developing world increased by nearly 28 million during this period (Figure 1). In addition, there are indications that price fluctuations are rising as world cereal stocks are reduced (see Box 1). Moreover, micronutrient malnutrition is widespread, and its consequences are significant (Table 1).

The majority of the world's hungry people depend heavily, both directly and indirectly, on growth in the agricultural sector for both food and their livelihoods—either as farmers or as net purchasers of food. Most of the world's hungry, approximately 80 percent, live in rural areas, where access to markets, health care, education, and infrastructure such as telecommunications and roadways is scarce (Hunger Task Force 2003). These areas are often characterized by poor quality of natural assets, a fragile natural resource base,

[1] *Undernourishment*, or *hunger*, is defined as food intake that is continuously inadequate to meet dietary energy requirements. *Food insecurity* is defined as a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life (ACC/SCN 2004).

Box 1—Worrisome trends in global commodity prices

Recent trends in world food prices and stocks may warrant increased monitoring and attention. Over the past five years, global cereal production has remained flat at under 1.9 billion tons, which means that on a per capita basis, production has shrunk, according to data from the U.S. Department of Agriculture. In addition, current global grain stockpiles are falling fast, from approximately 580 million tons in 1997 to 300 million tons in 2003. In China, the situation has been changing particularly rapidly, with stocks falling by half during the past three years. Not surprisingly, this stagnation in production, coupled with the decrease in stocks, has driven prices for rice, wheat, and maize higher. In the case of wheat, the price has increased by more than 50 percent in four years.

Flat production is partly a result of low prices and low levels of investment in research and technology in recent years. The price increases expressed in U.S. dollars partly reflect the declining value of U.S. currency. But explicit trade policy changes as well as production constraints are affecting prices too. In this situation, industrialized countries could help with more open food-trade policies to facilitate global price stabilization.

Of particular concern are the potential effects of these price shifts on the poor: compared to 30 years ago—the time of the last world food crisis caused by high prices—many of the poorest of the poor are now more vulnerable to price increases because they no longer produce as much in the way of subsistence crops for home consumption as they used to. Many are now landless farmers, and many are urban poor. The world today also has a substantially larger middle class that will not adjust its eating habits because of higher food prices. Thus, at a global level there will be less collective "belt-tightening" as prices increase. This situation is compounded by the dismantling of public price-stabilization schemes in many developing countries.

These trends warrant increased monitoring and attention to the impact of short-term changes in cereal production and price on the poor. Moreover, the welfare and poverty effects of price changes brought on by both trade protection and liberalization are both highly relevant and need to be addressed on a country-by-country basis, with a focus on the impact on marginalized and highly vulnerable groups.

Table 1—Extent and consequences of micronutrient malnutrition

Deficiency	Prevalence in developing countries	Groups most affected	Consequences
Iron	4 to 5 billion people	All, especially women and children	Reduced cognitive ability, childbirth complications, and reduced physical capacity and productivity
Vitamin A	140 million preschoolers and over 7 million pregnant women	Children and pregnant women	Increased child and maternal mortality, blindness
Zinc	May be as widespread as iron deficiency	Women and children	Illness from infectious diseases, poor child growth, pregnancy and childbirth complications, and reduced birth weight
Iodine	2 billion people, of which 285 million are children	All, especially children	Slower fetal brain growth, Slower mental development of children, and reduced cognitive ability in schoolchildren

Source: ACC/SCN 2004.

and scarce soil, land, and water resources. Yet these populations lack access to information and technologies to provide greater returns in the presence of these resource constraints. Because of slow income growth and risky environments, farmers have little savings to invest in land and livestock improvements. Crop area expansion without technological improvements results in low crop yields and, combined with rising population, worsening food insecurity and hunger. In addition, population growth and degraded land resources have led to farm size reductions, to the point that some farms are barely productive, as in many parts of Sub-Saharan Africa (Table 2). These already vulnerable populations are severely affected by variable weather patterns, such as floods and droughts, and disease epidemics, especially HIV/AIDS, which erode physical and human assets and drive households deeper into poverty and hunger. Trade protection in wealthy countries and trade restrictions between developing countries further limit the ability of developing-country farmers to generate growth in their agricultural sectors, therefore reinforcing the negative synergies between low agricultural growth and food insecurity.

Approximately 17 percent of the world's hungry people are very young children, less than six years of age. The incidence of child hunger and malnutrition is a powerful indicator of the limited progress being made in the fight against hunger and serves as a benchmark for tracking the achievement of the Millennium Development Goal of halving the proportion of hungry people by 2015.[2] Although the absolute numbers of undernourished children in the developing world have declined from 172.1 million in 1980 to 135.5 million in 2000, progress has been slow and uneven (Figure 2). Although Latin America and South Asia have made major improvements in reducing child malnutrition, the number of hungry children is increasing rapidly in most parts of Sub-Saharan Africa (ACC/SCN 2004) (Figures 2 and 3). Clearly, these figures indicate that the Millennium Development Hunger Goal will not be realized without dramatically increased financial and political commitment. The rights-based approach to development and food security can help to generate political commitment (see Box 2).

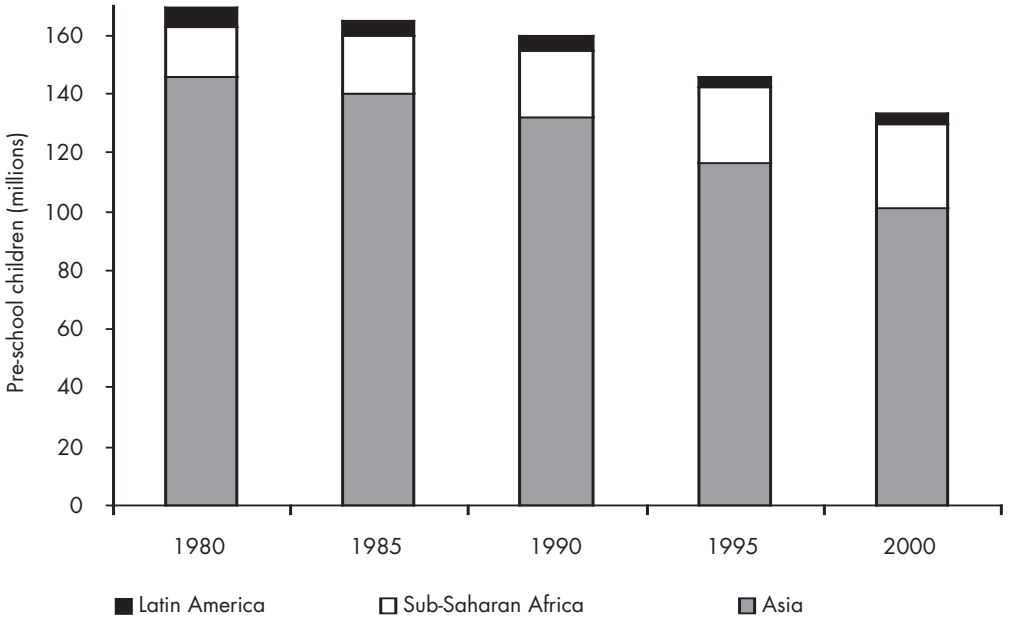
Table 2—Smallholder land distribution in selected African countries

Country	Household per capita land access				Gini coefficient land per capita
	Income quartile				
	1	2	3	4	
	(hectare)				
Kenya	0.08	0.17	0.31	1.10	0.56
Ethiopia	0.03	0.12	0.22	0.58	0.55
Rwanda 1984	0.07	0.15	0.26	0.62	
Rwanda 1990	0.05	0.10	0.16	0.39	0.43
Rwanda 2000	0.02	0.06	0.13	0.43	0.54
Malawi	0.08	0.15	0.25	0.60	
Zambia	0.12	0.26	0.48	1.36	0.50
Mozambique	0.10	0.23	0.40	1.16	0.51

Source: Jayne et al. 2003.

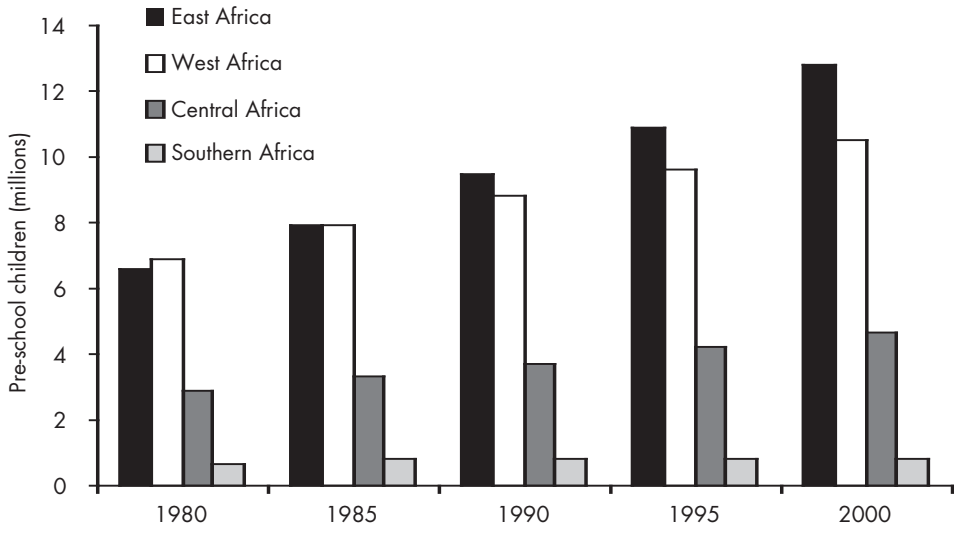
[2] The Millennium Development Goals call for halving the *proportion* of the world's hungry people. The World Food Summit Goal, as promulgated at the 1996 World Food Summit, calls for halving the absolute *number* of hungry people.

