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AFTES Working Paper No.17

Natural Resource Management

LAND DEGRADATION AND REHABILITATION IN ETHIOPIA: A REASSESSMENT

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May 1995

Environmentally Sustainable Development Division
Africa Technical Department

Land, Water & Natural Habitats Division
Environment Department

The World Bank

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A REASSESSMENT

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EXECUTIVE SUMMARY

The *purpose* of this paper is to assess the extent of land degradation in Ethiopia, review its causes, take stock of past attempts to remedy the problems, and suggest appropriate future investment priorities.

Land degradation is defined here as a process that lowers the productivity of the land, assuming other factors such as technology, management, and climate are held constant. This is commonly regarded as a major environmental problem in Ethiopia; however, there are few empirical assessments of the extent and rate of land degradation and their results vary considerably. A recent assessment by the National Conservation Strategy Secretariat has considerably reduced the previous estimates made by the *Ethiopian Highlands Reclamation Study* (FAO 1986b) regarding the impacts of soil erosion, but added estimates of substantial costs due to nutrient losses. *This report suggests that even these revised estimates are probably overestimates of the actual rates of land degradation; however, nutrient losses in particular remain a concern.*

Previous analyses of soil erosion have not made allowance for the redeposition of eroded soil within and between areas of productive land use. The analysis presented in this paper indicates that even under the least favorable redeposition scenario, only cropland and areas already considered to be unproductive are suffering net soil losses in excess of suggested rates of soil formation (with 24 and 48 tons loss per hectare per year, respectively). Many other land areas appear to be receiving small net gains from redeposition. For croplands, this analysis suggests that the net soil loss is probably half or less of the gross figures reported in the most optimistic of the previous analyses. *The immediate gross annual financial losses estimated in this study were US$2 million due to soil erosion and roughly US$100 million due to nutrient losses resulting from the removal of crop residues and dung from cropland.*

These revised estimates do not indicate that land degradation is a trivial problem in Ethiopia. Rather, they indicate that the problem of land degradation is of a different nature than previously thought. In addition, the forces leading to land degradation problems can only increase with growth in population; consequently, advantage should be taken of any opportunity to address land degradation problems, as prevention is generally more cost-effective than cure.

The direct *causes of land degradation* are apparent and generally agreed : inappropriate forest clearance and soil surface exposure, detrimental crop cultivation practices, the burning of dung, removal of crop residues, and overgrazing are all familiar themes. More indirectly, a number of factors act as driving forces: poverty, insecure tenure, population growth, and economic policies. Other institutional factors such as weak research, extension, and management of public lands also play a role.

Past efforts to combat land degradation have relied heavily on Food For Work programs as an incentive and have been biased toward labor-intensive activities such as terracing, bund construction, and tree planting. Although the physical achievements of these programs have been impressive, there are questions about their long-term viability due to the lack of community participation in the design of conservation measures, the level of labor input required, and the opportunity costs of foregone production associated with the construction of some physical soil conservation measures. As a result, the technical quality and long-term maintenance of some structures and the survival rates of trees have been inadequate. Furthermore, only relatively small areas of the country have benefited from these donor and government-funded interventions.

Soil conservation objectives can be met through a variety of both biological and structural soil conservation measures; there is considerable technical guidance available on the choice of conservation measures for particular circumstances. Some financial and economic analyses of these measures indicate that, from a *financial perspective, measures to combat soil erosion will only pay off with long-term time horizons and low discount rates.* The reduced rates of erosion suggested by this paper indicate that the level of investment that society should direct to combating this type of land degradation is lower than previously considered desirable and that proportionally more resources should be directed to dealing with nutrient losses and other major problems such as education and health services, including family planning services. In particular, proposals for investment in the more expensive types of conservation measures, such as terraces, should be critically evaluated and more emphasis should be placed on *lower-cost, biological approaches* to soil conservation and land husbandry.

The reassessment presented in this paper also highlights the greater importance of *energy demands* and their potential impacts on soil *nutrient losses.* This suggests that greater attention needs to be given to both the supply and demand implications of alternative energy resources. For many rural households, expanding localized private tree planting presents one of the few socially acceptable and nondamaging supply possibilities; however, the scale of tree planting that the Ethiopian Forestry Action Plan (1994) has estimated is required to bridge current and projected fuelwood deficits does not appear to be achievable under even the most optimistic scenarios. Furthermore, individual proposals for expanded tree planting need careful assessment to ensure that actual fuelwood shortages rather than local fuel-type preferences are leading to the use of dung and residues as fuel.

The need for greater emphasis on low-cost biological approaches to soil conservation and local tree-planting initiatives to meet energy requirements underscores the necessity of creating an *enabling environment* that will maximize the opportunities for individual farmers and households to take *private initiatives* in land husbandry. Such an enabling environment will require a *secure tenure* situation with regard to land and tree utilization rights; *stable economic conditions;* demand-driven, problem-oriented agricultural and land management *extension and research services;* remunerative market *prices; infrastructure development* to secure improved access to markets; and business contracts between governments and local communities to secure better management of public lands in a *decentralized* administrative environment.

Even given an enabling economic and institutional environment, public *subsidies* for conservation appear warranted, particularly when the off-site externalities associated with degradation are high. Farmers can be expected to apply a higher discount rate than society at large and are likely to ignore off-site impacts of land degradation. They may also have imperfect information about the long-term impacts of land degradation and possible remedies.

Society at large is also suffering from uncertain information about the rates of land use change and land degradation. The paper suggests some rules of thumb for identifying the priority areas for government and donor intervention, including the need for *targeted research* on the productivity implications of the nutrient losses associated with alternative energy sources, erosion and redeposition processes under various cropping regimes, and effects of alternative land tenure options; however, the major emphases of this paper, in terms of future actions, are the need for government to provide an *enabling environment for local initiatives* and the *site-specific* nature of appropriate *interventions*.

FOREWORD

Land degradation is a major concern discussed in the National Environmental Action Plans of many African countries. In the case of Ethiopia, many view this issue as the country's primary environmental problem. Accordingly, this paper offers a critical review of the mainstream view of land degradation and its impacts on the Ethiopian economy. The result is a drastic revision of previous land degradation cost estimates in two respects.

First, the authors argue that past estimates have overestimated the impact of soil erosion and that new data and more reasonable assumptions suggest that this problem is more manageable. Second, the authors conclude that loss of fertility due to nutrient depletion is a much more serious and immediate problem. Dung and crop residues are removed from cropland to serve as energy source and fodder for livestock. In the absence of other external inputs, the result is "nutrient mining" with subsequent depressed yields of major crops.

These results have important policy implications. Paramount attention needs to be given to the creation of an enabling environment that encourages farmers and other landholders to adopt more conservation oriented land management practices with secure tenure, market-based prices and public support for research and extension. Within such a framework, greater emphasis should be given to ecological approaches to managing soil erosion and land degradation problems. In particular, the authors suggest that emphasis in targeted public interventions should not be limited to high-cost and labor-intensive physical structures but should also include soil cover management and promoting alternative supplies of fuel and fodder. The latter, in particular, would reduce the pressure to remove dung and crop residues from cropland, improve ground surface cover and thereby help to mitigate erosion.

The paper is written by two staff members of the World Bank: Jan Bojö, Senior Environmental Economist in the Environmentally Sustainable Development Division of the Africa Technical Department (AFTES), and David Cassells, Environment Specialist in the Land, Water and Natural Habitats Division of the Environment Department (ENVLW). Thanks to Pamela S. Cubberly for a light edit of the text.

The paper is published as an AFTES Working Paper in collaboration with ENVLW so as to make it widely available to planners and natural resource management specialists engaged in the critical task of devising ways of reverting land degradation in Africa and other parts of the world.

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LAND DEGRADATION AND REHABILITATION IN ETHIOPIA: A REASSESSMENT[1]

This paper is one of several contributions to the World Bank's Country Environmental Strategy Paper (CESP) for Ethiopia. Its *purpose* is to assess the extent of land degradation in Ethiopia, discuss its causes, analyze past attempts to remedy the problems, and suggest appropriate future measures from the perspective of the World Bank.

The intended *audience* for this paper is primarily Bank staff involved in country assistance to Ethiopia or land degradation issues in general. It will be circulated to Ethiopian (and some non-Ethiopian) civil servants and researchers involved in the subject matter.

The *scope* of this paper is determined in relation to other contributions to the CESP work. Land degradation is closely related to forestry and rangeland management. The former is partially integrated into this paper, whereas aspects of forestry relating to biodiversity conservation and plantation management are dealt with directly in the CESP. Rangeland management is also the subject of a stand-alone paper (World Bank 1993a) but is focused more on the pastoral groups inhabiting the lowlands of Ethiopia; hence, the issue of overgrazing will be discussed here as an integral part of more general farming systems.

It is important to note an additional geographical limitation: this report is focused on the Ethiopian Highlands, defined as areas over 1,500 meters above sea level, including associated valleys. This boundary roughly divides the country into a mixed-crop cultivation region and a nomadic livestock area. This is not very restrictive in terms of land degradation, the highlands cover 535,000 square kilometers or 44 percent of the territory. It also contains almost 90 percent of the human population, over 95 percent of the regularly cropped area, and about two-thirds of the livestock herd (FAO 1986b, p. 26).

The treatment of Eritrea also deserves comment. Since 1993 Eritrea has been an independent state separated from Ethiopia. As most reports on land degradation were written well before this event, there is often no easy way to separate data pertaining to Eritrea from current day Ethiopia. This need not be a major concern, as the qualitative statements will not be altered by this inclusion. The land area of Eritrea is about 124,000 square kilometers or 10 percent of the former Ethiopia. Approximately one-eighth of Eritrea would fall under the classification "Ethiopian Highlands" and, hence, will appear as a part of the discussion below.

The inclusion of Eritrea will "bias" the aggregate figures somewhat in different directions depending on the issue. On the one hand, the region has more than half of its highland soil in the

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[1] The authors would like to thank Peter Sutcliffe and Hans Hurni for detailed and constructive comments on a previous draft. Useful comments have also been received from Hailu Mekonnen, Christian Pieri, and Peter Dewees.

(Hurni 1988a, p. 126). When looking at land that is, or soon will be, out of production, Eritrea has a higher than average representation. On the other hand, the rates of soil loss are likely to be lower in Eritrea than the highland average, as rainfall is probably less erosive due to lower precipitation.

After a brief summary of key concepts, this paper starts by analyzing the available reports on the nature and extent of land degradation in Ethiopia and provides a critical reassessment of the problem. It then discusses some of the direct as well as indirect causes behind these processes and takes stock of current efforts to combat these problems. It concludes by making recommendations for effective future policy and interventions.

1. LAND DEGRADATION: AN ASSESSMENT OF THE PROBLEM

Before entering into the assessment of land degradation, there is a need to clarify the key concepts involved. Land degradation is defined here as a process that lowers the productivity of the land, assuming other factors such as technology, management, and weather are held constant. The major uses of land in Ethiopia are agricultural and pastoral and, hence, ultimately dependent on soil productivity. By implication, land and soil degradation become almost synonymous concepts. Soil degradation (FAO 1979) can manifest itself as:

1. water erosion (sheet, rill, gully erosion, mass movements)
2. wind erosion
3. biological degradation (decrease in humus)
4. physical degradation (increase in bulk density, decrease in permeability)
5. chemical degradation (acidification, toxicity)
6. excess of salts (salinization, alkalinization)

Although the list above provides some structure for discussion of the different aspects of land degradation, it does not directly identify a key concept: nutrient loss. The treatment of this process varies among sources. Barber (1984, pp. 2–4) deals with this issue under the heading of "chemical degradation." By contrast, the U.N. Food and Agriculture Organization (FAO) (1979, p. 19) treats chemical degradation as including the leaching of bases and toxicity only. The rate of change of soil humus content is discussed, including a variable for the annual addition of easily decomposable organic matter "including crop residues [and] manure" and it appears that FAO would place nutrient loss primarily under the heading of biological degradation rather than chemical degradation. In this report, the loss of nutrients is considered to be a key component of chemical degradation of the soil that follows but is not solely caused by biological degradation. Nutrient losses occur through a variety of processes, including leaching, direct removal or destruction of organic matter, physical erosion of the soil mass, and nutrient cropping in excess of natural or managed nutrient inputs.

The term "desertification" has also become common in public debate and is sometimes used as a synonym for land degradation. Many definitions of desertification are available (Glantz and Orlowski 1986); however, a widely quoted one is "Desertification is the diminution or destruction of the biological potential of the land and can lead ultimately to desert-like conditions" (UNEP 1984, p. 12); hence, this concept refers to an extreme end result of a multitude of possible degradation processes. Although politically catchy, the term "desertification" invokes an image of moving sand dunes that is misleading in the context of this report. The report therefore uses the land degradation concept and its subcategories to specify more clearly what processes are at work and avoids passing any definitive judgment that the ultimate result is "a desert."

