6. Land Degradation and Food Security

This report defines food security in terms of secure and sustainable access to sufficient food for active and healthy lives, whether access derives from production or exchange. Most studies of the effects of land degradation focus on selected measures of productivity, but land degradation may also affect food security, through its impacts on food production as well as on incomes and food prices. Citing studies in Africa, Asia, and Latin America, Scherr (1999b) notes that poor farmers tend to rely disproportionately on annual crops cultivated on marginal lands, often with insecure tenure—characteristics associated with a higher vulnerability to both land degradation and food insecurity. The potential impact of land degradation on food security at a global scale is difficult to quantify, given limited data and complex interlinkages, but preliminary findings are provided by recent efforts using global simulation models of agricultural production and trade.

Baseline estimates from ERS and IFPRI models

Several institutions have developed models of global food production and trade, but these have rarely been used to explore the impacts of land degradation. IFPRI's IMPACT model is a partial-equilibrium simulation model that determines supply, demand, and prices in a competitive market for 16 crop and livestock commodities in 36 countries and regions as functions of specified initial conditions (Rosegrant et al., 2001). Demand is specified as a function of prices, income, and population, while supply depends on prices and technology through their impacts on crop area and yields. Baseline projections indicate that global cereal demand and supply will increase at about 1.3 percent per year through 2020, while prices continue their long-term decline (although at a slower pace than in the past). Food security is indicated in the IMPACT model by the number of malnourished children, which is projected to decline by 21 percent to 132 million by 2020 (but increase 34 percent in Sub-Saharan Africa).[8]

Similarly, the ERS food security assessment (FSA) model is a partial-equilibrium simulation model used to project food availability and access in over 60 developing countries in five regions (North Africa, Sub-Saharan Africa, Asia, Latin America, and the New Independent States of the former Soviet Union) (Shapouri and Rosen, various years). Each country model includes three commodity groups: grains, root crops, and other crops. Production is determined by a system of area and yield response functions, where area is a function of crop yields, prices, and exogenous polices, and yields are a function of inputs (namely labor, fertilizer, capital, and technology). Commercial imports are modeled as a function of domestic prices, world commodity prices, and foreign exchange availability.

Food security is assessed in the ERS model by measuring the size of and trends in several alternative food gaps. The *status quo gap* measures the additional amount of food needed, beyond domestic production and commercial imports, to support 1997-99 levels of per capita consumption for each country. The *nutritional gap* is the gap between available food and food needed to meet the minimum daily caloric intake requirements estimated by FAO (FAO, 2000). (National average requirements vary but fall in the range of 2,000-2,310 kilocalories per person per day when allowing for moderate activity. Note that these requirements are significantly higher than consumption levels needed to meet the weight-for-age threshold that IFPRI's model uses to define child malnutrition, so results from the two models are not directly comparable.) The status quo and nutritional gaps do not account for access to food by individuals and households within a country, however, so ERS also projects food consumption by different income groups based on income distribution data for each country. The *distribution gap* measures the amount of food needed to raise the food consumption of each income quintile to the nutritional standard. Finally, based on the distribution gap and the projected population, ERS projects the number of people who cannot meet their nutritional requirements.

Over the past four decades, growth in agricultural production at a global scale has come predominantly from increases in yields, and this pattern is projected to continue in the future (FAO, 2000). These trends, subject to regional variation, are apparent in historic data and incorporated in baseline projections (table 6.1).

In the baseline analysis (assuming that recent conditions, trends, and policies continue), food gaps of each type are projected to grow during the next decade (table 6.2). The total status quo food gap for the 67 countries (needed to

[8]Malnutrition is indicated in the IMPACT model by weight-for-age at least two standard deviations below the median, using U.S. National Center for Health Statistics/World Health Organization standards (Rosegrant et al., 2001).