Figure 2—Child undernourishment in the developing world, 1980–2000



Source: ACC/SCN 2004.

Figure 3—Child undernourishment in Africa by region, 1980–2000



Source: ACC/SCN 2004.

Box 2—Overview of the human right to food

In the aftermath of World War II, the international community codified a set of human rights principles—the Universal Declaration of Human Rights—for the purpose of promoting a more just and peaceful world order. Prominent in the code was the right to food and other basic necessities. Five decades later, the World Food Summit Plan of Action called upon the UN High Commissioner for Human Rights

> . . . To better define the rights related to food . . . and to propose ways to implement and realize these rights as a means of achieving the commitments and objectives of the World Food Summit, taking into account the possibility of formulating voluntary guidelines for food security for all. (FAO 1996, Plan of Action paragraph 61)

Since then, the UN High Commissioner and the FAO, along with nongovernmental organizations and some national governments, have collaborated in a series of expert consultations and conferences focusing on the right to food. In 1999, the UN Committee on Economic, Social, and Cultural Rights adopted General Comment 12, defining the right to food. It acknowledges that the right to adequate food will have to be realized progressively, and within the limits of available resources, but it emphasizes that states have an obligation to take the necessary action to mitigate and alleviate hunger. (United Nations Committee on Economic, Social, and Cultural Rights 1999).

In 2003 and 2004, the FAO convened four sessions of an Intergovernmental Working Group for the Elaboration of a Set of Voluntary Guidelines to Support the Progressive Realization of the Right to Adequate Food in the Context of National Food Security. In September 2004, the FAO Committee on World Food Security approved the guidelines, which are the first such set of voluntary operating principles created to help states implement a particular human right—and on November 22, 2004, they were approved by the FAO Council, which is composed of Ministerial representatives of FAO member states. Although these guidelines do not create any binding obligations, they offer broad and practical suggestions, and encourage international cooperation in support of national government efforts. The guidelines are available at: <http://www.fao.org/righttofood/common/ecg/51596_en_VGS_eng_web.pdf>.

Recognition of state obligations with respect to the right to food empowers civil society to demand that these rights be fulfilled by their governments. Contrary to what is sometimes argued, states that take on these obligations are not required to supply three meals daily to all citizens. Rather, the state must respect (that is, not interfere with) the right of everyone within its borders to have access to adequate food, protect that right from encroachment by others, facilitate opportunities by which that right can be enjoyed (for example, through employment or access to land), and only in the last instance fulfill the right to food for those unable to do so themselves. Perhaps most importantly, as South African Human Rights Commissioner Charlotte McClain-Nhlapo has pointed out, the rights-based approach to food security makes "the critical shift from treating hunger and food insecurity as a charitable endeavor to recognizing adequate food as a right that must be protected by law" (McClain-Nhlapo 2004, 4).

2. Exploring Risks to and Opportunities for Food Security in the 21st Century

Given the number of undernourished people in the developing world and the increasingly complex risks to food security, policymakers are faced with an enormous agenda. Freeing people from hunger will require more and better-targeted investments, innovations, and policy actions, driven by a keen understanding of the dynamic risks and forces that shape the factors affecting people's access to food and the links with nutrition.

The International Food Policy Research Institute's (IFPRI's) International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) provides insight into the management of these risks through appropriate policy actions. By projecting future global food scenarios to 2050, the IMPACT model explores the potential implications of policy inaction and action in several main risk areas and the effects on child malnutrition in the developing world, commodity prices, demand, cereal yields, production, and net trade.

In this paper we present three scenarios of different policy alternatives, involving varying risks and opportunities: a progressive policy actions scenario, a policy failure scenario, and a technology and natural resource management failure scenario. We further explore new and salient food and nutrition security dimensions related to each of the scenarios.

Progressive policy actions scenario

In a progressive policy actions scenario, we assume a new focus on agricultural growth and rural development. Developing countries' public investments and government expenditures on agriculture and rural development, appropriately supported by official development assistance, increase between 2005 and 2015 and stabilize thereafter. Investments in education, social services, and health increase. The rate of agricultural technology improvement is high owing to increased investment in agricultural research and development. Irrigation efficiency and water use efficiency improve in this scenario, and the rate of irrigation expansion is moderate to high. Furthermore, producer support to farmers in wealthy countries declines substantially, dropping to half of current levels in 2010, and half of this level in 2020.

Policy failure scenario

In the policy failure scenario, we assume trade and political conflicts, with no progress on global agricultural trade negotiations and increased levels of trade restrictions worldwide. Today, we cannot exclude political-economic forces from producing such outcomes. The policy failure scenario assumes decreases in yield growth for all crops and fish, and decreases in numbers growth for all livestock. It also shows policies that lead to stagnant world trade and slow growth in developing countries' net imports. This impasse in agricultural trade liberalization further contributes to the growing food deficit in developing countries. Compatible with these scenario elements are political conflicts and low investments in social services and agricultural research and development. Producer support to farmers in wealthy countries triples from current levels by 2020 and remains steady through 2050, and the population transition to lower birth rates is delayed, resulting in higher population growth than in the progressive policy actions scenario.

Technology and natural resource management failure scenario

Water mismanagement, declining irrigation efficiency, lack of adaptation to climate change, and pest problems in agriculture characterize this scenario. Low agricultural investments undermine the development of new agricultural technology and contribute to marginal levels of irrigation efficiency and lack of improvement in water use efficiency. In addition, investments in many sectors, including education, social services, and health, are low in developing countries. The lack of growth in agricultural yields is the outcome of all of the above and also partly a result of weak income growth in developing countries and only moderate income growth in industrialized countries. Again, the demographic transition is assumed delayed in this scenario.

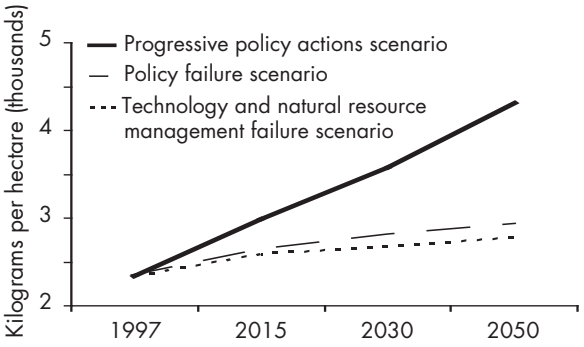
For a more complete description of the IMPACT model and of each of the three scenarios, see the Appendix.

3. Progressive Policy Actions Scenario

Through increasing investment in rural development, health, education, and agricultural research and development, developing country governments and the international community are able to dramatically reduce the number of food-insecure people, leading to a worldwide decline in hunger. Increased investments in crop research, technological change and dissemination, and reform of water management systems serve to boost water productivity and the growth of rainfed crop yields. Improved policies and increased investment in rural infrastructure help link remote farmers to markets and reduce the high risks associated with rainfed farming. Bolstered by the development and dissemination of improved technologies and better infrastructure, crop production and yields increase in developing countries (Figure 4). Notably, the bulk of the growth in production is driven by yield increases, rather than by expanding land area (Figure 5). Furthermore, in this scenario, producer subsidies in wealthy countries decline in half by 2010, and then are halved again in 2020. Because of the removal of producer support, which drives world prices artificially low, beef prices rise slightly after 2010 (Figure 6). Spurred by growth in the agricultural sector, average incomes in developing countries increase. Rising incomes bolster demand for high-value agricultural products, such as meat, dairy, and fruits and vegetables; for instance, global livestock production more than doubles (Figure 7).

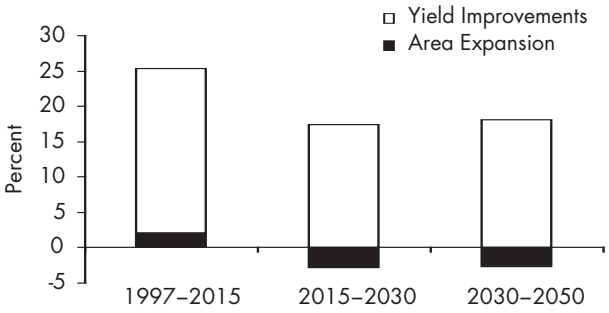
As a result of these impacts, average per capita calorie supplies for developing countries exceed 3,400 per day, well in excess of minimum requirements (Figure 8). Gains in child nutrition in developing countries are steady and occur in all regions, including Sub-Saharan Africa, after 2015 (Figures 9 to 13). As represented below, the progress in

Figure 4—Projected cereal yields in developing countries, all scenarios



Source: IFPRI IMPACT projections 2004.

Figure 5—Projected sources of growth in world cereal production, progressive policy actions scenario



Source: IFPRI IMPACT projections 2004.

reducing child malnourishment dramatically diverges from the results of the policy failure and technology and natural resource management failure scenarios. Latin America and China virtually eliminate child malnutrition by 2050 (Figures 12 and 13). See the appendix for more details on the assumptions and projections made under this scenario, such as those concerning the fertility, mortality, and migration of populations, and the nonfood determinants of childhood malnutrition.

Promising Policy Initiatives

Do we have reason to hope that the international community and governments are moving toward progressive policy action to combat hunger and malnutrition in the developing world?

There are positive signs. Developing countries and the broader international community have collectively embraced the goals of the World Food Summit, sponsored by the Food and Agriculture Organization of the United Nations, and the United Nations Millennium Development Goals, both of which call for dramatic reductions in hunger and increased political will and monetary support. In addition, bilateral and multilateral donors are placing renewed emphasis on agriculture and rural development. The World Bank's new rural strategy, released in 2002, is a crucial example. Whether donors will provide additional resources to support agriculture and rural development is a key issue. Donor assistance to agriculture and rural development has notably declined in recent years: at the end of the 1990s, the level of official development assistance provided to agriculture was lower than at the beginning of the decade in real terms.