1.1 A Review of Existing Data and Studies

There are a number of studies that describe the nature and extent of land degradation in Ethiopia. The main work includes the *Highlands Reclamation Study: Ethiopia* (FAO 1986b and 1986c) from the mid-1980s, the work of the Soil Conservation Research Project throughout the 1980s and still continuing, and the recent contributions by Ethiopia's National Conservation Strategy Secretariat (Sutcliffe 1993). A final major contribution to the discussion comes from the *Ethiopian Forestry Action Plan* (Ethiopia 1993), as the continuing deforestation and degradation of woodlands are intimately linked to the problem of land degradation.

The Ethiopian Highlands Reclamation Study (EHRS)

The study represents a major effort to assess the land degradation problem in physical and monetary terms. Apart from the two main volumes of more than 700 pages (FAO 1986b and 1986c), more than 20 detailed working papers were produced.

In a detailed assessment for the EHRS, Barber (1984, pp. 14–15) puts great emphasis on sheet and rill erosion and the interrelated physical degradation processes as the dominant degradation processes in the Ethiopian Highlands in terms of the processes' spatial extent and their influence on land productivity. This is reinforced by Wright and Adamseged (1984, p. 15), who states that among erosion categories, the most important type in all zones is sheet and rill erosion. In terms of the *extent* of the erosion problem, the EHRS concluded that, by the mid-1980s, about half (or 27 million hectares) of the highland area was "significantly eroded" and over one-fourth (14 million hectares) was "seriously eroded." Over 2 million hectares are described as "beyond the point of no return" (FAO 1986b, p. 190).

In terms of the *rate* of land degradation, the estimated rates of soil loss pertain to the impact of water erosion only, but this approach should capture the major force at work, according to the EHRS. The gross loss for cropland was put at 130 tons per hectare per year, whereas the average for all land in the highlands was put at 35 tons per hectare per year. It is not clear from available sources exactly how this figure is derived, but it is the result of a FAO-modified USLE-type[2] of calculation.[3] It is admitted that "this method . . . probably overestimates erosion rates in absolute terms . . . ," but it is defended on the grounds that it gives an overview of relative rates of erosion. (ibid., p. 208).

It is assumed that only 10 percent of the gross loss represents a net annual loss to the system but that the 90 percent that is redeposited is spread proportionally on several categories of land, as indicated below. This assumption appears to be based on personal communication from Hans

[2] USLE = Universal Soil Loss Equation. The standard reference is Wischmeier and Smith (1978).

[3] Reference is made to a source document by Boerwinkel and Paris: Methodology Used in the Development of a Soil Loss Rate Map of Ethiopian Highlands, published by LUPRD/FAO in 1984, but it has so far not been possible to locate a copy of this. In any case, the information base available has improved since then, and enabled Hurni (1988a) to derive new estimates using a similar methodology.

Hurni (ibid., p. 200), who is a leading international authority on land degradation in Ethiopia. Table 1 below clarifies the EHRS estimate that net losses from cropland still amount to about 100 tons per hectare per year (130 less 26), in spite of the assumed redeposition rate of 90 percent.

Table 1: Croplands: Gross Soil Loss and Redepositions

	(t/ha/yr)	*(percent)*
Gross loss	130	100
Redepositions on:		
grazing land	74	57
cropland	26	20
forest land	18	14
Net loss to agriculture	13	10

Source: Adapted from FAO 1986b, pp. 207–208. Figures do not add due to rounding.

The EHRS quotes the 1981 statement of the USA National Soil Erosion/Soil Productivity Research Planning Committee that "erosion reduces productivity first and foremost through loss of plant-available soil water capacity," which is seen to reflect a growing consensus in the scientific literature (ibid., p. 221). Based on this premise, the impacts of physical soil losses are derived in a series of steps.

First, the average estimated soil loss is taken as 35 tons per hectare per year for the highlands as a whole (ibid., 1986b, p. 208). This translates to a reduction in soil depth of about 7 centimeters over 25 years (ibid., p. 215), which implies a reduction of 2.8 millimeters per year (or 12.5 tons per millimeter per hectare). Second, this reduction is compared with the average remaining soil depth in the highlands. It is found that this is a reduction of about 8 percent of the average soil depth over 25 years, or 0.3 percent per year. For croplands, erosion rates are higher at about 100 tons per hectare per year, which implies a reduction of some 8 millimeters per year.

Third, the question is raised as to what this reduction in soil depth and water-holding capacity entails for crop production. Without any formal model, the EHRS reviews international evidence and makes "guesstimates" (ibid., p. 222) for the rates of decline in average crop yields. These are assumed to be an average of 2.2 percent (1–3 percent over zones) annually as a share of the 1985 level for cropland and 0.6 percent (0–1 percent) annually for grassland (ibid., p. 223). These are the main assumptions, which are also tested for sensitivity in "low" and "high" scenarios. Put differently, the assumed crop loss is about 0.3 percent per millimeter soil lost.

The EHRS deals with downstream effects more in passing but notes that sediments may have both positive and negative effects. "Much land in Egypt might never have developed if it were not for sediment deposits coming from the Ethiopian Highlands" (ibid., p. 224). Somewhat contradictorily, however, it also states that "any farming benefits accrued from deposition of sediment are insignificant and short-lived." It is argued that topsoil sediment will be replaced by subsoil sediment at a later stage and that deposition leads to reduced permeability of the soil with damaging impact on productivity. No quantitative estimates of downstream impacts were made in the EHRS.

For on-site effects, the EHRS derives estimates of *monetary costs* at both farm and national levels. With elaborate and appropriate qualifications for the weaknesses in data and methodology, reductions in crop and livestock production over the period 1985–2010 are derived.

Four types of costs are specified, each per three zones—Low Potential Cereal (LPC), High Potential Cereal (HPC), and High Potential Perennial (HPP)—and three altitude classes for the cost of:

1. lost cropland
2. lower crop yield
3. lost grazing land
4. lower grass yield

The annual average was specified as about 2 percent of the agricultural GDP in 1982–83 (ibid., pp. 228–229). Most of the loss (80 percent) is attributed to crop losses. Losses would increase over time to a total present value (at 9 percent discount rate) of EB4.2 billion (1985–86 prices) over 25 years. Translated to 1994 price levels, this is about EB6.8 billion.[4]

From a financial perspective, the results are grim. Income reductions would amount to about 30 percent on average for the highlands, with losses of over 50 percent in the LPC zone. It is noted that technological development, resettlement, food aid, and nonagricultural development would serve to mitigate this depression of income but that net losses would nevertheless be more than Ethiopian peasants could afford (ibid., p. 230)

The attention to land degradation in Ethiopia has been largely focused on soil erosion, but as noted above, the concept is much more complex than that. In a contribution to the EHRS, Wright and Adamseged (1984, p. 10) has put considerable emphasis on biological degradation, describing this as "the most widespread and most serious feature of all agricultural land in the highlands" and notes that many forms of physical degradation are secondary features of biological degradation (see also the discussion of the importance of soil cover management in section 2.1 below). It should be noted that *forms of land degradation other than soil erosion due to water are not explicitly estimated by the EHRS in terms of their quantitative significance and monetary costs.*

The Soil Conservation Research Project

The national body with the mandate to conduct research in Ethiopia with reference to land degradation is the Soil Conservation Research Project (SCRP), funded by the Swiss Directorate for Development Cooperation and the Ethiopian Government. The executing agency is the Institute of Geography, University of Berne, Switzerland. The Ethiopian counterpart is the Ministry of Natural Resources Development and Environmental Protection. The research program has been conducted at three levels:

1. a national level exploratory survey on rainfall erosivity

[4] EB = Ethiopian Birr. Approximately EB6 = US$1 in April 1994.

2. regional- and district-level data collection on land use
3. catchment and plot-level collection of soil conservation data

There is a network of eight stations [5] across the country, measuring soil losses, runoff, and crop yield on experimental plots using different conservation techniques. Recent years have seen some changes in the approach to land degradation research. There is now more emphasis on socioeconomic variables, and research is more production-oriented and adapted to local conditions.

An interesting result from several of the research stations is that the yields per hectare (measured in 1988) on conserved land were generally less than those on nonconserved land, due to the physical loss of production area to allow the construction of the structures; hence, although overall soil loss and runoff were reduced, soil was redistributed within the conservation structures and there was not a sufficient increase in yield to compensate for the loss of land due to the installation of these structures (SCRP 1991).[6]

As a part of the SCRP's efforts, Hurni (1988a) has derived measures of soil loss using USLE, calibrated for Ethiopian conditions on the basis of plot-level data. It is important to note that the figures presented in table 2 below are *gross* soil losses, not net losses from the agricultural system. Redeposition was omitted in the absence of data. Soil formation rates, on the other hand, have been estimated by Hurni and put at 3–7 tons per hectare per year.[7] These estimates can be directly compared with the gross "loss" figures given below.

The table brings out several important points. First, for the first two categories, which cover about 70 percent of the land area, soil formation alone is of the same order of magnitude as the *gross* loss from grazing land. This fact brings little comfort if the land is already degraded beyond useful utilization, but for remaining grasslands it is a striking result.

Second, the gross losses for cropland are about eight times those of grassland losses; hence, the conversion of grassland to cropland has important implications for the rates of erosion and the spread of land degradation in the future. Third, the table illustrates the familiar proposition that perennial vegetation such as forests and woodland/brushland crops offer much better protection against erosion than annual crops.

It is clear, however, from Hurni (1983, p. 132) that the "soil formation" concept utilized involves three separate processes:(1) accumulation on the surface of the soil (decomposition of organic material, deposition of material transported by water and wind), (2) soil formation within the A horizon (humus formation, root development, and decomposition), and (3) weathering of parent material (development of the B horizon)

[5] Two of these stations are located in now independent Eritrea and are no longer counted as part of the SCRP by their staff.

[6] The issue of profitability of conservation measures will be discussed further in section 3. See also Ståhl (1993, p. 508), who states that there is empirical data to show that it pays. Local circumstances will determine profitability, but stylized calculations can still be of guidance.

[7] The bulk density of Ethiopian soils varies somewhat, but as a simple rule of thumb, 1 millimeter of soil depth over one hectare corresponds approximately to 10 metric tons (Hurni 1988a, p. 127).

Table 2: Gross Soil Loss Rates per Land Cover Type

Land Cover	Area (%)	Soil loss (t/ha/yr)
Grazing	47	5
Uncultivable	19	5
Cropland	13	42
Woodland/bushland	8	5
Swampy land	4	0
Former cropland	4	70
Forests	4	1
Perennial crops	2	8
Total	**100**	**12**

Source: Adapted from Hurni (1988a) and revised as per Hurni (letters to the authors, June 15, 1994, p. 5 and June 16, 1994, p.1).

Thus, there is an element of overlap if both redeposition and soil formation are added to counter gross losses. The exact extent of this double counting can only be determined if separate figures are given for the processes 1–3 above, which is not the case as only the aggregate is observed. Conceptually, this would not be a problem if all redeposition is actually included, but the figures for "soil formation" are much lower than the figures for "redeposition" earlier (see table 1), which appears counterintuitive given the process definition in number 1 above.

Hurni comments only briefly on the productivity implications of his erosion results. In Hurni (1988b, p. 10), a decline rate for agricultural production of 2 percent per year due to land degradation is postulated. This appears to be based on empirical measurements from Hurni (1985b, p. 9) in which data from 52 plot samples of barley are regressed on soil depth. This shows an annual decline in the yield of barley on the order of 2 percent per year, based on an erosion rate of 66 tons per hectare per year.[8]

The National Conservation Strategy Secretariat (NCSS)

As part of NCSS work on land degradation, Sutcliffe (1993) has conducted a review of past estimates and provided his own path-breaking analysis of the problem. He derives new estimates for on-site soil erosion impacts as well as impacts from the loss of nutrients through the use of dung and residues for fuel. Off-site impacts are not estimated. The major conclusion of his work is that the most frequently used estimates of land degradation (EHRS) are in fact greatly overestimating the extent and rate of the *erosion* problem. On the other hand, he argues that the cost of *nutrient losses* is much more significant than previously documented.

[8] Hurni (letters to the authors, June 15, 1994, p. 5, and June 16, 1994, p. 1) has confirmed the yield equation: $Y = 0.38 + 0.032X$ (where Y = barley yield in tons and X = depth of reworkable soil in centimeters), which implies a yield reduction of 320 kilograms per 10 centimeters of soil lost and not 250 kilograms as given in Hurni (1985b). With an average yield of 1,820 kilograms per hectare (X = 45 centimeters), this implies a relative loss of about 1.5 percent per year, given the loss rate of 66 tons, that is, about 8.25 millimeters per year with the bulk density of the area (1.25 cubic centimeters per gram).