Table 6.1—Growth in area, yield, and production, selected developing countries

Region (No. of countries)	Area cultivated	Historic change, 1980-99 Area	Yield	Production	Baseline projection, 2000-10 Area	Yield	Production
	% of potential	*% per year*					
North Africa (4)	76	0.5	3.0	3.5	1.7	0.3	1.9
Sub-Saharan Africa (37)	21	2.2	0.4	2.6	1.2	1.3	2.5
Asia (10)	67	0.1	2.4	2.5	0.1	1.6	1.7
Latin America & Caribbean (11)	18	0.7	0.4	1.1	0.6	1.1	1.7
New Independent States (5)	52	na	na	na	0.7	1.0	1.8
All (67)	32	0.6	1.8	2.4	0.5	1.3	1.8

Notes: Sub-Saharan Africa figures exclude Nigeria. "All" excludes New Independent States for 1980-99. "na" = not available.
Sources: FAO (2000), ERS database.

Table 6.2—Food security in 2000 and 2010 (baseline scenario)

Region	Status quo gap 2000	2010	Nutritional gap 2000	2010	Distribution gap 2000	2010	Hungry people 2000	2010
	Million metric tons						*Millions*	
North Africa	0.4	0.8	1.6	0.9	2.0	1.1	48	31
Sub-Saharan Africa	3.3	8.3	11.0	16.5	15.3	22.5	344	435
Asia	2.6	3.2	2.9	3.5	5.5	5.3	307	177
Latin America & Caribbean	0.3	0.5	0.7	0.9	1.9	1.8	62	47
New Independent States	0.4	0.0	0.8	0.3	0.4	0.4	13	6
Total	7.0	12.7	17.1	22.1	25.0	31.0	774	694

Source: Shapouri and Rosen (2000).

maintain per capita consumption at the 1997-99 base level) is estimated at 7.0 million tons for 2000 and 12.7 million tons in 2010. The total nutritional gap is projected to increase from 17.1 million tons in 2000 to 22.0 million tons in 2010, while the total distributional gap is projected to increase from 25.0 million tons in 2000 to 31.0 million tons in 2010. In each case, the largest share of the gap is accounted for by Sub-Saharan Africa, followed by Asia.

Based on the distribution gaps, ERS estimated the number of people (in each income quintile) whose consumption would fall short of the minimum nutritional requirement in each country. While food gaps are projected to grow in magnitude, the number of people failing to meet the nutritional target is projected to decline by 2010, both in total and for all regions except Sub-Saharan Africa. This means that nutritional disparity among and within countries will intensify more than food deficits will spread. In other words, the hunger problem will get more severe in the most vulnerable countries and/or among the lower income groups in those countries, even while the total number of hungry people declines. For the 67 countries, the number of people failing to meet the nutritional target is projected to decline from 774 million in 2000 to 694 million by 2010. About 44 percent of the projected total for 2000 are in Sub-Saharan Africa, with another 40 percent in Asia; by 2010 the Sub-Saharan African share will rise to 63 percent, while that of Asia will fall to 26 percent.

Alternative scenarios

Over the past four decades, growth in agricultural production at a global scale has come predominantly from increases in yields, and this pattern is projected to continue (FAO, 2000). In many low-income countries, however—particularly in Sub-Saharan Africa—yields have stagnated in recent years and most increases in agricultural output have stemmed from area expansion (table 6.1). While additional land is still available to be brought into food production, in most countries it is marginal land with lower productivity, more uncertain rainfall, and potentially greater vulnerability to degradation, implying lower and more variable crop yields. Moreover, continued conversion of range and forestland to cropland involves increasingly high economic and environmental costs, and area growth cannot be sustained indefinitely. In South Asia, for example, over 80 percent of potentially arable land is already cultivated (FAO, 2000).

These trends imply that for most food-insecure countries, constraints on land area and quality will play an increasingly important role in determining food security in the future. The baseline model projects trends in area and yields, implicitly reflecting actual historic losses due to soil erosion and other forms of land degradation. To explore the possible impacts of land degradation on food security, we compared the baseline results with two alternative scenarios: (1) reduced losses in cropped area, and (2) reduced losses in crop yields.