In 2003, the Heads of State Summit of the African Union agreed in its Maputo Declaration in the New Partnership for Africa's Development (NEPAD) framework to move toward directing 10 percent of public expenditures to agriculture, in order to bolster food security on the continent (see Box 3, page 13). By contrast, in the 1990s, African governments devoted on average just 5 percent of public expenditures to agriculture. It is encouraging that African policymakers at the highest level are expressing a commitment to reverse the downward spiral in food and agriculture in Sub-Saharan Africa, where per capita food production has declined over the past 30 years and child malnutrition is severe and growing. Two African Summits in 2004 had agriculture and food security high on the agenda, and the IFPRI 2020 Conference on Food and Nutrition Security in Africa attracted African leaders to a focus on action (2020 Africa Conference Advisory Committee 2004).

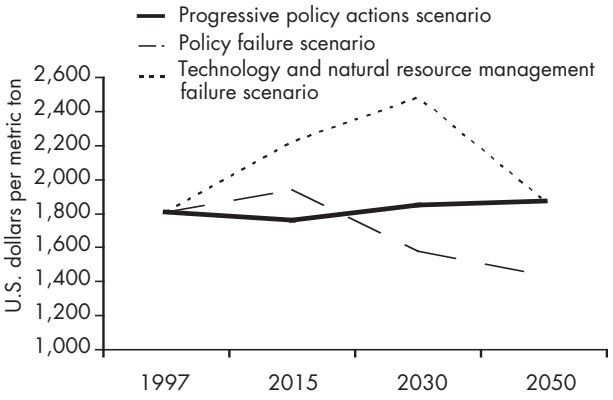
Latin American ministers of agriculture met in early November 2003 for a major initiative to map out opportunities to improve food security. They adopted an ambitious agricultural initiative, AGRO 2003–2015 Plan of Action for Agriculture, wherein they recognized agriculture as a key component for the development of their countries. The plan contains a broad agenda to promote prosperity in rural communities, create food security, alleviate poverty, and foster the sustainable development of agriculture and the rural environment.

Individually, developing-country governments around the world are showing a new spirit of action to address food insecurity and undernutrition. Preliminary results of an ongoing review by IFPRI suggest that most of the governments of the 34 countries in which the highest number and percentage[3] of the world's food-insecure people live have recently declared policy goals regarding food security. Most of these countries have already taken steps to translate declarations into redesigned policy actions. At least 22 countries have redesigned existing policies or adopted new agriculture and nutrition policies to enhance food security in the last five years.

A major element of the success of these strategies and declarations will be the concomitant increase in domestic budgetary allocation to agri-

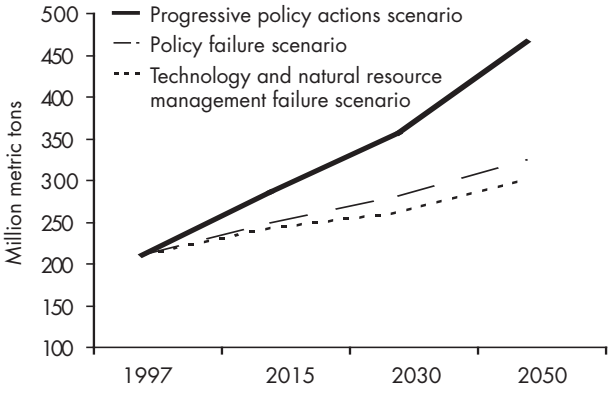
[3] These include the 20 countries with the highest number of malnourished people and the 20 countries with the highest percentage of malnourished population in 2002 (Afghanistan, Angola, Armenia, Bangladesh, Brazil, Burundi, Central African Republic, China, Democratic Republic of the Congo, Eritrea, Ethiopia, Haiti, India, Kenya, Democratic Republic of Korea, Liberia, Madagascar, Mongolia, Mozambique, Nigeria, Pakistan, Philippines, Russian Federation, Rwanda, Sierra Leone, Somalia, Sudan, Tanzania, Tajikistan, Thailand, Uganda, Vietnam, Zambia, Zimbabwe).

Figure 6—Projected world beef price, all scenarios



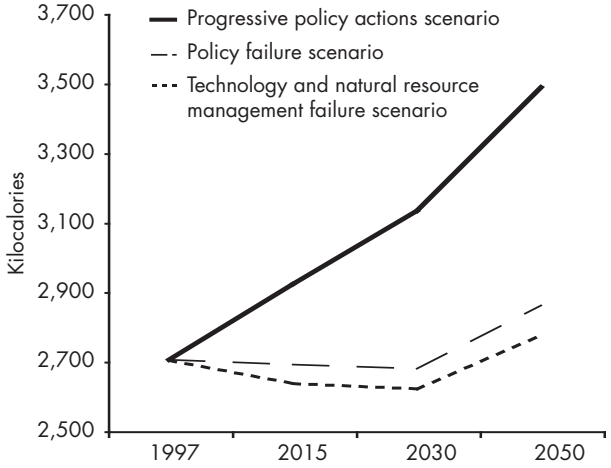
Source: IFPRI IMPACT projections 2004.

Figure 7—Projected world livestock production, all scenarios



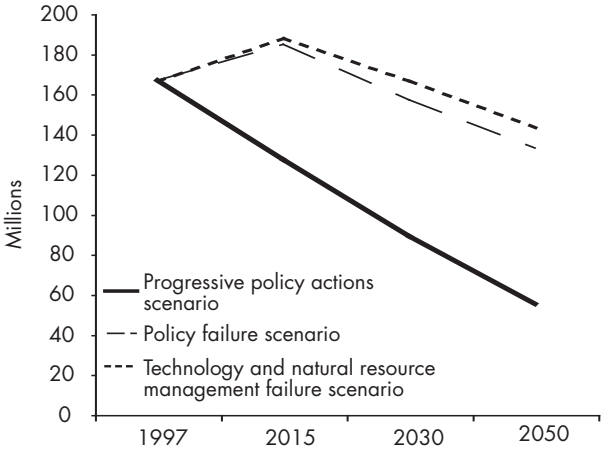
Source: IFPRI IMPACT projections 2004.

Figure 8—Projected daily calorie consumption in developing countries, all scenarios



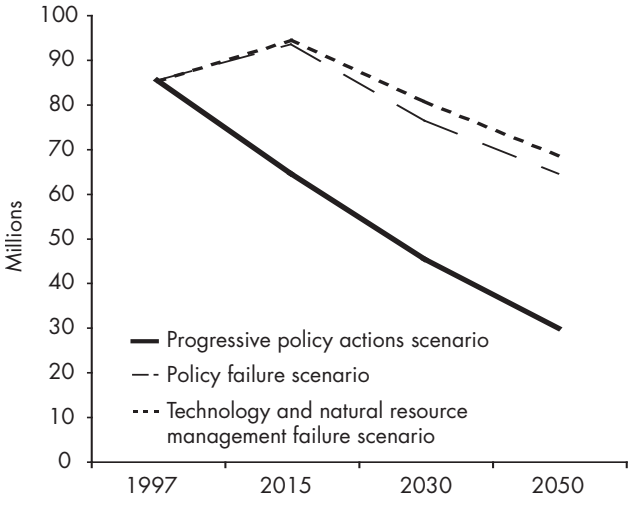
Source: IFPRI IMPACT projections 2004.

Figure 9—Projected child undernourishment in developing countries, all scenarios



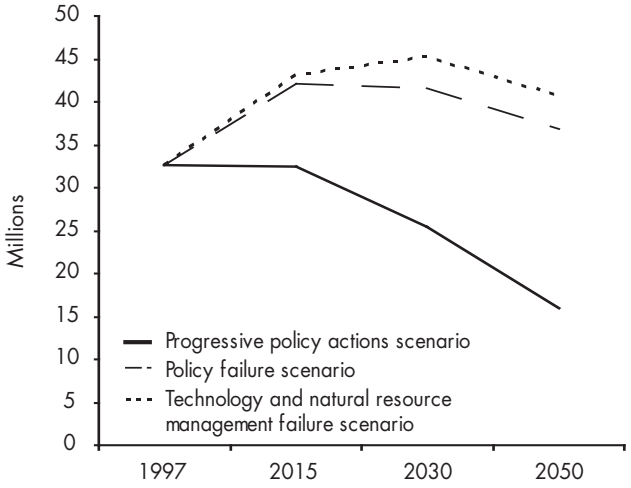
Source: IFPRI IMPACT projections 2004.

Figure 10—Projected child undernourishment in South Asia, all scenarios



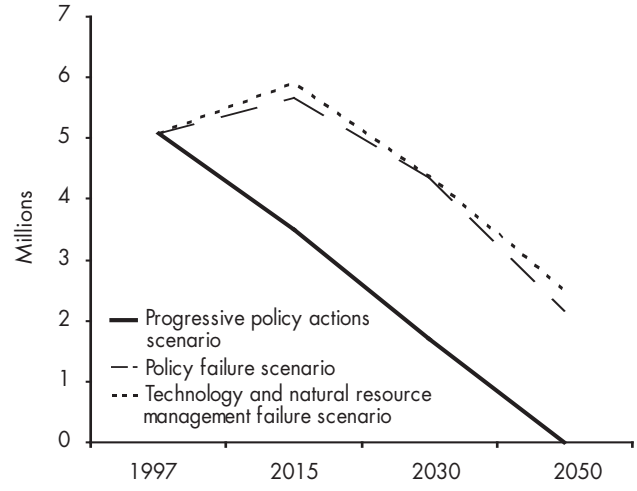
Source: IFPRI IMPACT projections 2004.