The potential implications of these significant differences require careful evaluation of his methodology. The first part of the calculations, concerning the impact of water *erosion*, proceeds in a series of steps:

1. The erosion rate estimates by Hurni (1988a), quoted above, are used.

2. A soil life model developed by Stocking and Pain (1983) is used as the analytical framework to establish the minimum required depth for cultivation of different crops and also the maximum required beyond which erosion does not immediately affect crop cultivation. The future user cost of depletion of the soil depth, however, is incorporated in the calculations.

3. A model developed by FAO (1986a) is used to relate monthly values of rainfall, water-holding capacity, evapotranspiration, and crop water requirements to derive a Water Requirements Satisfaction Index (WRSI). This, in turn, is required to derive the relationship between the WRSI and relative reductions in crop yield.

4. Estimates from the EHRS regarding crop mix, absolute yields, and areas for three attitudinal ranges in each of the three major agro-ecological zones (HPP, HPC, and LPC), make it possible to project losses in crop production. Losses in crop residue production are converted to tropical livestock unit (TLU) equivalents. The time perspective applied covers 1985 to 2010.

5. "Current," that is, 1985–86 (ibid., p. 52), market prices in Ethiopian Birr (EB) are used to determine the financial implications for Ethiopian peasants, whereas world market prices in US$ were used to determine the economic impact for society as a whole.

The second part of Sutcliffe's report concerns the impacts of *breaches in the nutrient cycle* due to dung and residue use as fuel. Building on a methodology developed by Newcombe (1984) but using more recent estimates of actual use of dung and residues as fuel from the Ethiopian National Energy Commission, the new estimates are derived in two major steps:[9]

1. The amounts of nitrogen (N) and phosphorous (P) lost and their impact in terms of lost crop production are calculated.

2. The burnt crop residues are evaluated in terms of livestock feed and converted to potential increases in TLUs, which in turn are priced.

The financial and economic implications were spelled out as for the impacts of physical land degradation. The *results* regarding two aspects are astounding. The first is shown in table 3. A comparison with the EHRS has been included, as this is the only major, original previous study that derives comparable estimates. While keeping in mind that these estimates only concern soil *erosion* impacts, it is apparent that Sutcliffe's estimates represent a significant reduction in estimated damage.

[9] In a third step, the replacement value of nutrients lost was calculated, using the price of chemical fertilizers. Since replacement with chemical fertilizer does not generally take place in Ethiopia, we leave that part of the calculations aside here.

Table 3: Soil Erosion Damage Estimates

Year	EHRS (I)	Sutcliffe (II)	Relation (II/I)
Crop production losses *(rounded to thousands of tons)*			
1985	120	9	7%
2010	2,580	332	13%
Livestock production losses *(rounded to thousands of TLUs[a])*			
1985	7	n.a.	n.a.
2010	153	n.a.	n.a.
Cropland lost *(thousands of hectares)*			
2010	7,600	489	6%
Pastures lost *(thousands of hectares)*			
2010	n.a.	5,747	n.a.

Source: Adapted from Sutcliffe (1993)
a. Tropical livestock units.

It should be recalled, however, that Sutcliffe also adds calculations for the cost of breaches in the nutrient cycle (ibid., pp. 13–15). The result of these calculations shows losses that are much larger than those for erosion. In physical terms, the 1990 losses are estimated as (1) almost half a million tons of grain (about four times the 1985 estimate for physical land degradation losses) and (2) more than 1 million TLUs (compared to only 7,000 TLUs lost in 1985 due to erosion). Obviously, the monetary implications of nutrient losses are increased in proportion to the increase in physical losses.

Taking losses from both erosion and nutrient loss together, Sutcliffe (ibid., p. 16) estimates total crop losses at about 0.5 million tons in 1985 (the base year for his calculations). Adding livestock losses, he derives a total cost of EB581 million in 1985. This corresponds to about EB934 million in 1994 (see appendix 2).

The discrepancies between these results and earlier studies are so large that they require a note of explanation. There are a number of differences in the methodologies used to calculate erosion impacts (Sutcliffe 1993, p. 4). First, improvements have been made in the estimates of rainfall erosivity (Krauer 1988) since the EHRS was published. Second, a more detailed subdivision of the soil texture factor in deriving erodibility estimates is now available (Hurni 1988a). These and other factors resulted in the considerably lower estimate of gross soil loss by Hurni, as compared to the EHRS.

Furthermore, the EHRS applied the productivity loss of about 2 percent per annum to the entire crop production area, regardless of soil depth (ibid., p. 31). Sutcliffe uses a more sophisticated model, implying crop losses set in only after reaching a depth of not more than 90 centimeters, while still accounting for the future user cost.

A fourth point is that the EHRS appears to have extended the "cropland" definition at one point to include another 21.1 million hectares of "open and wooded grassland." The figures for soil loss pertaining to cropland were applied also to this extended area, ignoring actual gains in topsoil cover on grazing land (ibid., p. 32). Finally, the EHRS applied the percentage increase in noncultivable areas (depth less than 10 centimeters) to *all* land in the highlands, not only cropland, to arrive at the estimate for wasteland, resulting in the terrifying estimate of 7.6 million hectares of "cropland" lost in the year 2010.

Taken together, these factors account for the considerable differences between the EHRS and Sutcliffe estimates. The judgment is made here that the latter represent an improved information data base and some improvements in terms of methodology. Some reservations remain and will be commented on in detail below. The conclusion remains, that the *new estimates have painted a much less devastating picture of degradation due to erosion than previous studies.*

With regard to nutrient losses, however, the new results by Sutcliffe work in the opposite direction. As shown above, the EHRS did not estimate the costs of removing dung and crop residues from agriculture. Sutcliffe derives high costs on this account: almost EB1 billion as an annual cost, expressed in 1994 prices. This can be compared with the gross erosion cost calculated by the EHRS: about EB135 million per annum for their base year with adjusted prices to 1994.[10] Although there are reasons to reduce Sutcliffe's estimates of these costs, they remain a significant factor for policymakers (see further discussion in section 1.2 below).

The Ethiopian Forestry Action Plan (EFAP)

Land degradation and the potentially ameliorative role of both farm forestry and community forestry are primary concerns of the *Ethiopian Forestry Action Plan* (EFAP) (Ethiopia 1993). The incidence of land degradation and its impacts are described (ibid., pp. 43–47), although much of this description is based on the EHRS and an early draft of the NCS work described above. The report also summarizes historical evidence of the decline in both size and quality of Ethiopia's forest resources—some 35 percent of the land area of 120 million hectares was once covered by coniferous or broad-leaved closed forest, with a further 30 percent of the landscape originally being covered by savannah woodlands (ibid., p. 17).

Ethiopia's forests have been declining in size and quality over many centuries of human occupation. Records of early European travelers described a mixed agricultural and forest landscape in the Ethiopian Highlands; however, these trends have accelerated over the last century and the last few decades in particular. The EFAP (ibid., 1993, p. 17) reports estimates that indicate that by the 1950s high forests had been reduced to 16 percent of the total *national* land area and that these forests had further declined to 3.6 percent by the early 1980s and 2.7 percent by 1989. EFAP estimates also suggest that between 150,000 and 200,000 hectares of forest are currently being lost each year.

The loss of forest resources has been especially severe in the Ethiopian Highlands, where the majority of the country's human and livestock populations lives and where the bulk of cultivated land occurs. The EFAP (ibid., p. 17) estimates that natural high forests originally covered almost

[10] See Sutcliffe (1993) p. 16, FAO 1986b, pp. 228–229, and price index in appendix 1.

90 percent of the highlands, about 40 percent at the turn of the century and only some 5.6 percent at present.

The enormous reduction in the area of forest has led to a marked increase in both grass and shrub vegetation. The transformation is most advanced in the north and east of the country where population has been concentrated for many centuries. Indeed, it is only in the south and southwest of the country that significant blocks of forest remain and even here pressures for agricultural development and resettlement are rapidly diminishing forest cover. The EFAP (ibid., p. 18) suggests that a continuation of current trends will see Ethiopia's natural forests reduced to only scattered remnants in inaccessible areas within 15 years.

The EFAP has taken the lower figure of current range of deforestation estimates (150,000 hectares per year) and estimated the associated depreciation costs using natural resource accounting approaches suggested by Ahmad, El Serafy, and Lutz (1989) and Repetto and others (1989). This analysis suggested that, in timber values alone, deforestation represents a loss of potential annual income of some EB138 million (Ethiopia 1993, p. 11). This is the equivalent of approximately one-third of the contribution of forestry to GDP, which in the 12 years 1980–81 to 1991–91 accounted for an average of some 2.5 percent of GDP and some 5.5 percent of the agricultural sector (ibid., p. 10, annex 1.1, p. 1).

1.2 A Reassessment of Land Degradation Impacts

A major conclusion of the review in the previous section is that there are enormous differences in the results of the few major studies of land degradation in Ethiopia. In this assessment, Sutcliffe's results (1993) are a benchmark, as the data base for his calculations appears superior. There are, however, several reasons to assume that even these results may overestimate the damage done by land degradation.

First, there may be an element of double counting involved. Residues or dung used as fuel both have an opportunity cost in terms of lost crop production (including loss of future residue production). There is also the additional option of feeding residues to livestock. The opportunity cost is the *higher* of the two use values, but they cannot logically be added. Adjusting for this would reduce Sutcliffe's estimate downward by more than 20 percent. Still, a fundamental point remains: nutrient losses are costly.

Second, there is probably double counting within the estimates of the *livestock losses* from burning residues instead of using them as livestock feed. The cost is derived as the sum of the value of flow products and services from livestock plus the value of livestock as a "store of wealth." The latter is derived by calculating the capital recovery value, obtained by annualizing the sale price of the livestock over its expected (remaining) length of life (ibid., pp. 10, 46). An example is given in which the market value of a four-year-old cow (EB350) is annualized over the remaining eight years of her life at a 9 percent rate of discount. This implies an annualized value of about EB63. This is taken to be "an annualized value of the store of wealth of one cow." The market value, however, should reflect the net value of the total flow of goods and services emanating from the cow over its expected (remaining) lifetime *plus* the store of wealth value and other intangibles. Therefore, double counting will occur if the flow values are accounted for separately.

An additional critique under the same heading is the use of the price at age four of the cow: the net value of the *entire* life cycle of a livestock unit needs to be considered in an economic calculation. This should be less, as there has been a period of investment preceding the sale at age four. It is not possible to adjust Sutcliffe's figures in detail to account for these two points, as only totals have been given in available documentation; however, they clearly would revise the damage estimate downward considerably.

Third, Sutcliffe follows Hurni not only in using his estimates of gross soil losses but also in *not adjusting for redeposition of soil* to arrive at net losses. This issue is complex and important and warrants both detailed discussion and further investigation (see appendix 2). The conclusion of the calculations presented there is that the net soil loss to cropland is probably on the order of half or less of the gross figures used in previous analyses. Assuming that the productivity impacts are approximately linear, this would imply dividing *the erosion damage estimates presented by Sutcliffe* roughly by two. Furthermore, in subsequent communications, Sutcliffe has indicated that more detailed USLE calculations taking account of the likely distribution of slope and soil depth classes has itself reduced average losses from cropland to some 20 tons per hectare per year (without any allowance for redeposition processes).

Fourth, we would like to raise the issue of *plant availability of removed nutrients* contained in dung and residues. The implicit assumption appears to be that it is highly available for plant growth, in the sense that the nutrient content is a perfect substitute for commercial fertilizer. This is more likely for dung than for residues.

Measures of Economic Losses

What are the economic implications of these results? First, the different ways of expressing the economic cost of land degradation should be reviewed. Several different measures can be used, and any comparisons across studies require careful scrutiny of the assumptions applied. It is essential that economic costs are defined in terms of (1) the counterfactual scenario assumed and (2) the time horizon used. Different concepts emerge:

1. *Gross Annual Immediate Loss (GAIL)*: This is the loss of gross agricultural output in a single year due to land degradation in the same period of time. The comparative format is generally if no land degradation took place. The concept is "gross" because it does not account for (1) the cost of combating land degradation or (2) any cost reductions related to lower production.

2. *Gross Discounted Future Loss (GDFL)*: Because the loss of soil particles is irreversible, the *loss in any one year* will affect production in all future years. In other words, this concept captures a loss of natural capital and is relevant for any discussion on adjusting the System of National Accounts to better reflect environmental damage. The value of future costs is translated to a current value using a discount rate (r). For an infinite time horizon, the GDFL = GAIL/r. As discussed in appendix 1, this concept does not apply to nutrient losses.