Reduced area losses to land degradation

Arable land in Asia, Africa, and Latin America has expanded by about 5 million hectares per year over the past four decades and now accounts for about half of the world's total arable land (FAO, 2000). Data on land degradation at a global scale are scarce, but recent estimates suggest that 5-6 million hectares of arable land worldwide are irreversibly lost each year as a result of soil erosion, salinization, and other degradation processes (Scherr, 1999b). If that degradation occurs in rough proportion to total arable area, then roughly half (about 2-3 million hectares per year) could be assumed to occur in developing regions. The gross increase in arable area in developing regions would then be about 7-8 million hectares per year, or 2-3 million hectares per year faster than the net rate apparent in simple historic trends. Our first alternative scenario explores the impacts of these irreversible losses in arable land by considering what might have happened in the absence of such losses. Accordingly, area expansion is assumed to be half again as rapid as the rate used in the baseline model for each country (table 6.3).

Results of the first alternative scenario are presented in table 6.4. (Note that food security impacts are felt through changes in production and commercial imports but not through changes in income.) Reduced area losses have the greatest impact on food gaps in Sub-Saharan Africa, where low levels of commercial imports mean consumption is heavily dependent on domestic production, which in turn has been based over the past two decades primarily on expansion in cultivated area. Status quo, nutritional, and distribution food gaps projected for 2010 in Sub-Saharan Africa decrease to 5.0, 12.0, and 17.8 million tons respectively (down 40, 27, and 21 percent relative to baseline projections). Reduced area losses have smaller impacts on food gaps in Latin America, despite the historic importance of area growth, because of the region's greater reliance on commercial imports. Impacts on food gaps are small in other regions as well, due to the combined effects of lower dependence on area growth as a source of increased domestic production and greater reliance on commercial imports as a source of consumption. For the 67 countries studied, status quo, nutritional, and distribution gaps projected for 2010 decrease by 28 percent, 22 percent, and 16 percent, respectively, relative to the baseline.

Table 6.3—Growth in area, yield, and production, selected developing countries, 2000-10

	Scenario 1 (reduced area losses)			Scenario 2 (reduced yield losses)		
Region	Area	Yield	Production	Area	Yield	Production
	% per year					
North Africa	2.5	0.3	2.8	1.7	0.4	2.2
Sub-Saharan Africa	1.8	1.2	3.0	1.2	1.4	2.6
Asia	0.1	1.6	1.7	0.1	1.7	1.7
Latin America & Caribbean	0.9	1.0	2.0	0.7	1.2	1.9
New Independent States	1.1	0.9	2.0	0.8	1.0	1.7
All	0.8	1.2	2.0	0.5	1.4	1.9

Note: Sub-Saharan Africa figures exclude Nigeria.
Source: ERS analysis.

Table 6.4—Food security in 2010 (Scenario 1: reduced area losses)

Region	Status quo gap	Nutritional gap	Distribution gap	Hungry people
	Million metric tons			*Millions*
North Africa	0.6	0.8	1.0	31
Sub-Saharan Africa	5.0	12.0	17.8	400
Asia	3.2	3.4	5.2	146
Latin America & Caribbean	0.4	0.8	1.6	42
New Independent States	0.0	0.3	0.3	7
Total	9.2	17.2	26.0	626

Source: ERS analysis.

Under the baseline assumptions, the number of people whose consumption falls short of the nutritional target in 2010 was projected to be 694 million for the 67 countries, or 22 percent of their total population. Under the reduced-area-loss scenario, the projected number of people with nutritionally inadequate diets in 2010 falls 10 percent to 626 million, or 20 percent of the projected population of those countries.

Put differently, for the 67 countries as a group, projected food gaps are 38, 28, and 19 percent higher in the baseline than they are in the reduced-area-loss scenario (for status quo, nutritional, and distribution gaps, respectively) as a result of irreversible losses in cropland due to land degradation. As a result, the number of people with inadequate diets is projected to be 11 percent higher in the baseline than in the reduced-area-loss scenario. Most of the difference is accounted for by Sub-Saharan Africa.