Figure 11—Projected child undernourishment in Sub-Saharan Africa, all scenarios



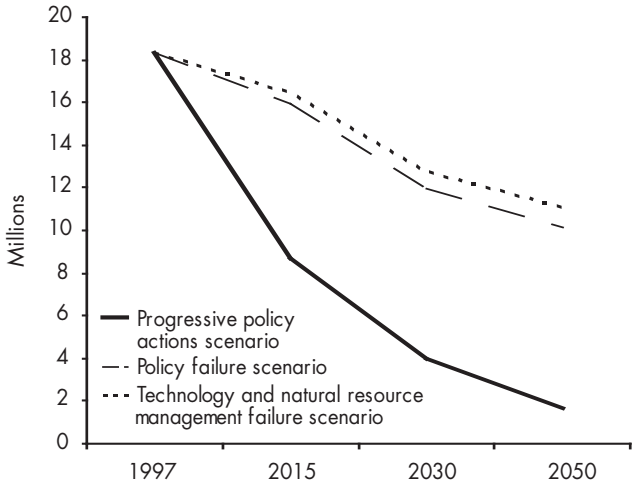
Source: IFPRI IMPACT projections 2004.

Figure 12—Projected child undernourishment in Latin America, all scenarios



Source: IFPRI IMPACT projections 2004.

Figure 13—Projected child undernourishment in China, all scenarios



Source: IFPRI IMPACT projections 2004.

culture and rural development, along with investment in human development, such as in education and health care. However, despite these new commitments to reduce malnutrition and hunger, an increase in the share of public spending devoted to these key areas has not accompanied these initiatives. In a subset of 20 of these 34 most food-insecure countries for which information on government spending is available, only 10 have increased their agriculture spending as a share of total expenditures, whereas 10 others have decreased their agricultural outlay. Similar analysis of government health spending reflects that only six countries have increased their health spending share, while 11 actually decreased this share (IMF 2003).[4] Clearly, real impacts on the ground will not be felt from policy declarations alone: food-insecure countries must put more public investment into agriculture, rural development, and human development to accompany their ambitious initiatives.

Even the progressive policy actions scenario does not result in food and nutrition security for all in the foreseeable future. Complementary policy actions on a larger scale for social security and large-scale interventions to improve human resources—such as early childhood nutritional action, school feeding, and social safety nets—are needed on a sustained basis to achieve food security for all (Coady 2001; Skoufias 2001; Ahmed and del Ninno 2002). Finally, the elimination of food insecurity will not happen until women achieve full social and economic participation and rights. Despite their central role in both traditional and modern agricultural households, women in many countries are undervalued and lack many civil liberties. Women's lack of equal access and opportunity in areas such as secondary and higher education has stunted their productive potential. Perhaps more important than their economic potential, this denial of access and opportunity inhibits women's individual freedom and the broad realization of their social participation. Achieving full food security at the household level will require expanded opportunities for women (Runge et al. 2003).

4 The ratio of agricultural expenditure to total expenditure, and ratio of health expenditure to total expenditure, comparing first and latest data available for each country for the period 1991–2004.

Box 3—The New Partnership for Africa's Development (NEPAD) and the Maputo Declaration

The New Partnership for Africa's Development (NEPAD) is a pledge by African leaders to develop a program for action for the redevelopment of the African continent. The goals of NEPAD are to promote accelerated growth and sustainable development, eradicate widespread and severe poverty, and halt the marginalization of Africa. NEPAD has given high priority to agriculture and has determined that it will act as the prime engine of African economic growth. For NEPAD, agriculture will be the economic sector to deliver broad-based economic advancement through improved food security, income generation, and diversified export growth.

NEPAD's strategy is outlined in the Comprehensive Africa Agricultural Development Programme (CAADP) prepared by the NEPAD secretariat with FAO's assistance. This program outlines five priority areas: (1) extending the area under sustainable land management and reliable water control systems; (2) improving rural infrastructure and trade-related capacities for market access; (3) increasing food supply and reducing hunger; (4) improving agricultural research and technology dissemination and adoption; and (5) improving responses to disaster and emergencies. NEPAD also seeks to ensure the establishment of regional food reserve systems, linked to Africa's own production, and the development of policies and strategies under the African Union and regional economic communities to fight hunger and poverty in Africa. African Union member states pledged to allocate at least 10 percent of national budgetary resources for the implementation of these goals within five years.

With new political initiatives such as NEPAD paving the way, efforts to strengthen the political commitment to achieving Africa's food and nutrition security are gaining momentum. Specifically, the all-Africa conference, "Assuring Food and Nutrition Security in Africa by 2020, facilitated by IFPRI and held in Kampala, Uganda, April 1–3, 2004, sought to provide a forum to build strategies for ending food and nutrition insecurity in Africa. By bringing together key traditional and new actors and stakeholders from across the continent, the 2020 Africa Conference offered a unique opportunity to focus on prioritizing actions, strengthening actors, and facilitating partnerships. In addressing implementation constraints, the 2020 Africa Conference noted that no food or nutrition security strategy, whether at a continental, regional, country, or local level, is viable if it does not include a well-developed and well-articulated implementation framework. The conference also made clear that a collective effort to ensure political will and commitment at all levels is critical to undertake the necessary actions to end hunger and malnutrition in Africa. More information can be found at: <http://www.ifpri.org/2020africaconference/index.htm>.

4. Policy Failure Scenario

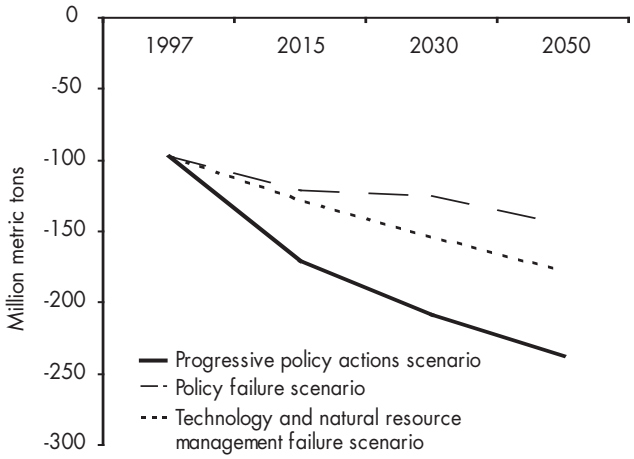
The policy failure scenario assumes greater political discord and more extensive agricultural protectionism, together with the failure of policies to deal with food emergencies related to conflict. In this scenario, developing countries' net cereal trade is substantially less than in the other two scenarios (Figure 14), because of unfavorable terms of trade and low income growth in developing countries. World prices for some commodities decline because producer subsidies increase, while at the same time domestic food prices increase because of the consumer taxation effect of trade restrictions. Slow growth and trade restrictions lead to stagnation in average per capita calorie availability, which remains only slightly above minimum requirements until after 2030, when availability increases (Figure 8).

In addition, crucial investments in agriculture, rural development, and poverty reduction are forgone or displaced. Because of limited investment in agriculture research and technology, this scenario has a high level of crop area expansion owing to relatively rapid population growth and slim yield improvements in developing countries (Figures 4 and 15). Irrigated area as a proportion of total cereal area declines (Figure 16). This scenario also results in relatively flat maize prices, declining per capita cereal demand, and falling beef prices after 2020 and in flat meat demand (Figures 6, 17, 18, and 19).

As a result of the policies in this scenario, the number of malnourished children in developing countries rises between 1997 and 2015, after which there are only modest declines (Figure 9). Furthermore, the impact of the policy failure scenario would severely worsen the already desperate situation of people affected by conflict and HIV/AIDS.

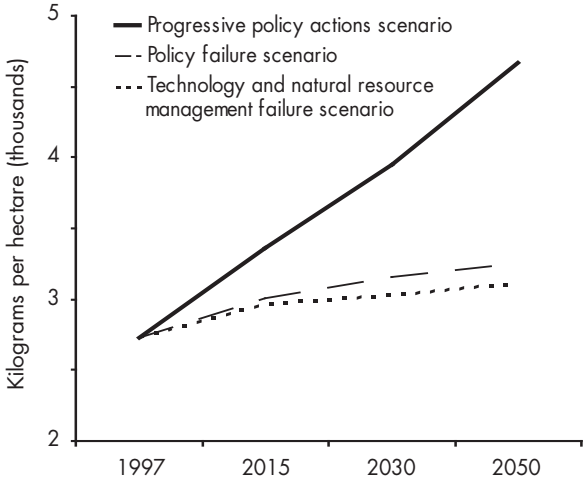
The deleterious results of this scenario on food production and availability severely worsen the plight of already vulnerable households, driving them deep-

Figure 14—Projected net cereal trade in developing countries, all scenarios



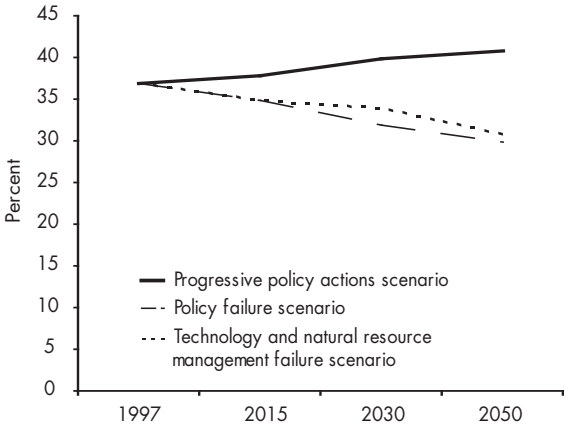
Source: IFPRI IMPACT projections 2004.