3. *Gross Discounted Cumulative Loss (GDCL)*: This concept captures the fact that land degradation is a cumulative process, in which each year's erosion and nutrient removal is followed by another, adding layers of cost on top of each other.

Applying these concepts in the context of Ethiopia, Sutcliffe's estimates can be used as the best available benchmark. Although the necessary information and time to rerun his models is not available, some rough adjustments can be made to his calculations (see appendix 1 for details). The results of these analyses are presented in table 4.

Table 4: Reassessment of Land Degradation Costs[a] *(EB million)*

	Erosion	**Nutrient Loss**
GAIL	1×10^1	6×10^2
GDFL	1×10^2	n.a.
GDCL	3×10^3	8×10^3

Source: Authors' calculations.
a. See appendix 1 for more detailed background.

The results from the various methods presented in table 4 need to be considered in the light of the high level of uncertainty, associated with the data used in the calculations and only illustrate the order of magnitude of the problems. The relative differences in the costs due to erosion and nutrient loss calculated using the GAIL + GDCL measures illustrate both the immediate significance of nutrient breaches and the longer-term cumulative effects of physical soil erosion. No distinction is made between financial (market) and economic (social or shadow price-based) costs, as the recent liberalization of major markets in Ethiopia has made such adjustments of minor importance. A discount rate of 10 percent was used in the calculations, as this is the World Bank standard.

The figures above mean little unless some comparisons are made. First, we can repeat the comparison with other studies. The *rate* of erosion calculated in this analysis is approximately half that of Sutcliffe's (see appendix 1) but our erosion loss estimate is about 7,000 tons or EB10 million rather than the 7,300 tons and EB12 million (recalculated to 1994 prices) suggested by Sutcliffe (1993, p. 16, table 4.3,). The small difference in spite of the discrepancy in erosion rate assumption is due to the use of a higher production figure in our study. By contrast, the EHRS estimate is 120,000 tons (FAO 1986b, p. 224).

The nutrient losses (GAIL) presented in table 4 are lower than for Sutcliffe but of the same order, whereas no comparison with the EHRS is possible due to the absence of similar calculations in that study.

These results can also be compared with other economic parameters. The total GAIL in table 4 corresponds to about 3 percent of the agricultural GDP.[11] Obviously, almost all of that is on the nutrient loss account, and further studies of that cost are therefore imperative to narrow down current uncertainty. The GDFL represents a hypothetical "soil capital loss correction" for the System of National Accounts, and would correspond to about 0.3 percent of GDP in 1994.[12]

[11] This is based on the agricultural GDP for 1992 (US$2,984) as reported in the *World Development Report* (World Bank 1994) adjusted for inflation of the dollar until 1994 (3.9 percent per year): US$3,221.

[12] Taking the GDP of Ethiopia in 1992 of US$6,257 million (World Bank 1994) x 6 = EB37,542 million and adjusting for inflation with the annual average inflation of the dollar (based on 1980–92 [ibid.]) to arrive at EB40,527 (1994).

Finally, the GDCL (EB11.4 billion in total) could be compared with the level of investment in soil and water conservation. Updated figures on this are lacking but as a starting point can be taken from the estimate by Aggrey-Mensah and others (1984, p. 34) that the cost for 1978–82 was about EB371 million. Updating this to 1994 (EB688 million)[13] and adding an average of the same annual cost since then[14] suggests cost estimates on the order of EB2.2 billion; hence, future losses far outweigh the level of investment.

Policy Implications of the Reassessment

What are the implications of the drastic revisions in estimated magnitude and character of land degradation problems in Ethiopia? First of all, the results with respect to erosion damage are quite encouraging, as they suggest that the problem is much more manageable both in extent and rate. Second, the new results do not render the problems of land degradation in Ethiopia trivial by any means. Rather, they redefine the nature of land degradation problems. Gross losses due to land degradation are sizable in relation to the agricultural GDP. Furthermore, these are losses that directly affect the livelihood of many of the poorest of Ethiopians.

Third, the lower estimated rate of erosion and high cost of nutrient loss alter the calculation bases for specific interventions. This implies that (1) lower investment levels to combat erosion will be warranted for society as a whole and that more resources can therefore serve to address nutrient losses and other major social problems and (2) that the more expensive types of conservation measures (e.g., terraces) will be even more doubtful as proposed measures. Thus, it would seem that higher priority should be given to biological methods that contain both physical erosion and nutrient losses, although the exact implications for particular areas can only be determined by applying the lower rates of degradation to local circumstances, a task beyond the scope of this paper.

Fourth, the reassessment of the costs of soil erosion and the new work on the costs of nutrient losses has come to focus attention more on the need for energy substitution than structural soil conservation; hence, the search for cost-efficient methods on both demand and supply sides of the energy consumption equation stands out in importance. Equally, the social and cultural difficulties with regard to fuel substitution need to be recognized (see Dewees 1989) Participatory planning will be necessary to ensure that interventions, such as expanded tree planting, conform with the needs and priorities of farmers in the target areas.

Finally, despite the fact that the extent and rate of the erosion problem is probably much less than suggested previously by the EHRS, the rate of land degradation will *increase in the future* without effective countermeasures for the following reasons:

1. Population growth will result in (a) more intensive use of land under cultivation with lower levels of residue retention and shorter fallow periods and (b) the expansion of cultivation onto more marginal lands, some of which are on very steep slopes.

[13] Taking the mid-year 1980 as a reference: $371 \times 1.024^{11} \times 1.428$ (see appendix 1).

[14] That is, 688/5 = 137.6. Multiply by 11 years (1983–93) and add to previous estimate.

2. Redeposition of eroded sediment may reduce the permeability of the soil at the point of redeposition, thus potentially inducing higher runoff in the future.

3. Soil fertility often declines with soil depth, which implies that vegetative cover may decline over time as the richer upper horizons are lost.

4. Even to the extent that fertility in the soil is relatively uniform, soil erosion is a selective process that removes a comparatively fertile selection of soil particles.

Hence, although current erosion damage is lower than some estimates have suggested in the past, there is still a sizable and growing problem affecting a large part of the Ethiopian population. Furthermore, the nutrient loss problem is of significant and immediate concern. Understanding of this problem is limited, however, and further targeted research on this topic should be a high priority for Bank support. The results from this research could have important implications for determining investment priorities in the future.

2. LAND DEGRADATION: PROXIMATE AND UNDERLYING CAUSES

This section first discusses a number of *direct* causes that have an apparent link to land degradation: forest clearance, existing crop cultivation practices, the burning of dung, removal of crop residues, and overgrazing are all familiar themes. More *indirectly*, a number of factors are the driving forces behind these manifestations: poverty itself, insecure tenure, economic policies, and population growth. Other institutional factors such as weak extension services and weak management capacity of public lands also play a role.

2.1 Direct Causes of Land Degradation

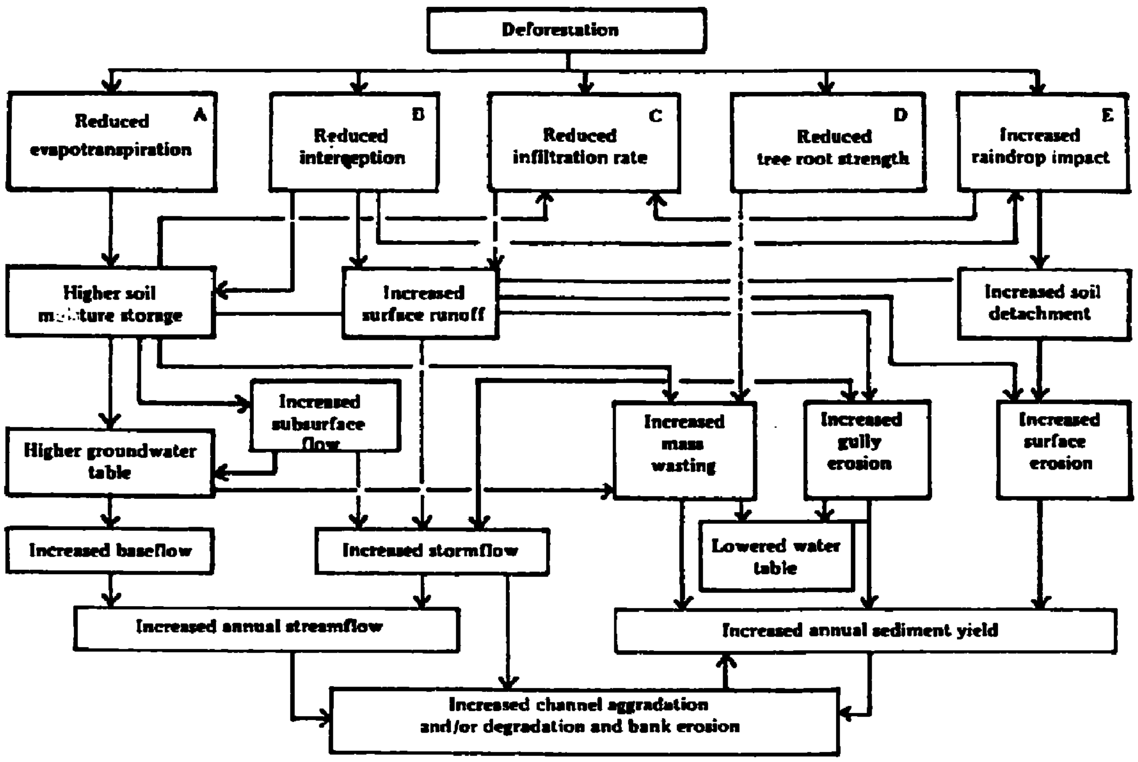
The direct causes discussed in this section include the clearing of forests and woodlands, crop cultivation practices, the use of dung and crop residues, and overgrazing.

Clearing of Forests and Woodlands

Soil erosion, land degradation, and the decline in both the size and quality of forest resources described in sections 1.1 and 1.2 above result from multiple and often mutually reinforcing factors (see figure 1); however, the EFAP (Ethiopia 1993, p. 44) also states that *the* major driving force behind land degradation is the massive removal of vegetative cover, which is itself due to an expanding population with its increasing demand for crops, grazing land, and fuelwood. The EFAP also suggests that the removal of vegetative cover for use as fodder and fuel leads to an increase in surface runoff and thus to an increase in soil erosion.

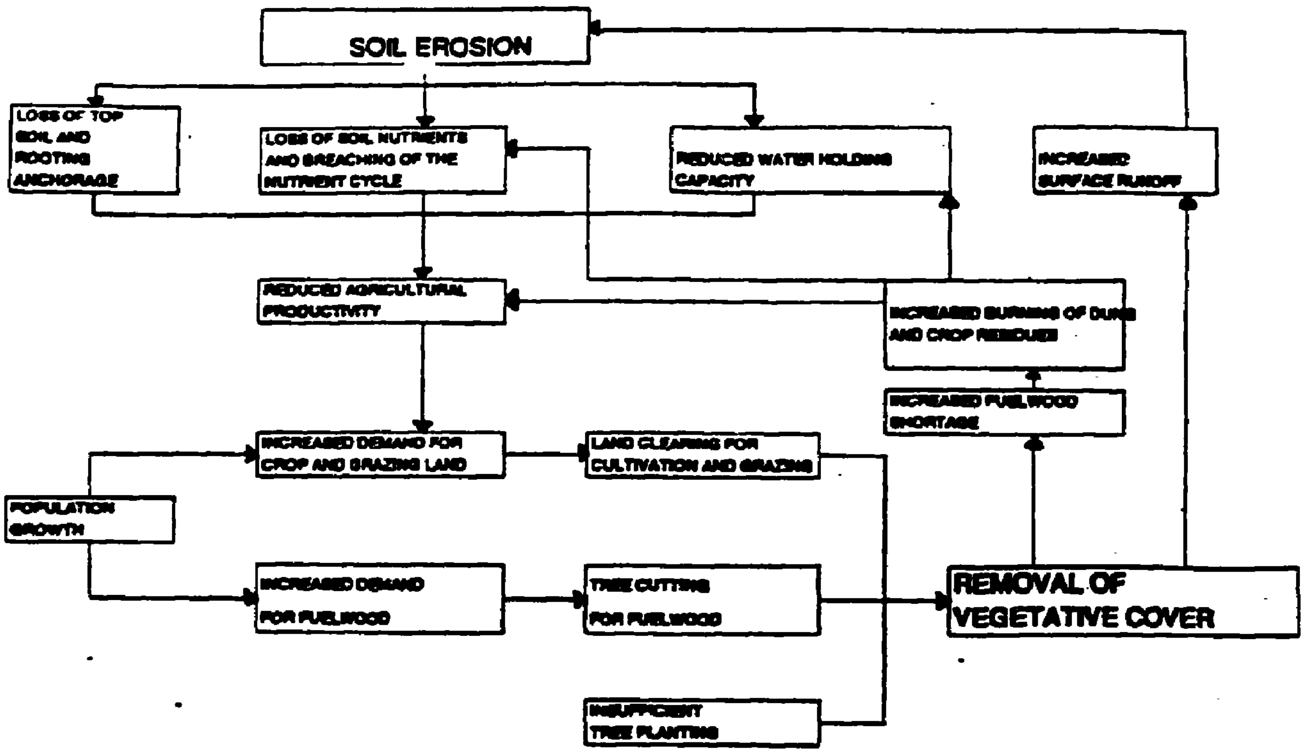
These suggested influences are consistent with the general scientific understanding of the protective role of forest ecosystems; however, these influences are expressed in a complex manner across a landscape and caution must be used in ascribing both causes and possible solutions to particular instances of land degradation, as a range of hydrological and soil interactions can follow the removal of forest cover (figure 2). Cassells and others (1987, pp. 46–49) have reported that,

Figure 1: Influences on the Land Degradation Process



Source: EFAP (Ethiopia 1993, p. 45)

Figure 2: Some Likely Hydrological Changes Following Deforestation



Source: Cassells and others (1987, p. 38) although research in both temperate and tropical latitudes has demonstrated that reductions in forest cover can lead to changes in both soil erosion and stream sedimentation, such research has equally demonstrated that in many circumstances *appropriate management* of both forest and nonforest land use can ensure that catchment areas do not suffer adverse erosional or hydrological impacts, a perspective subsequently endorsed in the more recent UNESCO review of tropical forest hydrology (Bruijnzeel 1990, pp. 113, 117–118, 184).