Reduced yield losses to land degradation

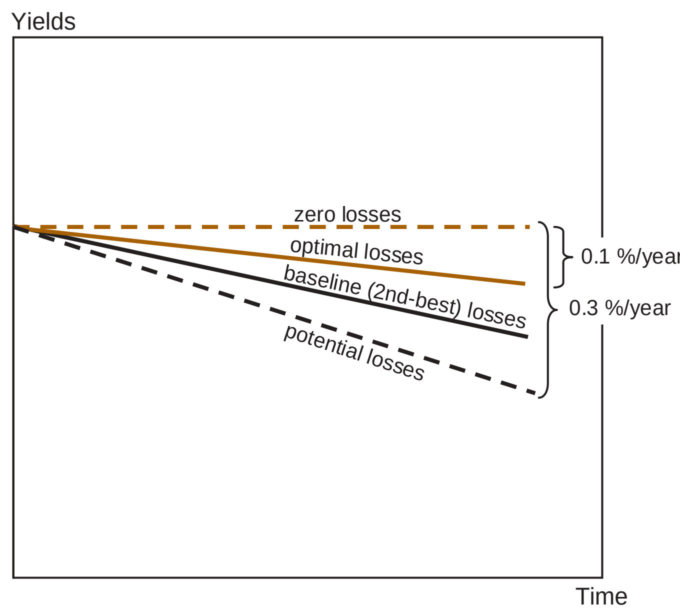
Given the importance of yield growth as a source of production growth in most regions, and the regionally varied impacts of land degradation on productivity, it is of interest to consider how food security might be affected by land degradation over time, even if cropland is not lost irreversibly to degradation. Agronomic studies suggest that soil erosion reduces crop yields by an average of 0.3 percent per year if all other factors are held constant. Economic analysis indicates that actual losses are smaller (although magnitudes remain unclear) because farmers have incentives to adjust their practices to reduce soil erosion.

As noted earlier, the baseline model implicitly reflects historical farming practices and rates of soil erosion and other forms of land degradation in low-income developing countries. If erosion continues at historical rates and other factors are held constant, yields will follow the baseline trajectory (fig. 6.1). Reducing erosion would raise yields relative to the baseline. If erosion rates increase in the future, yields would fall relative to the baseline. We assume that farmers in low-income developing countries have adjusted their practices to reduce soil erosion to a certain extent but not to the full extent that would be optimal under secure tenure and well-functioning markets as studied by Hopkins et al. (2001). Lacking more precise data, we assume that the baseline thus reflects second-best strategies that are midway between maximum potential losses (with no farmer response) and optimal losses under well-functioning markets.

To explore the impacts of soil erosion on crop yields, our second alternative scenario restores area growth to baseline levels and increases yield growth rates for each country by a portion (one-third) of the potential annual erosion-induced yield losses estimated for each region and presented in table 4.4 (i.e., 0.49 percent for Africa, 0.24 percent for Asia, 0.46 percent for Latin America, and using the global average annual loss of 0.30 percent for the New Independent States). This corresponds to an assumption that baseline yield growth rates are 0.1 percent lower, on average, than they would be if economic and environmental conditions in low-income developing countries allowed optimal choices closer to those found by Hopkins et al. (2001) for the United States (table 6.3).

Results of the second alternative scenario are presented in table 6.5. As was the case for reduced area losses, impacts of reduced yield losses are greatest for Sub-Saharan Africa, where food gaps for 2010 fall 9-18 percent (distribution and status quo gaps, respectively) relative to the baseline. In the other regions, due to a combination of faster baseline yield growth, smaller losses to erosion, and/or greater reliance on commercial imports, the food security impacts of reduced yield losses are generally smaller. For all 67 countries studied, distribution and nutritional gaps projected for 2010 decrease by an average of 7-10 percent, respectively, while status quo gaps decrease by an average of 13 percent. The number of people with nutritionally inadequate diets under the reduced-yield-loss scenario falls 5 percent from the baseline analysis to 657 million, or 21 percent of the total projected population of the 67 countries in 2010.

Figure 6.1—Yields at different rates of land degradation



Source: ERS.