Figure 15—Projected world cereal yields, all scenarios



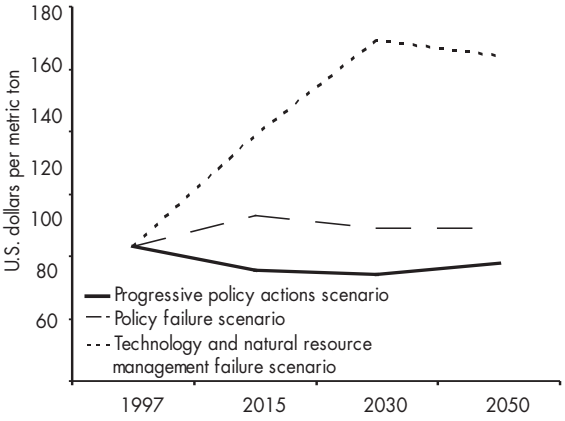
Source: IFPRI IMPACT projections 2004.

Figure 16—Projected irrigated cereal area as a share of total cereal area in developing countries, all scenarios



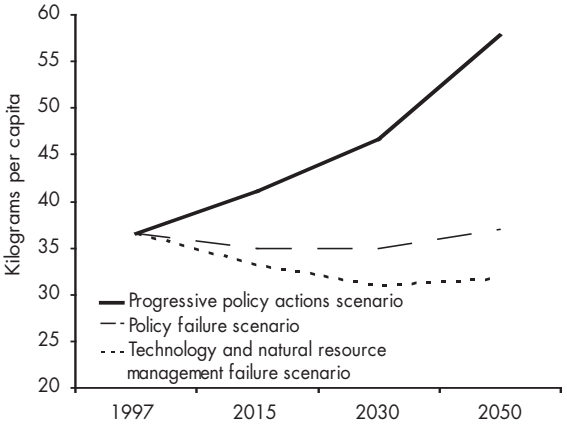
Source: IFPRI IMPACT projections 2004.

Figure 17—Projected world maize price, all scenarios



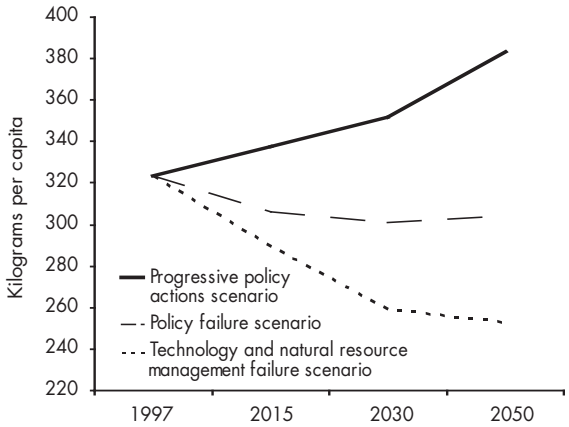
Source: IFPRI IMPACT projections 2004.

Figure 18—Projected world meat demand per capita, all scenarios



Source: IFPRI IMPACT projections 2004.

Figure 19—Projected world cereal demand per capita, all scenarios



Source: IFPRI IMPACT projections 2004.

er into poverty and exerting an irrevocable impact on people's health and nutritional status, especially children. See the appendix for more details on the assumptions and projections made under this scenario.

Stalled Agricultural Trade Agreements and Market Reforms

IFPRI research has demonstrated that farm subsidies in the Organization for Economic Cooperation and Development (OECD) countries have displaced approximately US$40 billion in net agricultural exports per year from developing countries and reduced agri-

cultural incomes in those countries by nearly US$30 billion (Diaz-Bonilla and Gulati 2003). The governments of the OECD member countries spend about US$75 billion annually on subsidies to their own farmers and agricultural industries and force their consumers to pay about US$240 billion a year extra for food because of their own protectionist measures (Diaz-Bonilla and Gulati 2003). These combined payments depress global farm prices and bear no relation to production costs. In addition, high tariffs on agricultural imports from the developing world—four to five times greater than tariffs on manufactured goods—keep crucial developing-country exports, such as beef, sugar, and cotton, from entering the developed-country markets, thereby stymieing opportunities for growth, poverty reduction, and improvements in food security and nutrition. The negotiation framework that World Trade Organization member countries agreed to at the Doha Round of trade negotiations in July 2004 should facilitate addressing these issues, but the real negotiations and actions are yet to come, and positive outcomes remain highly uncertain. Failure to reduce OECD agricultural protection could lead to retaliatory protectionism in developing countries.

For their part, developing countries themselves must work to reduce their own biases against the agricultural sector along with maintaining a trade policy that reduces agricultural protectionism, in order to improve the benefits that the developing world and its poor farmers can reap from trade in farm products. Agricultural protectionism in developing countries translates into higher food prices for domestic consumers and net buyers of food. This added tax on food has a negative impact on poor households, who already spend a large share of their budget on food, and is mainly received by large agricultural producers. Furthermore, many developing countries do not adequately invest in their agricultural and rural sectors, favoring instead the industrial sectors. Targeting key investments to reduce poverty and hunger in the rural sector, such as toward health care, infrastructure development, land tenure, water access, technology, and political participation for poor groups, could do much to facilitate opportunities for poor farmers to compete in broader markets.

Food Emergencies: Conflict and HIV/AIDS

The prospects for peace are encouraging in some long-term conflict zones. Angola's civil war recently ended after nearly three decades, and cease-fire negotiations are under way in Sudan and the Democratic Republic of the Congo. However, conflict in the northern Darfur region of western Sudan contin Furthermore, peace in Liberia seems to exist primarily on paper, and conflict continues to exist in Iraq, Afghanistan, Burundi, and Uganda. Violence has recently broken out in Haiti, severely complicating an already precarious food-security situation. Women and children are especially affected by conflict and its aftermath, as conflict compromises their already disproportionately vulnerable situations. The vast majority of displaced persons are women and children.

The ongoing presence of conflict has long-term ripple effects on food security, destabilizing markets, reducing productivity, and diverting crucial and sparse resources and investments at both the government and household level. Civil and political conflict thus exists in tandem with food insecurity in some parts of the world where food security is low. Conflict causes food insecurity by destroying social welfare, devastating physical and health infrastructure, destabilizing market opportunities and agricultural development, and increasing susceptibility to agricultural shocks, such as bad harvests or risky weather. As conflict depresses production and income from cash crops and livestock, this in turn further depresses food security and reduces resistance to unfavorable harvests or crop losses.

Research by IFPRI and the FAO has estimated the developing world's conflict-induced losses of agricultural output at $121 billion in real terms during 1970–97 (Messer, Cohen, and D'Costa 1998). In Sub-Saharan Africa, the losses in the 1980s and 1990s accounted for more than 50 percent of all aid received, and far exceeded foreign investment inflows (Messer, Cohen, and D'Costa 1998). The food security impact was particularly devastating, because in almost all of the affected countries, the majority of the workforce depended on agricultural livelihoods (Messer, Cohen, and Marchione 2001). Consistent with these findings, the World Bank esti-

mated that civil war lowers per capita gross domestic product by 2.2 percentage points per year (World Bank 2000a). In addition, military spending often comes at the expense of agriculture and rural development spending, health, primary education, and food and nutrition investments. In the late 1990s and early 2000s, low- and middle-income countries devoted nearly 13 percent of government budgets to defense, but only about 5 percent to agriculture and rural development (FAO 2001).

HIV/AIDS and Food Insecurity

The HIV/AIDS epidemic is inextricably linked to issues of food and nutrition: food insecurity may drive people toward livelihood strategies that increase the risk of contracting HIV/AIDS, and HIV/AIDS, combined with food and nutrition insecurity, leads to severe malnutrition and deepened poverty (Gillespie and Haddad 2002). Adequate income generation, which in Sub-Saharan Africa and other developing regions is still mostly linked to agriculture, and access to sufficient and healthy food and nutrition are thus essential components in fighting HIV/AIDS and helping HIV/AIDS victims to live healthier, longer, and more productive lives.

The pandemic of HIV/AIDS has had a severe impact on food security by killing breadwinners, increasing dependency ratios, orphaning millions of children, dramatically increasing HIV/AIDS-related expenses, rapidly depleting assets, and diverting crucial resources from sustainable investments in household food security. In households affected by HIV/AIDS, food consumption has been shown to drop by 40 percent (Diaz-Bonilla and Gulati 2003). In addition, HIV/AIDS reduces the ability of nations to prevent and mitigate food emergencies, by taking the lives of crucial professionals in social services and government (Piot and Pinstrup-Andersen 2002). Moreover, the pandemic is reinforced by and worsens other crises, as shown by the southern African food crisis of 2001–02, where climatic stresses were exacerbated by conflicts, poverty, resource degradation—and HIV/AIDS.

Studies have also shown a link between AIDS and decreased agricultural production. Households are affected in many ways when household members are infected by AIDS, including income loss, loss of assets that must be sold to cover the costs of illness, and the loss of skills as the household members with knowledge of farming and wild products succumb to the disease (de Waal and Whiteside 2003). A decline in available household labor due to AIDS mortality and morbidity has a significant impact on household agricultural productivity. One study from Zimbabwe showed a reduction of 61 percent in marketed maize due to AIDS-related deaths, compared with a 45 percent reduction due to adult household member deaths from other causes (Kwaramba 1998).

HIV infection, compounded by inadequate dietary intake, leads to or worsens malnutrition. Malnutrition in turn shortens the asymptomatic period of HIV infection, hastens the onset of AIDS, and ultimately death, and may also increase the risk of HIV transmission from mothers to babies. Child care in households affected by HIV/AIDS is often compromised, and when the productive capacity of the household diminishes, more nutritionally vulnerable babies and young children suffer most (Jayne et al. 2004).