The key role of soil surface cover in providing protection against surface erosion helps to provide a frame of reference for determining the appropriateness of land management practices, in particular watershed environments (Weirsum 1984). Forest and nonforest land management practices that can maintain effective surface cover will be unlikely to generate excessive levels of soil surface erosion; thus, within the limits of available technology, local economic circumstances, and the local biophysical environment, practices in pasture, cropping, and agroforestry can be developed to maintain surface cover and ensure that surface erosion is not excessive. Equally, poorly managed forestry practices such as excessive burning, overgrazing, or extensive soil disturbance during logging operations can destroy the surface cover and, despite the residual presence of trees, produce high rates of surface erosion.

These general observations have been confirmed by fieldwork undertaken in Ethiopia. The results of the SCRP show that the different vegetative covers associated with different production systems provide different levels of protection against erosion. For example, the vegetative cover provided by a mixed crop of sorghum and beans, as compared to teff, reduced annual soil loss from 282 tons per hectare to 1 ton per hectare (Grunder 1988, p. 148). The EFAP (Ethiopia 1993, p. 54) has further estimated that natural pasture would limit soil loss to 6 tons per hectare per year and that it appears that grass cover is sufficient to effectively stabilize soils under most Ethiopian conditions.

Although forests are not the only land cover that can provide effective protection against surface erosion, it should be recognized that forests frequently have a more direct influence on slope stability problems such as soil slips and shallow landslides. Many studies have demonstrated that tree root systems contribute to soil strength by providing additional soil cohesion; in terms of slope stability, this can be of critical importance where the shear strength and shear stress forces within a soil mass are finely balanced (Cassells and others 1987, p. 48). In these circumstances, forest disturbance can lead to considerable acceleration of mass wastage that cannot be easily stabilized without extensive engineering works and reforestation.

In the Ethiopian context, little mention of mass instability problems is made in the literature, although some shallow movements and small rotational hillside failures were observed in a few instances during the mission. In general, however, it would appear that, despite the often steep slopes, shear stresses and shear strength are not finely balanced in most soils in the country. Land conservation concerns should therefore be focused on the control of surface erosion processes, and the more flexible array of approaches should be available to address these processes.

Crop Cultivation Practices

The major crop cultivation area in Ethiopia is the highlands, as described in section 2. Of this area, only about 15 percent or 6.6 million hectares is cultivated land. The bulk of this consists of small-scale farming units with (at the mid-1980s) about 300,000 hectares cultivated by State Farms or Peasant Associations. In spite of its limited area, crop cultivation is the major source of income in the highlands; its extent determines what areas are left over for livestock and forestry (FAO 1986b, p. 117).

Crop cultivation is dominated by cereals, which account for about 70 percent of the area. A further 20 percent is divided among perennial crops such as coffee, enset (or "false banana"), oilseeds, fruit trees, cottons, and some roots and tubers. The remaining 10 percent is devoted to pulses. Teff, sorghum, and maize are the most common cereals below 2,000 meters, whereas wheat and barley are grown above this limit.

Enset is unique to Ethiopia and found in the highlands between 1,600 and 3,000 meters in the High Potential Perennial crops (HPP) zone. It requires intensive use of manure, which makes it superior to seed farming in terms of fertility maintenance, and it also provides good ground cover (Ethiopia 1988a, p. B20). Enset areas are known to be able to support some of the highest densities of people in Ethiopia.

Few reliable agricultural statistics on yield and area harvested are available; however, the available statistics do not indicate any significant changes from the late 1970s to mid-1980s in terms of yield and areas cultivated. This is obviously puzzling, given the rapid population growth, and appears not to be credible (FAO 1986b, p. 122).

There are two fundamentally different agrotechnologies in traditional rural Ethiopia. One is based on the plow and annual crops, the other is based on the hoe and cultivation of perennial crops, roots, and tubers (Ethiopia 1988a, p. B12). The latter is in the south and southwest, whereas the former occupies roughly the central and northern highlands.

From the perspective of land degradation, current cropping practices have a number of important implications. First, the emphasis on annual rather than perennial crops implies that land cover is low during a period of the year. Since farmers are often reluctant to plant before the rains have started, the first rainstorms will expose the ground to the full force of erosive precipitation. Second, the popularity of teff implies that large parts of the cropland are prepared to make a fine seedbed, with multiple plowings. Once the crop is established, however, teff provides good ground cover. Third, the low level of irrigation reinforces the dependence on rainfed agriculture and contributes to the exposure of soils to incipient rains. Fourth, although statistics do not bear this out, it is obvious from informal evidence that there is an expansion of cultivation into more marginal, often steeply sloping areas. As the level of erosion depends greatly on slope, this will aggravate the problem of soil loss over time.

The only systematic review of traditional conservation practices available is by Ethiopia's Ministry of Agriculture (ibid.). "Traditional" is taken to mean practices that have evolved as part of farming systems over hundreds of years and that are presently still practiced. Basic practices such as crop rotations, manuring, and fallowing are common in the highlands; however, with increasing population pressure and demand for dung as fuel, fallow becomes shorter and the availability of manure to maintain fertility becomes inadequate. Traditional terracing is "fairly ubiquitous" in the highlands and not an isolated random phenomenon. There are, however, areas where terracing was widespread two hundred years ago or more and where only remnants are found today. Where rainfall is high and soil conditions make waterlogging likely, drainage furrows have been developed.

Dung and Crop Residues

A number of sources indicate that the burning of dung and crop residues has become more common in Ethiopia as fuelwood demands outstrip supplies. The EFAP (Ethiopia 1993, p. 6) notes the impact of these practices on land degradation, as materials used for energy consumption are no longer available as inputs to maintain soil fertility. It also suggests that the present burning of dung and crop residues represents a loss in crop production equivalent to some 700,000 tons of grain, a loss[15] that it has suggested is of the same order of magnitude as that experienced from soil erosion. With the consequent cycle of falling production and falling soil productivity, the EFAP has further estimated that some 20,000–30,000 hectares of cropland are abandoned annually because cropping can no longer be supported by the soils.

Although there is considerable uncertainty about the extent of the use of dung and crop residues as substitutes for fuelwood, the potential impact of these practices on land productivity does give cause for alarm. The estimates summarized in table 5 suggest that the use of dung and crop residues for fuel accounts for between 18 percent (Ethiopian Energy Authority [EEA] 1989–90 Survey cited in Sutcliffe 1993) and 58 percent of total energy use (Newcombe 1984). Methodologically, the 1989–90 EEA study is more reliable, as it is based on a nationwide survey of both urban and rural households. Newcombe's report was based on indirect estimates of fuelwood deficits, which were then used to categorize areas into particular categories with a series of hypothetical fuel mixes for dung and crop residues. These hypothetical mixes were then used as substitutes for the estimated fuelwood deficit—namely, in the most severe deforestation category, only 20 percent of energy demands were met from fuelwood with a maximum of 90 percent of dung used as a fuel and only 10 percent of cereal straw used as fuel.

A number of studies have reported trends of increasing substitution of dung and crop residues for fuelwood as fuelwood demand exceeds available supply (for example, see Sarin 1990, p. 28, for descriptions from northwestern India). In Ethiopia, the EFAP (Ethiopia 1993, annex 6.2, p. 1) reports recent studies by the Forest Research Centre in two highland villages. In one of these villages, actual energy consumption in fuelwood equivalents was 1.15 cubic meters per capita per year with maize and sorghum stalks accounting for 69 percent of total fuel use. In the other village, actual energy consumption was some 1.23 cubic meters per capita per year with about 50 percent of total fuel consumption coming from the burning of dung.

These actual figures are similar to the hypothetical scenarios suggested in Newcombe's study. They illustrate the potential for a significant downward spiral of agricultural productivity and widespread loss of cropland from fuelwood substitution associated with rapid population growth and a growing fuelwood deficit. The potential growth of this problem needs to be fully recognized and indicates that interventions to promote farm forestry should be given high priority in the overall response to the problem of land degradation. Equally, the social and cultural dimensions of fuel preference and use need to recognized. Individual proposals for expanded tree planting need careful assessment to ensure that actual fuelwood shortages rather than fuel type preferences are leading to the use of dung and residues as fuels.

Fuelwood use itself is not thought to be a major source of deforestation except where there is demand for commercial sales of fuelwood to urban areas (Mercer and Soussan 1992, pp. 128,

[15] This compares with the NCS estimate of 459,300 tons (Sutcliffe 1993, p. 15).

183). Rural people rarely fell trees for fuelwood alone but utilize branches and material from trees near their houses and in the agricultural landscape for fuelwood supplies; however, for landless or land-poor people, access to communal lands provides an important source for the supply of their energy needs. As forests are cleared for agriculture and other uses, their reliance on other sources of fuels such as dung and crop residues is likely to increase within the availability of these latter resources. The EFAP (Ethiopia 1993, annex 6.2, p. 4) estimates that dung resources are likely to increase in availability by some 1.1 percent per year, whereas crop residues are likely to remain much as they are today. With population growth in excess of 3 percent, the proportional use of both these resources will clearly be constrained.

Table 5: Estimates of Consumption of Household Energy *(percent)*

	World Bank 1984	Cesen 1986		MoA 1990		EEA 1989–90	
Fuel	***Total***	***Urban***	***Rural***	***Urban***	***Rural***	***Urban***	***Rural***
Wood/Charcoal	42	81	82	72	77	75	82
Dung	34	8	10	18	23	8	10
Crop residues	24	6	8	-	-	6	8
Kerosene, gas	0	2	0	0	0	8	0
Electricity	0	3	0	10	0	3	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Ethiopia 1993, annex 6.2, p. 3.

With the current high reliance on fuelwood and the lack of practical alternatives in many rural areas, addressing the growing fuelwood deficit is important for both human well-being and minimizing pressure on the productivity of the agricultural land resource. The EFAP (ibid., pp. 72–73) has estimated that current demand for fuelwood is on the order of 45 million cubic meters per year with a projected demand of 89 million cubic meters per year by 2014, although the per capita consumption figures reported for Ethiopia are high by east African standards. Ethiopian annual per capita energy consumption was taken as 241 kilograms of oil equivalent, the midpoint estimates given for Ethiopia in a range of surveys over the last decade. Comparative figures for Mali and Rwanda are 217 kilograms and 147 kilograms respectively (ibid., annex 6.3).

The current sustainable production from all forest sources is only 12.5 million cubic meters per year (ibid., p. 74). In the absence of a substantial reduction in per capita energy use, meeting current demands would require the establishment of the equivalent of some 2.1 million hectares of block plantations growing at 15 cubic meters per hectare per year. This is more than ten times the combined area of existing industrial, peri-urban, and community woodlots. It implies an enormous area with widely dispersed farm forestry production systems. To close the projected gap between fuelwood availability and supply at year 2014, the equivalent of some 6 million hectares of block plantations would be required (ibid., p. 75). This equates to some 6 percent of the total utilizable land area in Ethiopia and would require the establishment of the equivalent of some 400,000 hectares of block plantations per year over a 15-year period.