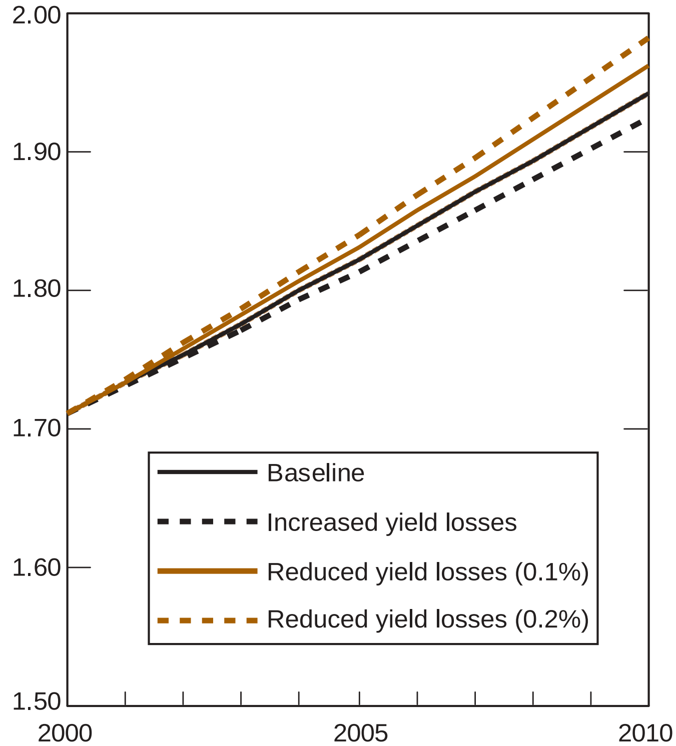
In other words, for the 67 countries as a group, projected food gaps in 2010 are 15, 11, and 8 percent higher in the baseline than in the reduced-yield-loss scenario (for status quo, nutritional, and distribution gaps, respectively) as a result of crop yield losses due to soil erosion. Thus, the projected number of people with inadequate diets is 6 percent higher in the baseline than in the reduced-yield-loss scenario.

In an earlier analysis using IFPRI's IMPACT model, Agcaoili et al. (1995) simulated the effects of a hypothetical 10-percent decline in productivity due to land degradation in developing countries through 2020, along with additional degradation-induced limits on yields and area growth in Pakistan and China. Their analysis suggested that adverse effects on global food supplies would be sufficient to reverse the decline in world food prices projected in IFPRI's baseline, but that effects on nutritional status would be modest at the global level, due to the potential for substitution from other producing areas (Scherr and Yadav, 1996). Impacts on supply could be much greater in areas where degradation is most severe, however, and child malnutrition in developing countries was projected to increase by about 4 percent relative to baseline numbers as a result. (Recall that IFPRI defined child malnutrition with respect to a standard different than that used by ERS to define nutritional and distribution gaps.)

All of these projections are subject to a considerable margin of error due to limitations in data on land degradation and its impacts on productivity over time, as well as to the inherent limitations of existing models (including assumptions about changes in area and yield). For example, the reduced-area-loss scenario projected that a total of 626 million people in the 67 countries studied would have nutritionally inadequate diets if area losses to irreversible degradation were eliminated. If area losses were doubled instead, the projected number of hungry people would rise to 1.0 billion. Similarly, the reduced-yield-loss scenario projected that 657 million people would be hungry if yield losses to soil erosion were reduced by an average of 0.1 percentage points. If yield losses to erosion were reduced by an average of 0.2 percentage points instead, the projected total number of hungry people would fall to 627 million (fig. 6.2 and 6.3). Such improvements would contribute to meeting the 1996 World Food Summit objective of halving the number of undernourished people in the developing world by 2015 but would not be sufficient to meet this objective.

If yield losses to erosion increased by an average of 0.1 percentage points, the number of hungry people would rise to 980 million. Asia was the region most sensitive to changes in both area and yield growth rates.

Figure 6.2—Cereal yields in low-income developing countries under alternative yield-loss scenarios