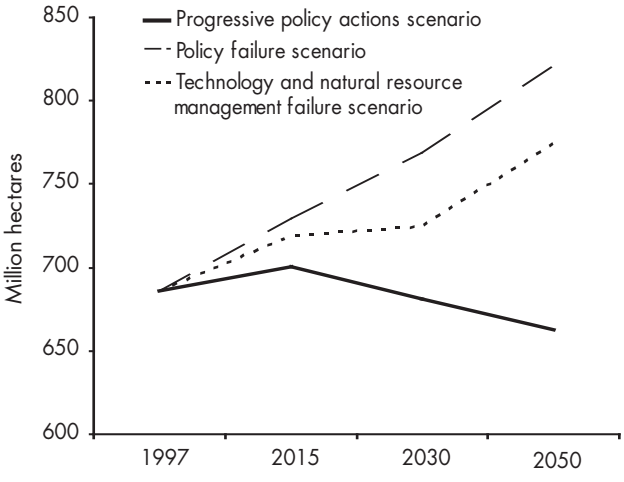
Creating availability of and access to food and proper nutrition for those at risk of infection or already infected are therefore critical policy actions needed to both reduce the prevalence and slow the onset of the disease. Agricultural policy in Sub-Saharan Africa must be designed to meet the challenges posed by the HIV/AIDS pandemic, in synergy with other policies, in particular, labor, health, education, and nutrition policies. By enhancing agricultural productivity and food and nutrition security, agricultural policy can make an enormous impact on slowing and mitigating the spread of HIV/AIDS in the region. Agricultural technologies, for example, need to help poor households adapt to labor constraints imposed by HIV/AIDS while raising productivity levels (Gillespie and Haddad 2002), and diversified production and enriched foods can improve the nutrition of affected households. Making agriculture work for those at risk and affected by HIV/AIDS will be crucial for halting and reversing the downward spiral of increasing hunger and malnutrition in the region.

5. Technology and Natural Resource Management Failure Scenario

In the technology and natural resource management failure scenario, agricultural trade protectionism does not increase as in the preceding scenario, but technology and natural resource failures are severe. In this scenario, yield growth falls even more than in the preceding scenario, forcing farmers to move into marginal producing areas, causing a more rapid expansion of cereal area into less productive land that does not compensate for the yield shortfalls (and causes environmental degradation) (Figures 16 and 20). As a result, maize prices rise substantially through 2030 and fall off only gradually thereafter (Figure 17). Beef and other meat prices, which are affected by the price of feed, follow a similar pattern (Figure 6). These price trends together with slower income growth due to poor growth in agriculture result in a decline in global per capita meat demand through 2030, followed by a slight increase as population growth declines, and a decline in global per capita cereal demand throughout the period to 2050 (Figures 18 and 19).

Developing-country per capita calorie availability is essentially unchanged over 1997–2050 and remains at an average level of bare adequacy (Figure 8). Given unequal access to the food that is available, millions of people actually consume less than the minimum. Child undernourishment is even greater than in the policy failure scenario in all developing-country regions (Figures 9-13). Overall, the technology and resource management failure scenario results in the worst impact on food security and child nourishment in the developing world. Below, we briefly explore why natural resource management and technology adoption in agriculture are so critical to the world's most food-insecure people. See the appendix for more details on the assumptions and projections made under this scenario.

Figure 20—Projected world cereal area, all scenarios



Source: IFPRI IMPACT projections 2004.

Natural Resource Use and Institutions

Unsustainable management of the natural resource base upon which agriculture depends impinges considerably on food security. In many developing countries, poverty, weak agricultural productivity, and environmental degradation interact in a vicious downward spiral. This is especially true in resource-poor areas with fragile soils, irregular rainfall, relatively high population concentrations and growth rates, and stagnant productivity in agriculture. Such areas are home to hundreds of millions of food-insecure people. Nearly two-thirds of the rural population of developing countries (1.8 billion people) live in such areas, including marginal agricultural areas, forests and woodlands, and arid zones. Poor agricultural productivity and land degradation are severe, cereal yields are exceedingly low, and

deforestation, overgrazing, soil erosion, and soil nutrient depletion are widespread.

A great deal of environmental degradation, particularly soil degradation and deforestation, is concentrated in resource-poor areas that have not adopted modern technology and where yield growth has failed to keep up with population growth. Poor rural people often cannot privately afford to invest in land improvements. As part of this vicious cycle, degradation and lack of access to high-quality land frequently push poor people into clearing forests and pastures for cultivation at the expense of wildlife habitat and rangeland, contributing to further degradation, productivity losses, and reduced biodiversity.

These negative trends in less-favored areas must be countered through a range of initiatives. The rate of investment in crop breeding targeted to rainfed environments is crucial to future crop yield growth. Strong progress has been made in breeding for enhanced crop yields in rainfed areas, even in the more marginal rainfed environments, but adoption rates can be enhanced with improved policies. Crop research targeted to less-favored areas should be accompanied by increased investment in rural infrastructure and policies to close the gap between potential yields in less-favored areas and the actual yields achieved by farmers. Higher priority should be given to farmers in less-favored areas for agricultural extension services and access to markets, credit, and input supplies. Successful development of these areas is more complex than in high-potential irrigated areas because of their relative lack of access to infrastructure and markets, and their more difficult and variable agroclimatic environments. Progress may also be slower than in the early green revolution because new approaches will need to be developed for specific environments and tried on a small scale before being disseminated more widely. Investment in rainfed areas, policy reform, and transfer of technology such as water harvesting will therefore require stronger partnerships between agricultural researchers and other agents of change, including local organizations, farmers, community leaders, nongovernmental organizations, national policymakers, and donors (Rosegrant et al. 2002).

Furthermore, unless properly managed, fresh water may emerge as one of the key constraints to global food production. Developing countries are projected to increase water withdrawals by 27 percent between 1995 and 2025, with the share of domestic and industrial uses in total water demand doubling at the expense of agriculture (Rosegrant, Cai, and Cline 2002). These increases, coupled with the growing need for irrigation water to meet food production requirements and the needs for potable and domestic use of water, could lead to a severe shortage of available water and, by reducing the amount of water available for agriculture and to poor farmers, a severe food crisis. As seen in the technology and natural resource management failure scenario, if current water policies worsen, agricultural production will drop as average cereal yield growth will decline from 1.9 percent per year between 1982 to 1995 to 0.30 percent between 1997 and 2050, as farmers will be unable to increase crop yields with relatively declining water supply.

A major factor in improving the use and management of natural resources for greater food security and poverty reduction involves strengthening the local institutions that govern resource use. Both systems of property rights and collective action create local incentives for investment in sustainable resource management strategies and improve food security, and both affect the application of agricultural technologies and natural resource management practices. Property rights and collective action also contribute to risk sharing, access to information, and improved technology use and management. Although property rights and collective action can work in mutually reinforcing ways, different types of agricultural technology application and natural resource management strategies may require greater emphasis on either property rights or collective action. For some types of technologies that require long time horizons between adoption and payoff, property rights are critical. For instance, farmers who do not have secure property rights are often not allowed to plant trees or lack incentives to do terracing. Furthermore, when the spatial scale of new technologies is increased—for instance, when a new technology is not effective

unless adopted by large groups of farms in an area, such as integrated pest management strategies—collective action is needed to make this investment work. Recognizing the rights of women to natural resources is also important for food security: IFPRI research suggests that where women have independent rights to land or are recognized as co-owners of land with their husbands, they also have more bargaining power within the household; this has been shown to increase the proportion of household income spent on food, education, and the welfare of children (Quisumbing et al. 1995).

Technology Adoption for Risk Reduction

New technological advances in the agricultural sciences also offer the potential to offset natural resource degradation, increase crop yield, and provide greater food security for the world's poor. Crop technology, soil fertility management, irrigation, and information technology collectively offer many benefits to improve agricultural productivity. Yet, hampered by low public spending in agricultural research and development, agrotechnology is slow to spread to the world's poorest farmers and most food-insecure populations.

Increased agricultural research and technology dissemination can help alleviate food security in a number of ways, such as by helping poor farmers increase their own farms' production, thus providing more food and nutrients for their own consumption and increasing output of marketed products to generate income. Agricultural technology adoption also leads to greater agricultural employment and higher wages, economic growth in the nonfarm rural and urban economies, lower per unit costs of food production and lower food prices (enabling greater physical and economic access to crops that are high in nutrients), increased access by the rural poor to decision-making processes, enhanced capacity for collective action, and reduced vulnerability to economic shocks (Hazell and Haddad 2001).

Institutions that proactively address risk inherent in technology adoption can also help poor farmers; for instance, without social safety net programs to assist farmers, they may be unwilling to invest in a technology to increase agricultural productivity if risky agroclimatic conditions make it probable that input investments will be lost in an unfavorable year. Government policies can also help improve agrotechnology adoption by poor farmers through the dissemination of technology packages that both large and small farms can adopt and by establishing efficient input, credit, and product markets so that small farmers can have access to modern inputs and information.

In the past two decades, information and communications technologies (ICTs) have greatly changed food and agriculture systems. Access to information and the ability to use it efficiently are critical for allocating resources, whether labor, capital, or natural resources, under market or nonmarket conditions, and for access to public goods. ICTs contribute to lowering the costs of market use for farm households and small rural enterprises; reducing costs and improving quality of public goods provision (such as research–extension linkages in agriculture, and education and health services); more effective use of existing social networks or their expansion; and creating new institutional arrangements and consequent strengthening of people's rights.

New technology that makes use of geographically referenced data, such as geographic information system (GIS) technology, can provide new insights into natural resource degradation, climate change, agricultural performance, and a variety of other global issues such as poverty, disease, and conflict. GIS maps may help governments do a better job of targeting and prioritizing investments in rural roads, electricity, health, and education. Participatory mapping, whereby local communities are involved in identifying key natural resource issues, constraints, and management arrangements, may help to build consensus on land uses and rights, helping to create local institutional structures for improved food security.