Such a scale of tree planting does not appear likely under even the most ideal conditions; growing pressure on forests, the off-site uses of dung and crop residues for fuel, and a tendency toward diminishing productivity of land resources seem inevitable. This, in turn, suggests that high priority should be given to developing a more comprehensive understanding of the social, cultural, and economic dynamics of energy use in rural areas. In the absence of such understanding, there is a danger of misdiagnosis of the problems of energy use and inappropriate reliance on unilinear solutions, such as expanded tree planting, when a more comprehensive approach is needed.

Overgrazing

With appropriate management, grazing systems can maintain effective soil surface cover and provide adequate protection against accelerated erosion (see section 2.1 above); however, high rates of surface runoff and erosion have been reported from heavily grazed and/or annually burnt grasslands in a number of studies in the tropics (Bruijnzeel 1990, p.118). In addition, Smiet (1987) has suggested that both grazing and agroforestry systems are more susceptible to land degradation than forests, as the margins of safety with these land uses are narrower and more easily exceeded due to factors such as fire and overgrazing.

In Ethiopia, Melese (1992, p. 18) has suggested that some 20 percent of soil erosion comes from grazing lands. In this regard, the EFAP (Ethiopia 1993, p 49) indicated that overgrazing is a particular problem in both the high and low potential cereal zones where current stocking rates are well in excess of estimated optimum stocking rates, as shown in table 6. In addition, although overall stocking on the lowland pastoral areas is less than the suggested optimum, localized overstocking and land degradation occurs close to water points and settlements.

Table 6: Current and Optimum Livestock Stocking Densities
(hectares/TLU)

Zone	Stocking Rates	
	Current	*Optimum*
HPP (highlands)	1.49	1.45
HPC (highlands)	1.28	1.51
LPC (highlands)	1.51	3.21
Lowlands	5.44	4.07

Source: Adapted from the EFAP (Ethiopia 1993, p. 49).

Livestock play a key function in the farming systems practiced by the highland populations, providing draft power for cultivation, direct income, food, and manure for both farm use and use as fuel. In addition, livestock have traditionally been the most important asset of rural people in the highlands, particularly in the absence of secure land tenure. Holding animals also has a cultural dimension in terms of asserting individual or family status within society.

Low livestock productivity is a major limitation, and many animals need to be kept to satisfy the requirements of a rural household—a breeding herd of at least 10–12 animals is considered necessary to maintain a pair of oxen for farm use (ibid., 1993, p. 49). Because livestock are important and because livestock raising is a risky undertaking, farmers also tend to try to gain some insurance by holding a large number of animals.

Low livestock productivity is a function of both poor animal health and nutrition. At present, there is a heavy dependence on natural pasture, although other feed sources include crop residues, cereals, and in some cases industrial by-products (ibid., 1993, p. 50). There is also considerable potential for forest-based fodder production systems. In this regard, Melese (1992, p. 21) has noted that overgrazed and devegetated hills can be reasonably revegetated within three to four years after closure to on-site grazing; however, the EFAP (Ethiopia 1993, p. 40) suggests that open farms and livestock pressure are major constraints on tree regeneration and farm forestry development in both the cereal and the agropastoral zones. A wider adoption of farm forestry and fodder-based systems will therefore depend on the development of measures to reduce the uncontrolled movement of animals, including stall feeding and controlled grazing. Future extension for farm forestry, soil conservation, and fodder production will also need to be fully integrated into agricultural and animal husbandry extension as discussed further below.

2.2 Indirect Causes of Land Degradation

Direct causes of land degradation are often immediately recognized, although their exact influence can be debatable. In addition, a more subtle network of factors can influence land management and often contribute to land degradation. A brief review is made here of factors pertaining to poverty, tenure, population growth, economic policies, and institutional factors such as weak extension services and the poorly developed capacity for the management of public lands.

The Poverty Trap

Poverty itself has been described as both the cause and effect of land degradation. Suffice it to say that a low income, immediate food needs, and lack of capital to finance improvements with long gestation periods will all act as disincentives to farm improvements with a conservation impact. This is not to imply that poor farmers by definition will degrade their soils; low-density slash-and-burn agriculture can give sufficient time for the soils to recover; however, poverty limits the farmers' options in dealing with adverse conditions.

Hence, one could well describe the poverty trap as an example of market and policy failures: with perfect capital and insurance markets, even the poorest could borrow against future income at a rate that coincides with the social rate of time preference. Such markets, however, are imperfect because of asymmetries in information creating problems of moral hazard, adverse selection, and high transaction costs.

Economic Policies

The government of Ethiopia is pursuing structural adjustment policies, including exchange rate adjustments and liberalization of other key markets. This will also impact on land use in ways that are complex and ambiguous. To the extent that currency depreciation encourages perennial tree crops at the expense of food crop annuals for domestic consumption, the impact is likely to be a beneficial one from a land degradation point of view. The improvement in soil cover when replacing maize with coffee bushes can be dramatic. Everything else being constant, a change in crop from maize to coffee can drastically reduce the rate of erosion. This, however, depends more on the particular type of management than on the crop (Hudson 1986; Young 1989).

A further caveat is that export promotion may also encourage the extension of cultivation into previously uncultivated areas. Some export crops (e.g., ground nuts) can also be more erosive than their food crop substitute; hence, it must be concluded that if property rights are incomplete and farmers only partially internalize environmental impacts in their decisions, there may be both positive and negative impacts from export crop promotion. This is a question that deserves further study.

Liberalizing prices and marketing will allow farmers to utilize modern inputs more effectively, and to market their enhanced outputs at remunerative prices. This should contribute to enhanced ground cover due to more vigorous stands and encourage more investment in land conservation. The removal of previous coercive resettlement and conservation works will also enable people to choose their habitation and methods of soil and water conservation in accordance with local conditions.

Decentralization as a policy may imply a more rigid regional structure, which will render voluntary resettlement across regional boundaries more difficult. Recipient areas are often plagued by both human and livestock disease and adverse cultivation conditions. Ethnic differences may also impede acclimatization of newcomers. Resettlement, however, appears to be inevitable to some degree, given the mounting pressure in some of the highland subzones.

Tenure

A variety of state, church, communal, and private land tenures have existed over time in Ethiopia. Historically, land has been the basis for both political and economic power and the tenure arrangements for agricultural land in particular have had a pervasive influence on both land degradation and political and social stability.

Land ownership characteristics have been described by Abebe (1993) and Zewde (1991, pp. 15–16, 87–92, 191–196). Historically, peasants in Ethiopia could claim ownership of a plot of land if they could show descent under a lineage system of land ownership known generally as *rest* (Zewde 1991, p.14); however, the peasants' control over the production of this land and indeed over their own labor was severely limited by the claims of both the lay and clerical nobility. A system of surplus appropriation, the *gult*, gave the nobility rights of tribute collection from the production of the peasants, who also had to undertake forced labor for the nobility in areas such as farming, grinding corn, and building houses and fences. *Gult* collection rights were commonly given as a reward for military service, and the system tended to foster a military ethos under which the peasantry were often at the mercy of a marauding soldiery.

The demands of the nobility and clergy on the peasantry were frequently exploitative. From the sixteenth century on, European writers have commented on the discrepancy between the apparent beauty and fertility of the Ethiopian landscape and the poverty and misery of its human inhabitants; Ethiopian writers have ascribed this discrepancy to the perverse outcomes of both the *rest* and the *gult* systems (Aregay 1986; Zewde 1991, pp 15–16). Aregay (1986, p. 129) in particular noted that:

> The low level of life of the Ethiopian peasantry and the ruling classes cannot, therefore, be attributed to primitive technology. The *rest* form of tenure and the endless segmentation of farms that it entailed deprived the peasant of the will to work and to seek improvement. It made him quarrelsome, while at the same time shutting and fixing him within the confines of his ancestral village. The *gult* system . . . made the ruling classes ever hungry predators, always destroying the administrative structures they wanted to build.

These traditional forms of land tenure had a communal character with peasants enjoying only usufructuary rights over the land; however, with the emergence of the modern Ethiopian state after the Battle of Awada in 1896, a steady process of privatization was set in place. The institution of the *qalad* land measurement system at the turn of the century was one of the forces that had a profound influence on land tenure in the south (Zewde 1991, p. 88). The major objective of this system was to facilitate land-based taxation; however, peasants in the southern regions who had formerly tilled the land under a lineage system of ownership, found themselves forced to purchase their own lands or be reduced to the status of tenants.

The *qalad* system also enabled the state to appropriate large areas of land for its own benefit or the benefit of individuals or institutions, such as the church, which it wished to reward. The ultimate objective of the government was evidently to broaden its own base of support, with the major beneficiaries being patriots, exiles, soldiers, and civil servants. The process of privatization accelerated after the liberation of Ethiopia from Italian occupation in 1941, although the northern provinces largely retained the traditional kinship system of land tenure until the end of the Hayla-Sellase[16] regime in 1974. Elsewhere, there was a growing concentration of land ownership in relatively few hands and a concomitant spread of tenancy.

In the last decade and a half of the Hayla-Sellase regime, as much as 65 percent of all land holdings were held under some form of tenancy (Zewde 1991, p. 192). Most tenancy agreements were verbal, involving sharecropping arrangements covering from a quarter to half of production. To facilitate both revenue raising and the interests of its supporters, government priority was given to commercial rather than peasant agriculture. With the rise in land values with commercialization and mechanization, the arrangement tended to be increasingly weighted against the tenant, often culminating in the tenant's eviction (Zewde 1991, p. 192). The cumulative effect of this process was to polarize rural society into landlords and tenants.

Efforts to introduce significant changes to this system foundered because they impinged on the vested interests of the landlord class, which dominated the state apparatus, including the Parliament. Parliamentary obstruction of a tenancy bill introduced to the Parliament in 1964 led to the initiation of the radical phase of the Ethiopian Student Movement under the banner of "Land to the Tiller" (Zewde 1991, p.195). This process ultimately culminated in the fall of the Hayla-Sellase regime in 1974.

In 1975 state ownership of rural land was introduced; since then, land has formally been the collective property of the Ethiopian people. In this system, no person or organization was allowed to hold land under private ownership. Individual households were allowed to farm up to 10 hectares of land, although in practice allocated areas were often less than 3 hectares (Bruce,

[16] There are several spellings given for Hayla-Sellase in various reports. We have used the spelling given in Zewde 1991.

Hoben, and Rahmato 1993, p. 1); however, households only had usufruct rights over the land they cultivated and these rights could not be transferred by sale, lease, or mortgage.

During the Derg regime, considerable land was reallocated under the auspices of the local Peasant Associations. This created further tenure insecurity and peasants became even more reluctant to invest labor and finance in their land for perennial cropping, forests, or soil and water conservation. In 1990, however, the Mengistu regime was faced with a series of military, civil, and economic crises and announced that its socialist agrarian reform program was no longer suited to Ethiopia's needs in the light of the new world order. A number of the program's most unpopular measures were rescinded, and, whereas land still formally belonged to the state, private initiatives in farming and marketing were encouraged.

Since coming to power, the Transitional Government of Ethiopia (TGE) has moved slowly on land policy for political and other reasons. The TGE postponed difficult and critical decisions on land tenure until after the 1994 elections, which should provide a clearer mandate for these decisions. Land has remained in formal state ownership, but government economic statements have confirmed a number of landholder rights (Bruce, Hoben, and Rahmato 1993, p. 7).

In the smallholder sector, current policy suspends further redistributions, holdings can be inherited or leased, and hired labor can be used. Farmers have full freedom of disposition of their production. Resettlement has been stopped, although a larger number of people resettled by the previous regime have returned home on their own initiative. There has been a call for the establishment of commercial farms by private individuals and companies. Land is to be provided for concessions in a way that will not prejudice the land rights of local people, and incentives will be provided through bank credit, tax concessions, and infrastructure improvement. Foreign investment will be permitted but only when nationals cannot meet the need. Unprofitable state farms are also to be abandoned or given on concession to private investors.

Due to land reallocation to peasants by the Derg regime and because of previous inheritance claims under the traditional tenure system, the land has been subdivided into smaller parcels, which in many cases are below the economic size needed to support a household unit. This has led to a number of problems, including scattered holdings, which inhibit efficient production systems. In addition, no cadastral survey exists to provide the occupier of the land with protection from loss of possession.

A number of reports have suggested that insecurity of land tenure is still a fundamental force leading to land degradation (Ethiopia 1993, p. 51; Ethiopia 1994b, pp. 14–16). Abebe (1992, p. 4) has suggested that tenure security is *the* overriding issue behind land degradation and that the remaining ones are subsidiary issues. The EFAP (Ethiopia 1993, pp. 27, 29, 41) has similarly suggested that the lack of security to land and tree tenure is inhibiting entrepreneurial, community, and individual investment in industrial, community, and farm forestry, respectively.