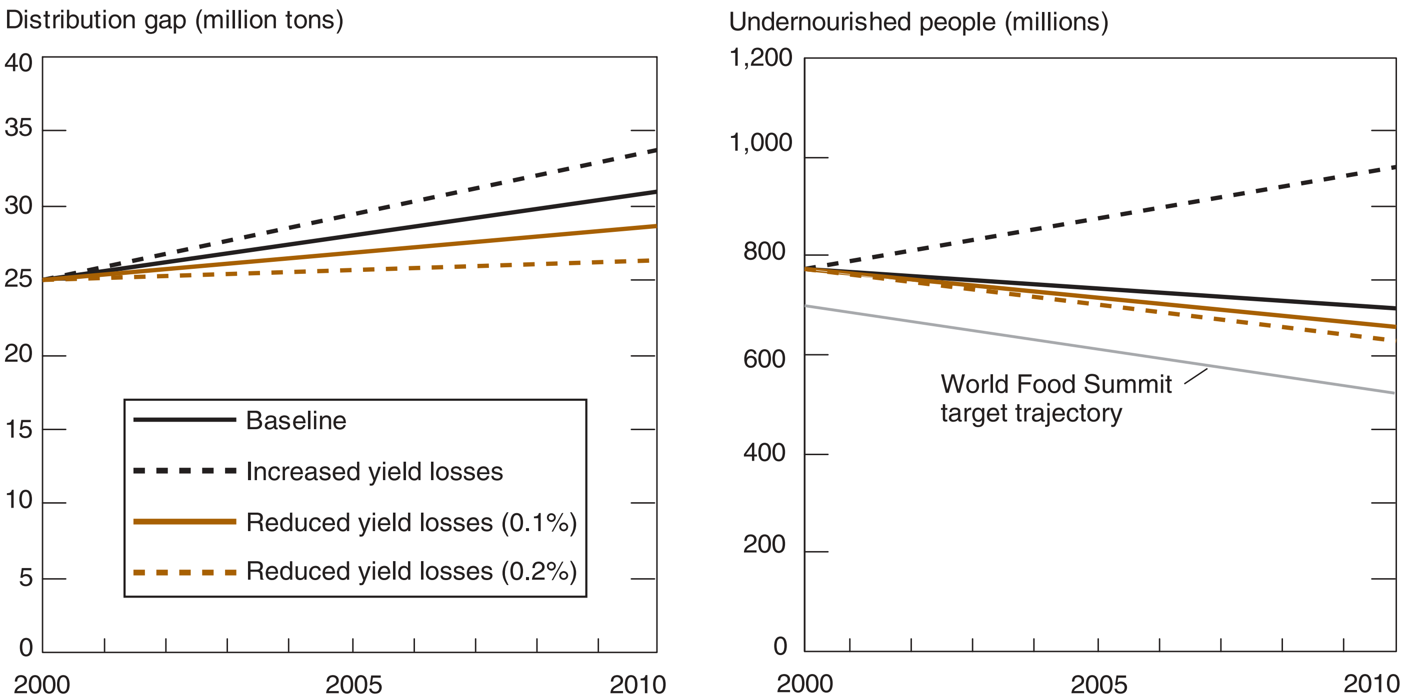
Source: ERS analysis.

Table 6.5—Food security in 2010 (Scenario 2: reduced yield losses)

Region	Status quo gap	Nutritional gap	Distribution gap	Hungry people
	Million metric tons			*Millions*
North Africa	0.7	0.9	1.1	31
Sub-Saharan Africa	6.8	14.5	20.5	428
Asia	3.1	3.4	5.1	146
Latin America & Caribbean	0.4	0.9	1.7	44
New Independent States	0.0	0.3	0.3	7
Total	11.0	19.9	28.7	657

Source: ERS analysis.

Figure 6.3—Food security in low-income developing countries under alternative yield-loss scenarios



Source: ERS analysis.

Implications and extensions

Data remain insufficient to accurately assess the probability of these alternative outcomes, but results nevertheless suggest the potential to "buy" improvements in food security through investments in conservation. Improved understanding of farmers' choices with regard to production and conservation practices is essential to increase our understanding of the potential costs and benefits of this link. It is also important to note that these projected food security impacts occur through reduced production (and thus availability), but reduced productivity also affects food security by reducing the income (and thus access to food) of individuals and households that depend on agriculture for their livelihoods. (The ERS model recognizes differences in income levels but does not currently permit endogenous changes in income resulting from changes in agricultural productivity.)

Future analyses will be able to take advantage of improved information on interactions between resources and food security. For example, IFPRI has recently extended its IMPACT model to incorporate data on water supply and use at the river-basin scale (Rosegrant et al., 2002), while ERS is upgrading its land and water resource database. Additional insights may be derived through analysis using static or dynamic global computable general equilibrium models that have been developed at ERS (and which incorporate interactions with nonagricultural sectors of the economy).