Public agricultural research expenditure is critical to providing technological solutions to the world's poor farmers. Scientific research generally requires uneven investments that the private sector is not always willing to shoulder, especially if the

incentives are unclear or unknown. But public agricultural research in developing countries is on the decline; excluding Nigeria and South Africa, total public agricultural research-and-development spending in Sub-Saharan Africa declined by 0.2 percent per year in the 1990s (Beintema and Stads 2004). Developed countries spend about 47 percent of the US$22 billion spent globally on public agricultural research, and they spend vastly more per farm and per unit of output than do developing countries, where spending is dominated by a few large countries including Brazil, China, and India (Diaz-Bonilla and Gulati 2003). For agricultural technology to successfully reach the world's most food-insecure populations, the public sector in developing countries must increase its budgetary allocation to agricultural research and development; in addition, the changing nature of global agricultural research investment requires that the public sector develop new partnerships among government, the private sector, nongovernmental organizations, and farmers.

6. Conclusion

Current efforts to reduce hunger are not satisfactory. Emergencies such as conflicts and the HIV/AIDS pandemic increasingly threaten and undermine food security; stalled agricultural trade negotiations pose a new set of risks and opportunities for vulnerable small farmers and for food security in developing countries; and natural resource degradation coupled with inadequate technology continue to pose major obstacles to improving the situation of the world's hungry. Although positive signs do exist on the policy front, new and old risks to food security are not being sufficiently addressed by proactive and progressive government policies and investments. As demonstrated, forgoing progressive policies and failing to mitigate potential failure scenarios will result in at best slowly declining—or in the case of Sub-Saharan Africa, increasing—numbers of hungry people. State failure and conflicts are root causes of food insecurity in many regions of the developing world, and insufficient investment in rebuilding societies after crises renders them vulnerable and fertile ground for violence.

Enhanced agricultural productivity for long-term food security remains relevant for billions of people because of the strong connections to job creation, income generation, price levels, and nutritional well-being. Implementing the policy changes outlined here will be expensive and will require difficult political choices. As the technology and natural resource management failure scenario underscores, governments must renew their commitment to agricultural technology improvement and natural resource sustainability through augmented investment in agricultural research and development that targets the needs of vulnerable, impoverished households. But the task is far from impossible, and the costs are far less than the benefits to humankind.

The progressive policy actions scenario outlines several of the most crucial steps. National governments and the international community must assume a new focus on agricultural growth and rural development, along with increasing their investments in education, social services, and health. Policies to encourage synergistic growth in the nonfarm sectors are also needed to spur broad-based economic growth. Underpinning these strategies and research agendas must be a firm commitment to reducing hunger and improving the welfare of the world's undernourished people. But investment and growth-oriented policy actions alone will not be sufficient to reach the Millennium Development Goal to cut hunger by half by 2015 and to end hunger soon thereafter. Only if these actions include sustained social safety nets will food and nutrition security be achieved in the foreseeable future.

Appendix

Technical Description of Scenarios

In this analysis we use the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) to project three future global food scenarios. IMPACT is a representation of a competitive world agricultural market for 32 crop and livestock commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes and meals, sugar and sweeteners, fruits and vegetables, and fish. It is specified as a set of 43 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. The model is written in the General Algebraic Modeling System (GAMS) programming language. The solution of the system of equations is achieved by using the Gauss-Seidel method algorithm. This procedure minimizes the sum of net trade at the international level and seeks a world market price for a commodity that satisfies market-clearing conditions. Additional technical details about IMPACT methodology can be found in Rosegrant, Meijer, and Cline (2002).

IMPACT generates annual projections for crop area, yield, production, demand for food, feed and other uses, prices, and trade, as well as livestock numbers, yield, production, demand, prices, and trade. The current base year is 1997 (using a three-year average of 1996–98) and the model incorporates commodity data from FAOSTAT (FAO 2000); income data from the World Bank (World Bank 1998, 2000b) and the United Nations (United Nations 1998); a system of supply and demand elasticities from literature reviews and expert estimates; rates for malnutrition from ACC/SCN (1996); WHO (1997); and calorie-malnutrition relationships developed by Smith and Haddad (2000). While the original version of the model made projections to the year 2020, the more recent version of the model used in this paper projects to 2050. Additional details can be found in Rosegrant, Meijer, and Cline (2002).

To explore food-security effects, IMPACT projects the percentage and number of malnourished preschool children (under five years old) in developing countries. A malnourished child is defined as a child whose weight-for-age is more than two standard deviations below the weight-for-age standard set by the U.S. National Center for Health Statistics/World Health Organization. The projected number of malnourished children is derived from a regression model of the functional relationship between the percentage of malnourished children and several factors: average per capita calorie consumption and nonfood determinants of child malnutrition such as the quality of maternal and child care (proxied for by the percentage of females undertaking secondary schooling as well as by females' status relative to men as captured by the ratio of female-to-male life expectancy at birth) and health

and sanitation (proxied for by the percentage of the population with access to treated surface water or untreated but uncontaminated water from another source). For more details on the regression model, see Smith and Haddad (2000).

This analysis presents results from three alternative scenarios, including a progressive policy actions scenario, a technology and natural resource management failure scenario, and a policy failure scenario. Details on the nonfood parameters used in the malnourished children projections and the population projections are presented in the following paragraphs, followed by a description of each scenario and parameter changes for each of those scenarios.

Average per capita consumption per day is determined for the three scenarios presented here from IMPACT runs to 2050 incorporating quantified parameters for the three scenarios, including assumptions on area and yield growth, population and income growth, food preferences, investment levels, and assumptions regarding openness to trade. The nonfood determinants of child malnutrition are assumed to improve slowly throughout the period, with generally greater improvements in the parameters from 2025 to 2050, based on investments in social services, including health and education. The indicators used for the quality of maternal and child care include the percentage of females undertaking secondary schooling and the ratio of female-to-male life expectancy at birth. The indicator for health and sanitation is measured by the percentage of the population with access to treated surface water or untreated but uncontaminated water from another source. These parameters are the same for the technology and natural resource management failure scenario and the policy failure scenario. These two scenarios experience slower improvements in these parameters than the progressive policy actions scenario (see Tables A1 and A2 for a detailed listing of nonfood parameters by region).

Population projections for these scenarios were taken from projections carried out for the Millennium Ecosystem Assessment (MA) scenarios, which are based on the International Institute for Applied Systems Analysis (IIASA) 2001 probabilistic projections for the world (Lutz et al. 2001). The projections were derived based on qualitative judgments about the magnitude of fertility, mortality, and migration in 13 world regions. Qualitative assumptions were then converted into quantitative assumptions based on conditional probabilistic projections. Using this approach, the high/medium/low categories were mapped to three evenly divided quartiles of the unconditional probability distributions, as defined in the IIASA projections, for each component of population change.

Single, deterministic scenarios for fertility, mortality, and migration in each of 13 regions were derived for each story line, defined as the medians of the conditional distributions for these variables. Population projections for each scenario were then produced based on the deterministic scenarios for each component of population change. Regional population projections were then downscaled to the country level.

Table A3 lists the qualitative assumptions about fertility, mortality, and migration for each scenario. These assumptions are expressed qualitatively as high/medium/low and in relative rather than absolute terms. That is, a high fertility assumption for a given region means that fertility is assumed to be high relative to the median of the probability distribution for future fertility in the IIASA projections. The same population projections were used for the two failure scenarios (policy failure and technology and natural resource management failure), while a lower rate of population growth was assumed for the progressive policy actions scenario. Table A4 lists the total population for several regions as well as the world total under each scenario.

Progressive Policy Actions Scenario

In the progressive policy actions scenario, we assume a new focus on agricultural growth and rural development. Cereal yield growth is the highest under this scenario, with an annual growth rate of around 1.7 percent for Sub-Saharan Africa, 1.4 percent for Latin America and South Asia, and 0.9 percent for China between 1997 and 2050 (Table

Table A1—Nonfood determinants of childhood malnutrition, progressive policy actions scenario

	Female-to-male life expectancy ratio				Share of female secondary education participation				Percent access to clean water			
Region/country	1997	2015	2030	2050	1997	2015	2030	2050	1997	2015	2030	2050
Nigeria	1.05	1.07	1.10	1.11	29.4	36.7	47.1	72.0	50.0	64.9	75.6	86.1
Northern Sub-Saharan Africa	1.07	1.07	1.07	1.08	9.0	11.4	21.2	55.0	37.9	51.3	62.6	77.2
Central and western Sub-Saharan Africa	1.06	1.06	1.07	1.07	18.9	21.1	25.2	37.0	54.5	66.6	74.8	77.8
Southern Sub-Saharan Africa	1.04	1.04	1.05	1.06	23.5	30.9	37.2	47.0	51.2	66.7	75.6	78.2
Eastern Sub-Saharan Africa	1.04	1.05	1.07	1.08	12.0	15.7	24.0	50.0	47.2	61.9	71.8	79.2
India	1.02	1.05	1.07	1.08	38.0	50.8	57.8	60.1	81.0	89.6	95.2	96.0
Pakistan	1.03	1.04	1.04	1.06	20.8	28.7	36.8	54.6	60.0	72.5	81.2	94.0
Bangladesh	1.03	1.05	1.09	1.13	13.4	21.1	31.9	56.1	79.0	82.9	88.6	99.0
Other South Asia	1.02	1.04	1.04	1.05	49.6	59.9	66.1	70.7	60.3	71.0	77.2	82.0
Indonesia	1.06	1.06	1.08	1.12	46.0	56.6	65.0	70.0	60.0	73.3	80.8	88.0
Thailand	1.08	1.08	1.08	1.09	54.1	63.4	70.6	76.0	89.0	94.3	96.9	96.9
Malaysia	1.06	1.07	1.07	1.08	64.8	75.6	80.5	81.2	77.0	87.2	92.2	93.2
Philippines	1.06	1.07	1.07	1.09	80.2	88.9	93.4	94.0	84.0	90.3	94.8	98.0
Vietnam	1.07	1.08	1.08	1.09	39.7	51.4	61.1	78.4	43.0	62.4	76.2	94.0
Myanmar	1.06	1.07	1.09	1.10	32.9	40.9	50.0	72.2	60.0	69.4	78.4	96.0
Other Southeast Asia	1.06	1.07	1.09	1.11	45.4	48.3	53.4	67.2	59.6	67.7	72.8	75.9
China	1.05	1.05	1.06	1.07	63.5	70.6	74.6	75.3	67.0	75.6	80.9	84.3
Latin America	1.10	1.10	1.10	1.11	56.6	59.7	64.2	72.0	77.5	80.2	84.0	86.1
West Asia/North Africa	1.04	1.05	1.05	1.05	58.5	67.7	72.8	74.5	81.9	88.2	92.4	94.0

Source: IFPRI IMPACT 2004.