The question of land tenure reform is, however, quite complex. The EFAP (ibid., p. 37) has also noted that even the limited recognition of tree tenure by the TGE's 1990 proclamation regarding usufruct rights to land has led to considerable expansion of small on-farm woodlots in peri-urban areas where the sale of firewood and poles is attractive. These perceptions seem to be supported by empirical research elsewhere in East Africa, which found that, in six out of the eight cases investigated, there were statistically significant positive correlations between land security and investments in land improvements (Place and Hazell 1993, pp. 14–16).

Land tenure reform should not, however, be seen as a panacea for the problem of land degradation. The exact nature of tenure reform still needs to be determined, and it needs to be recognized that there is a deep legacy of uncertainty and distrust from both the inequitable privatization of land ownership under the Hayla-Sellase regime and the collectivization and subsequent inequitable redistributions of the Derg regime. In addition, land tenure reform will need to consider the new pressures resulting from the demobilization of troops and the large number of people who have returned—or who in some cases are still likely to return—from exile and the forced resettlement programs of the Derg regime. Considerable research into the nature of tenure/equity/productivity relationships is therefore needed before informed policy making on tenure reform will be possible.

Rapid Population Growth and Increasing Pressure on the Land

The population of Ethiopia was estimated at 53 million in 1992 and to be growing at about 2.7 percent per annum until the year 2000 (World Bank 1993b). Although this is a somewhat lower rate of growth than in the previous decade (3.1 percent), it still implies a doubling of the population in about 26 years. This growth translates to increasing pressure on the land.

The average population density in the highlands was estimated as 61 persons per square kilometer in 1983, which implies a current density of about 84 persons per square kilometer[17] This would imply a theoretical average of only about 1.2 hectares per person. The intrazonal differences, however, are considerable. Average population density, therefore, has limited meaning, as the settlement pattern is closely correlated to climatic and soil conditions, and land over 2,000 meters is free from malarial mosquito (FAO 1986b, p. 59).

There is no simple correlation between elevation and population density. Mesfin (1992) has shown that in the Shewa and Wello regions, the greatest concentrations of human population are in the 2,600–2,800 meter belt. The explanation offered for this is that these areas offer an inviting topography, whereas lower belts have steeper slopes and, even further down, a higher incidence of drought and more environmentally related diseases.

In spite of the attempts at "villagization," rural settlements are generally not concentrated around a center but scattered around to maximize proximity to cultivated fields (FAO 1986b, p. 61). Organized resettlement has now been halted. Still, the number and size of urban localities (with over 2,000 inhabitants) is growing rapidly. The urban population has been estimated to have grown at about 6.6 percent during 1960–80 but may have slowed somewhat in the early 1980s due to unemployment in urban areas (ibid., p. 63).

Average food production per capita appears to have fallen in the first half of the 1980s (FAO 1986b, p. 316). Although production of food grain fluctuates strongly over years and some increases have been noted in the current decade, it is clear that a substantial structural food grain deficit has persisted for the last ten years (World Bank, Resident Mission, unpublished data). Most of this is met by food aid, as the country lacks commercial capacity to accommodate this deficit. In summary, food production has been unable to meet the demands of the rapidly growing population.

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[17] Assuming a growth rate of about 3 percent over 11 years.

The hypothesis that high population pressure is correlated with land degradation has been tested in a quantitative model developed by Grepperud (1994). The results show that both the ratio of rural population to arable land and the ratio of population-supporting capacity to rural population proves statistically significant in explaining the extent and distribution of soil erosion. This lends statistical credibility to a reasonable hypothesis; however, the apparent stability of the enset farming areas under high population densities (see p. 23) also demonstrates the importance of land management inputs.

Weak Extension Services

Weak, ineffective extension services are a major constraint on the wide adaptation of the levels of land husbandry that are needed to contain land degradation. Although agricultural and forestry research have had a long history in East Africa, there has not been a comparable history of problem-focused, farm-system research geared to the needs of smallholders. Research is underfunded; researchers do not communicate across disciplines or with extension officers; research has low status; the expertise of researchers is seldom drawn on for official policy formation; and the research infrastructure is on the verge of collapse in many institutions. Extension staff themselves lack transport, field support, instruction materials, and access to recent research findings. As a result, they are often ignorant about local farming conditions and may react with bureaucratic high-handedness when faced with farmers seeking advice (Ståhl 1993, p. 507).

In Ethiopia, centralized top-down planning of both soil conservation works and afforestation measures by the Mengistu regime in the recent past have left farmers with a legacy of distrust that will have to be overcome before extension to improve land conservation and agricultural productivity can become effective. The EFAP (Ethiopia 1993, p. 53) has suggested that extension advice regarding soil conservation at the farmer and community levels has been weak and not integrated with agricultural extension efforts. The main reasons for this are similar to those listed more generally above by Ståhl—poor training of extension staff, especially in biological conservation and agronomic techniques for improved land management; lack of operational support (transport in particular); poor supervision of field staff; organizational separation of development agents and catchment technicians; and low staff morale coupled with inadequate rewards and incentives.

Similar problems exist regarding the forestry sector. Bekele-Tesemma, Birnie, and Tengnas (1993, p. 1) have suggested that the approach and technical solutions suggested by extension workers have not attracted farmers' interest. They have suggested that extension messages have too often been geared to establishing single-species communal woodlots that are more relevant to the needs of industrial forestry than the multiple needs of the farmer or the pastoralist.

Due to the wide variety of agroclimatic and socioeconomic conditions in Ethiopia, no uniform extension package can be effectively applied countrywide. Rather, there is a need to involve local people in dialogue so that their needs can be given first priority. Bekele-Tesemma and others (ibid.) have suggested that the training given to extension officers to date has not equipped them well for this task and that farmers and pastoralists often have more detailed local knowledge of farming systems and tree characteristics than the extension officers. Consequently, farmers often have little respect for their advice.

Weak Management Capacity of Public Lands[18]

Public lands in Ethiopia are held in some 58 National Forest Priority Areas (NFAPs), which collectively cover some 2.8 million hectares (Ethiopia 1993, p. 23). Each of these areas may include natural high forest, plantations, and some nonforest lands; over half of the natural forest areas in the NFAP system are said to be heavily disturbed. Only three of the NFAP areas have had management plans completed, and only one of these plans is currently being implemented. The present inadequate data base for planning seems likely to continue to delay the preparation of meaningful management plans. The EFAP comments that despite significant external donor inputs, the State Forests Conservation and Community Development Department (SFCDD) has not to date demonstrated that it has the capacity to undertake either the preparation or implementation of appropriate management plans.

The growing stock in Ethiopian forests is being rapidly depleted, both as a result of forest degradation and continued deforestation. Continued depletion is also probably unavoidable in the immediate future as conflicts between the state's conservation and protection objectives and the immediate needs of local people are likely to increase as population pressures continue to grow; however, in the face of the country's growing needs for forest products and environmental services, improved forest management is an urgent need. The challenge, therefore, is to develop systems of management that will minimize further destruction of the remaining natural forests, while still balancing conservation objectives with the productive needs of local communities.

The development of such management systems will require the involvement and support of all interested stakeholders. Although there is general acknowledgment of the need for participatory approaches to forest management, the EFAP (Ethiopia 1993, p. 23) notes that extension officers, forestry staff, and land use planners all lack the required skills to engage in a new dialogue with farmers and community leaders. As noted above, extension officers have long viewed their task as telling farmers and community representatives what to do, rather than listening to their problems. Furthermore , the credibility of government officers with local communities is low because of the climate of distrust that has grown from the forced soil conservation and community forestry initiatives of the previous regime.

3. EFFORTS TO COMBAT LAND DEGRADATION

This section briefly reviews past efforts to mitigate land degradation. Substantial resources have been invested in this endeavor, especially during the last two decades. First, these efforts are put in a policy context. The nature of the overall program is then discussed.

3.1 General Policies

Before 1975 the agrarian economy of Ethiopia was mainly feudal. The revolution in that year brought land reform, and all lands became public property. Production was to be organized in units

[18] Since 1975, all rural lands in Ethiopia have been owned by the state as the collective property of the Ethiopian people and, thus, are legally public lands. In this section, however, public lands refer to lands that fall under the direct administrative responsibility of a government land management agency.

of small-scale farms, producers' cooperatives, and state farms. Although the latter forms of production were heavily favored by the government in terms of publicly funded investment, agricultural credit, and allocations of improved seeds and fertilizer, they nevertheless remained fairly insignificant in terms of their share of actual production. Government price regulation contributed to the depression of incentives for market production, resulting in agricultural output that did not keep pace with population growth (Belete, Dillon, and Anderson 1991).

The TGE came to power in 1991 and has instituted a series of reforms that profoundly affect land use. The overall policy approach is one of "Agricultural Development-Led Industrialization" (ADLI). Development of smallholder agriculture is envisaged in three phases (Ethiopia 1994a):

1. improvement of agricultural practices (seeds and so on)
2. investment in infrastructure and the use of modern inputs (roads, irrigation, and the use of fertilizers and pesticides)
3. increasing farm sizes, while shifting population out of agriculture.

The declared aims of the new agricultural strategy are to attain food self-sufficiency, reverse ecological degradation, and raise the competitive advantage of Ethiopia's agriculture. The strategy focuses on enhancing the productivity of smallholder agriculture but also encourages extensive mechanized farming and intensive commercial agriculture. The role of government is seen as one of providing an enabling environment for agriculture with macroeconomic policies, such as a market-determined exchange rate and free market policies for agricultural inputs and outputs. Marketing parastatals will be dismantled.

In summary, these policies lay a promising, market-based foundation for agriculture and, potentially, by implication also for soil conservation. Food self-sufficiency is hardly a target to pursue at any cost, but, given the weak immediate capacity to generate export income, this ambition is understandable. The level of *attention given to conservation, however, is minimal* in the available policy document. Administrative boundaries have served to limit and compartmentalize land degradation work; it is a concern that this issue is not addressed more directly in the agricultural strategy. In terms of public investment, the "modern" sector within agriculture appears to receive a particularly favorable hearing.

3.2 Programs

With the support of the European Union, FAO, and bilateral organizations, successive governments in Ethiopia have initiated considerable programs to combat soil erosion and land degradation. It has been estimated that between 1976 and 1985, some 600,000 kilometers of soil and stone bunds were constructed on cultivated land, almost half a million kilometers of hillside terraces were constructed, 500 million tree seedlings were planted, and 80,000 hectares were closed off for natural regeneration (Hurni 1988a).

Impressive as these physical data may seem, a number of caveats are in order (Hurni 1988a). First, the achievements do not match the vast needs; it has been estimated that it will take another 70 years until all the land in need of conservation will receive a first treatment. Conservation measures had covered 1 percent of the highlands by the mid-1980s (FAO 1986b, p. 233). Second, the survival rate of tree seedlings has been low, perhaps in the area of 20 percent. Third, many of the physical installations were based on simplistic rules of thumb, making them less well adapted to local conditions.

Maintenance over time is another serious problem. Much work for soil conservation has been promoted without creating awareness of the long-term needs for maintenance. Political instability has contributed not only to lack of interest in maintenance but also the active destruction of previous gains; hence, there was considerable cutting of tree plantations in 1991, as fuelwood and poles for construction were in short supply. Bunds were also plowed up because the accumulated, nutrient-enriched soil could be used to fertilize the fields. In the face of great uncertainty over future rules of land utilization, such short-term gains appeared attractive (Ståhl 1993).

There has previously been an element of coercion involved in soil conservation. In a sociological survey with 1,000 respondents, carried out in the mid-1980s, the EHRS registered that 22 percent stated that they had been coerced into doing conservation work (FAO 1986b, p. 243). Obviously, such methods will taint this activity strongly, as testified throughout Africa in the colonial era.

An additional problem concerns the way the conservation message has been delivered. Conservation has not been fully integrated into extension, which has largely remained crop production-oriented (ibid., p. 265). This has been discussed above as one of the indirect causes behind the continuing extent of land degradation.

4. A FUTURE STRATEGY

This section attempts to assess the problem of land degradation in Ethiopia and suggest priorities for future work, with due consideration to capacity constraints. The discussion in this section will proceed on two levels. First, there is a need to relate land degradation issues to an overall perspective on agriculture and general economic and social development. Second, there is a need to look more specifically at selective interventions to protect and rehabilitate land.

4.1 An Enabling Environment to Combat Land Degradation

Measures to combat land degradation should be seen as part of an overall strategy to promote sustainable agricultural and social development. The various levels of government in Ethiopia need to provide an enabling environment for agricultural growth and rural development through the following:

1. Provision of a stable economic environment with well-defined, secure, and socially acceptable property rights that will encourage land managers to take a long-term view of investments in their land.