A5). Livestock numbers growth also increases substantially under this scenario, with annual growth rates of approximately 2.5 percent in South Asia and China, 1.9 percent in Latin America, and 1.4 percent in Sub-Saharan Africa. Trade protection does not increase significantly, with producer subsidy equivalents (PSEs) dropping to half the current levels in 2010, and by half of this level in 2020. The total cereal area under this scenario expands slightly at the global level but decreases in certain regions. Growth in irrigated area is greater under this scenario than under either of the other two scenarios. Of the three scenarios presented here, the progressive policy actions scenario has greater improvements over time for the nonfood malnutrition variables described above than either the policy failure or the technology and natural resource management failure scenarios. The female-to-male

Table A2—Nonfood determinants of childhood malnutrition, policy failure scenario and technology and natural resource management failure scenario

	Female-to-male life expectancy ratio				Share of female secondary education participation				Percent access to clean water			
	1997	2015	2030	2050	1997	2015	2030	2050	1997	2015	2030	2050
Nigeria	1.05	1.06	1.07	1.09	29.4	36.7	42.7	50.1	50.0	64.9	73.8	76.8
Northern Sub-Saharan Africa	1.07	1.07	1.07	1.07	9.0	11.4	15.2	25.3	37.9	51.3	60.1	64.5
Central and western Sub-Saharan Africa	1.06	1.06	1.06	1.07	18.9	21.1	24.7	34.4	54.5	66.6	74.8	77.8
Southern Sub-Saharan Africa	1.04	1.04	1.04	1.04	23.5	30.9	36.6	44.1	51.2	66.7	75.4	76.8
Eastern Sub-Saharan Africa	1.04	1.04	1.05	1.05	12.0	15.7	18.9	24.6	47.2	61.9	70.2	71.0
India	1.02	1.05	1.07	1.07	38.0	50.8	57.2	57.3	81.0	89.6	95.2	96.0
Pakistan	1.03	1.04	1.04	1.04	20.8	28.7	36.1	50.9	60.0	72.5	79.1	83.5
Bangladesh	1.03	1.06	1.08	1.11	13.4	21.1	28.6	40.0	79.0	82.9	86.6	89.0
Other South Asia	1.02	1.03	1.04	1.04	49.6	59.9	65.1	65.3	60.3	71.0	76.4	77.9
Indonesia	1.06	1.06	1.06	1.10	46.0	56.6	63.8	63.9	60.0	73.3	79.4	81.0
Thailand	1.08	1.08	1.08	1.08	54.1	63.4	69.4	69.5	89.0	94.3	96.9	97.0
Malaysia	1.06	1.07	1.07	1.07	64.8	75.6	80.4	80.6	77.0	87.2	92.0	92.0
Philipp ines	1.06	1.07	1.07	1.07	80.2	88.9	93.3	93.3	84.0	90.3	94.3	95.5
Vietnam	1.07	1.08	1.08	1.08	39.7	51.4	58.9	67.1	43.0	62.4	73.5	80.4
Myanmar	1.06	1.06	1.07	1.08	32.9	40.9	49.0	67.4	60.0	69.4	75.7	82.5
Other Southeast Asia	1.06	1.06	1.07	1.10	45.4	48.3	50.1	50.9	59.6	67.7	73.7	80.3
China	1.05	1.05	1.06	1.06	63.5	70.6	74.5	74.6	67.0	75.6	80.6	83.0
Latin America	1.10	1.10	1.10	1.10	56.6	59.7	63.4	68.0	77.5	80.2	83.7	84.7
West Asia/North Africa	1.04	1.05	1.05	1.05	58.5	67.7	72.6	73.5	81.9	88.2	92.1	92.5

Source: IFPRI IMPACT 2004.

life expectancy ratio, the percentage of females with access to secondary schooling, and the percentage of population with access to an improved water supply are all higher by 2050 than in the other two scenarios (Table A1).

Policy Failure Scenario

A multidimensional policy failure scenario assumes decreases in cereal yield growth and livestock numbers growth. Model output data show annual cereal yield growth rates (from 1997 to 2050) of 1.06 for Sub-Saharan Africa, 0.69 for Latin America, 0.52 for South Asia, and 0.32 for China. Livestock numbers growth is also lower at 1.28 percent for China, 0.33 percent for Sub-Saharan Africa, 0.27

percent for South Asia, and 0.09 percent for Latin America (Table A5). This scenario also shows trade policies that lead to an increase in protection in many countries (demonstrated by a tripling of PSEs in 2020). This scenario has a greater level of crop area expansion than the progressive policy actions scenario because of high population growth and low yield improvements.

Irrigated area under this scenario remains relatively the same throughout the projection period. The nonfood determinants of the number of malnourished children also improve over time under this scenario but to a lesser degree than under the progressive policy actions scenario.

Technology and Natural Resource Management Failure Scenario

The technology and natural resource management failure scenario assumes even greater decreases in yield and numbers growth as well as declines in crop area growth but without the increased trade protection shown in the policy failure scenario. Annual crop yield growth is 0.85 percent for Sub-Saharan Africa, 0.54 percent for Latin America, 0.44 percent for South Asia, and 0.28 percent for China. Livestock numbers growth per year is also lower than under the other scenarios at 1.04 percent in China, 0.22 percent in South Asia, 0.20 percent in Sub-Saharan Africa, and 0.08 percent in Latin America (Table A5). Many of the remaining underlying factors in the technology and natural resource management failure scenario are similar to those under the policy failure scenario. The degree of crop area expansion is greater under this scenario than under the progressive policy actions scenario, while the irrigated area remains relatively the same throughout the projection period. Low investments under this scenario lead to low crop yield improvements in developed and developing countries. The female-to-male life expectancy ratio, the percentage of females with access to secondary schooling, and the percentage of population with access to an improved water supply also improve over time under this scenario, but at a lower rate than under the progressive policy actions scenario (Table A2).

Table A3—Fertility, mortality, and migration assumptions for population projections

Variable	Progressive policy actions scenario	Policy failure scenario	Technology and natural resource management failure scenario
Fertility	HF: Low	HF: High	HF: High
	LF: Low	LF: High	LF: High
	VLF: Medium	VLF: Low	VLF: Low
Mortality	D: Low	D: High	D: High
	I: Low	I: High	I: High
Migration	High	Low	Low

Source: Lutz et al. 2001.
Notes: I indicates industrialized-country regions; D, developing-country regions; HF, high-fertility regions (total fertility rate > 2.1 in year 2000); LF, low-fertility regions (1.5 < total fertility rate < 2.1); and VLF, very low fertility regions (total fertility rate < 1.5).

Table A4—Population by scenario (millions of people)

	Actual	Progressive policy actions scenario		Policy failure scenario		Technology and natural resource management failure scenario	
Region	**1997**	**2020**	**2050**	**2020**	**2050**	**2020**	**2050**
Latin America	486	637	742	710	944	710	944
Sub-Saharan Africa	602	858	1,109	956	1,570	956	1,570
South Asia	1,289	1,746	1,986	1,953	2,561	1,953	2,561
China	1,249	1,390	1,311	1,464	1,469	1,464	1,469
Developing countries	4,491	5,850	6,595	6,414	8,290	6,414	8,290
World	5,786	7,260	8,095	7,777	9,567	7,777	9,567

Source: Lutz et al. 2001.

Table A5—Parameter changes by scenario

Scenario	Cereal output yield growth rates[a]	Livestock output numbers growth rates[a]	Trade parameters	Improvement in nonfood malnutrition variables[b]	Population growth[c]
Progressive policy actions scenario	Latin America: 1.43 Sub-Saharan Africa: 1.72 South Asia: 1.40 China: 0.99	Latin America: 1.93 Sub-Saharan Africa: 1.43 South Asia: 2.56 China: 2.49	PSEs (producer subsidy equivalents) decline by half by 2010 then, to half of the 2010 value by 2020	Highest improvements	Slower population growth
Policy failure scenario	Latin America: 0.69 Sub-Saharan Africa: 1.06 South Asia: 0.52 China: 0.32	Latin America: 0.09 Sub-Saharan Africa: 0.33 South Asia: 0.27 China: 1.28	PSEs raised by a value of 1.0	Lower improvements	Faster population growth
Technology and natural resource management failure scenario	Latin America: 0.54 Sub-Saharan Africa: 0.85 South Asia: 0.44 China: 0.28	Latin America: 0.08 Sub-Saharan Africa: 0.20 South Asia: 0.22 China: 1.04	PSEs remain at 1997 values	Lower improvements	Faster population growth

Source: IFPRI IMPACT 2004.
[a] Cereal yield and livestock numbers growth are calculated using output values, not input growth values.
[b] See Tables A1 and A2 for greater detail.
[c] See Tables A3 and A4 for greater detail.

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