2. Alleviation of population pressure by providing family planning and other health and educational services to rural households to match voluntary demand.

3. Removal of any monopolistic remnants in agricultural markets and promotion of competition and market-based pricing of inputs and outputs.[19] This will encourage the more effective supply of modern inputs (enhancing ground cover) and encourage the cultivation of perennial crops for export with beneficial environmental qualities.[20]

4. Improving rural transport to improve market access for farmers, while maintaining protection for reserves and other remaining areas with high significance for biodiversity.

5. Funding of farming systems research with a focus on (a) enhancing understanding of the extent and rate of land degradation and (b) improving small-scale farming techniques, including directly yield-raising agronomic practices combined with soil and water conservation measures.

6. Delivery of problem-oriented, demand-driven information and extension services, including technical advice on conservation measures through a cost-effective, integrated network of extension agents. A prerequisite for this is the building of capacity among personnel to deliver appropriate conservation messages in an iterative, participatory process with farmers. This approach is already well developed in Carucci and others (1993).

If a conducive environment is provided for agricultural growth, small-scale farmers will undertake those conservation actions that appear financially attractive to them and they will maintain those investments because it is in their own interest to do so.

4.2 Targeted Interventions to Combat Land Degradation

Given that farmers will remain poor and are likely to apply a limited on-farm perspective, a short-term horizon, and a high discount rate when making their decisions, there is a valid case for well-targeted public intervention and investment in appropriate soil conservation measures. Past conservation programs have been criticized for lack of proper priority setting: " . . . the level of activity—in both physical and monetary terms—shows no logical relationship to the losses experienced from the effects of degradation." (Aggrey-Mensah and others 1985, p. xii).

Many ways of assigning priorities have been suggested in the land degradation literature. Barber (1984, p. 36) has suggested the use of both a Physical Erosion Hazard Index (EHI) and a Soil Chemical Erosion Hazard Index. The former compares the current erosion rate with what is considered "tolerable" to maintain at least a 50-millimeter soil depth for at least 100 years. This disregards any economic or financial conditions and simply shows that the most shallow soil and the ones degrading the fastest are the highest priorities. The latter index is more complex but relates soil fertility classes to qualitative categories of hazard in relation to organic matter content,

[19] This should not preclude government from making arrangements to protect the nation from the ravages of droughts, such as through stock holding of physical or financial reserves.

[20] Not all export commodities have environmentally beneficial impacts: tobacco, for example, requires substantial amounts of fuelwood for its curing, but this is not a significant alternative in the Ethiopian context.

several different nutrients, and aluminum toxicity. Again, there are no considerations regarding actual land use and output.

A second example can be taken from the EHRS. There is not much discussion of criteria in this study, but the following guidelines for prioritizing interventions are suggested:

1. urgency
2. possible speed of implementation
3. acceptability to peasants
4. technical success probability
5. potential economic impact

Each item was ranked with a number of stars from 1 to 3. An overall ranking was given, ostensibly based on the number of stars. This was *not*, however, carried through quite consistently. Top priority was given to broad categories of land (FAO 1986b, p. 25) while lowest priority was given to already irreversibly degraded wastelands. The latter appears immediately plausible without any formal process of prioritization, whereas the former leaves the decision maker with a residual problem not much different from the original one. In sum, the prioritization scheme, as developed, is based on vague criteria, is not consistent, and arrives at weak results.

In a separate discussion about priorities in the choice of conservation measures, economic rates of return (ERR) were compared across zones for the same type of investment, for example, bunds (ibid., p. 26) but also across mutually exclusive conservation investments in the same area (bunds versus terraces, and so on [ibid., p. 37]). The former is acceptable and useful, whereas the latter is inappropriate. The reason is that a relative rate of return pertaining to different investments does not provide any information about absolute returns; hence, decision makers may be misguided in choosing a small investment with high relative but small absolute returns, while foregoing a larger investment with lower relative but higher absolute returns.

The technical set of feasible conservation measures has been well elaborated (Thomas 1984b; Hurni 1985a). Specific conservation measures have also been analyzed from a cost-benefit perspective in two reports by Aggrey-Mensah and others (1984 and 1985) and by Sutcliffe (1993). The general message of the former two is that there is a whole set of economically viable interventions: structural measures as well as cover retention, crop intensification, and fertilizer use. Profitability, however, varies strongly across zones, and no blanket recommendations are given. An important result of Aggrey-Mensah's and Sutcliffe's work is that financial returns appear generally low and that the gestation period for return on conservation investment is generally long, sometimes counted in decades rather than years. In such cases, little spontaneous conservation would be expected to take place; indeed this is borne out by field observations.

Area-based conservation projects can only marginally contribute to the self-propelled efforts of farming households. It has been estimated (Aggrey-Mensah and others 1984, p. xii) that formal conservation measures had only covered 1.5 percent of the area in need of conservation measures as of 1983. Realistically, the resources available for soil conservation will continue to be limited; there is, therefore, a need to guide public support to this sector. There is also a need for targeted interventions as the off-site impacts of soil erosion will not enter into the private cost-benefit calculations. The protection of hydropower dams, for example, will often warrant conservation measures, but the extent of these must be based on site-specific evaluations.

Grohs (1994) has shown how careful selection of target districts in Zimbabwe can economize on resources. Using three criteria—predicted sheet erosion, gross annual crop income per farm, and future production potential—and a simple grouping in "high" and "low" categories allowed the division of the 53 districts into six categories. Targeting seven in the short run addressed more than half the annual income lost due to erosion. Such simple rules of thumb serve well to set the stage for more sophisticated and detailed analyses at a lower level of aggregation.

In conclusion, the following are noted:

1. Conservation and improvements to farm productivity must go together, and that measures to enable agricultural growth to take place will often coincide with the best interests of the environment.

2. Financially driven conservation measures will not be sufficient to become socially optimal, and additional, well-targeted measures are desirable where significant off-farm externalities exist. Such measures must be site-specific and take note of technical parameters as well as economic and financial conditions.

3. The guiding principle for conservation investments should be to maximize the net present value of the resources utilized. Areas that require particular attention include: zones (1) in which the process of land degradation is particularly high, (2) in areas in which the value of crops and/or livestock threatened is particularly high per area unit, and (3) in which significant off-site impacts of land degradation may be felt (e.g., hydropower or irrigation dams). Promising examples of the use of Geographic Information Systems for diagnostic approaches to land degradation in specific zones are given in Helldén (1987) and Griffiths and Richards (1988).

It would be unwise to attempt even further specification of measures at this stage: removing current disincentives to conservation practice and providing an environment in which land managers can define their own priorities and act on them are the major messages of this report.

APPENDIX 1:
Reassessment of Land Degradation Costs

This appendix provides a detailed background to table 4 in the main text.

The Gross Annual Immediate Loss (GAIL)

First, consider the cost of soil *erosion*. Using a matrix derived by Sutcliffe (1993 p. 41) relating various rates of soil loss per annum with relative decline in yield, but modifying the assumed soil loss rate to about 20 tons per hectare per year—or about 2 millimeters per year—an average for all cereals of 0.4 percent annual decline as a function of soil loss is obtained. The total cereal harvest in 1985 was some 6 million tons (ibid., p. 31). Not all of this is affected by erosion, however. The table below illustrates this point.

Table A.1: Distribution of Soil Depth Classes

Soil depth *(cm)*	Relative share *(percent)*
> 150	47
100–150	22
50–100	20
25–50	7
< 25	3

Source: Sutcliffe (letter to the authors, June 7, 1994, p. 10).

Starting with the first soil-depth class, a loss of about 2 millimeters per year, and the simplifying assumption that the critical depth is 100 centimeters for all crops concerned, the remaining time for this class to enter the critical phase is 500 millimeters/2 = 250 years; hence, even the user cost is negligible.

Taking the second category, only 2 millimeters/500 millimeters = 0.4 percent will enter into the critical phase per year. Only for that portion, the annual drop of 0.4 percent in yield would apply; hence, we will also disregard this depth class in our calculations.

Depth classes below 100 centimeters are taken to be affected by the annual decline in yield of 0.4 percent per year. As for the lowest class (under 25 centimeters) it is likely that some of that land will cease entirely to be of productive use; hence, the relative drop will be higher than assumed here, but the absolute drop will still not be very considerable given the depressed yield level that these areas must experience. Since the relative share of the last depth class is so small, we simplify by aggregating it with the other classes. In conclusion, the relative decline rate is taken to affect 30 percent of the cropland. This leads to a loss of grain of some 7,000 tons.

Prices used (EB890/ton) are from 1985–86 (ibid., p. 52) and are updated to 1994. This is done using the average rate of inflation for the period 1980–91 (2.4 percent [World Bank 1993b]), for 1986–90, and the quota of the Retail Price Index for Addis Ababa for May 1994 and January 1991 (World Bank, unpublished data). This is crude, but there is no better information available; hence, 890 x $(1.024)^5$ x (1.428) = EB1,431. This results in an economic loss of EB10 million, or about US$1.7 million.

The impact of lower crop yields on livestock feed availability is estimated at about EB1 million in 1985 by Sutcliffe. On the basis of the analysis presented in appendix 2, it is assumed that the physical impact of erosion could be halved. A figure of EB0.5 x 1.608 = EB0.8 million is therefore used as the estimate for 1994.

Second, consider the cost of nutrient losses due to the burning of dung and crop residues. Sutcliffe's revised calculations (letter to the authors, June 7, 1994, p. 10) show that the opportunity cost for burning of crop residues is livestock production foregone, not grain loss, although this is not far behind in value. If this is correct, then we should not concern ourselves with use of crop residues as energy, rather than livestock feed in this particular context of "land degradation" as is indeed the focus of this report. The removal of residues from land is rational, as its value is higher as livestock feed than as fertilizer[21]; hence, removal of crops does not constitute "land degradation" in a meaningful sense of the word, as it is taken from its best alternative use as livestock feed to be used as fuel. The conclusion is to take out the crop residue estimates of the total nutrient loss from our calculations.

Using the same basic model as Newcombe and Sutcliffe, a scenario can be reconstructed using functions relating dung quantities removed to nutrient content and nutrient loss to crop loss (6.9 kilograms per kilogram N or P [ibid., p. 11]); the result is a loss in 1994 of EB626 million, i.e. US$104 million.

Thus, total GAIL amounts to EB10 + EB0.8 + EB626 = EB637 million, or about US$106 million. The loss measure calculated amounts to about 3 percent of agricultural GDP. This is based on the agricultural GDP for 1992 (US$2,984 million) as reported in the *World Development Report* (1994) adjusted for inflation of the dollar until 1994 (3.9 percent per year): US$3,221 million.

Gross Discounted Future Loss (GDFL)

Because the loss of soil particles is essentially irreversible (for a given land unit) the annual losses (GAIL) continue over the years. The concept of sustainability encourages a long-term view of natural resource management; there is no logical reason to put a definite time horizon at a particular year in the future. The power of discounting will make future losses less and less significant, but in principle the time horizon should be infinite. This assumption also reduces the algebraic expression to one that is extremely simple: GDFL = GAIL/r, where r (the discount rate) is put at 10 percent, following standard World Bank practice. The result, about EB108 million for the erosion impact, is a present value of the loss of productive capacity over an infinite time horizon.

Accounting for future losses due to breaches in the nutrient cycle in any particular year is not strictly parallel to the accounting for erosion losses. In circumstances in which the supplies to the available nutrient store from mineralization, atmospheric precipitation, and retained organic matter were higher than the total of both crop removals and the nutrient breach, restoration of nutrient retention should allow full recovery of productivity; however, this does not mean that the crop yield would not have been even higher in year two, had the nutrient loss in year one not taken place. There are numerous reports of

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[21] A possible objection is that this disregards the cover aspect of crop residues. We have separately, however, accounted for the average soil erosion, given the average removal of crop residues from cropland; hence, that cost has already entered into our considerations. This does not imply that I may not be perfectly rational under certain conditions to leave more crop residues on the land.

positive responses to fertilizer application in Ethiopia (e.g., Ethiopia 1988b, p. 74); hence, there could be some lasting impact even if the original level of nutrients is replenished. The impact is not lasting over several years, however, as the nutrient store available in a particular year, if available to plants and used, would be absorbed by that year's crop, and hence (largely) removed. Therefore, the cost of the nutrient loss should be counted only once.

The conclusion is that *the GDFL concept does not apply* in the case of nutrient breaches. The GDCL applies, however, as there will be a stream of GAILs, probably increasing due to population growth and mounting scarcity of wood fuel.

Gross Discounted Cumulative Loss (GDCL)

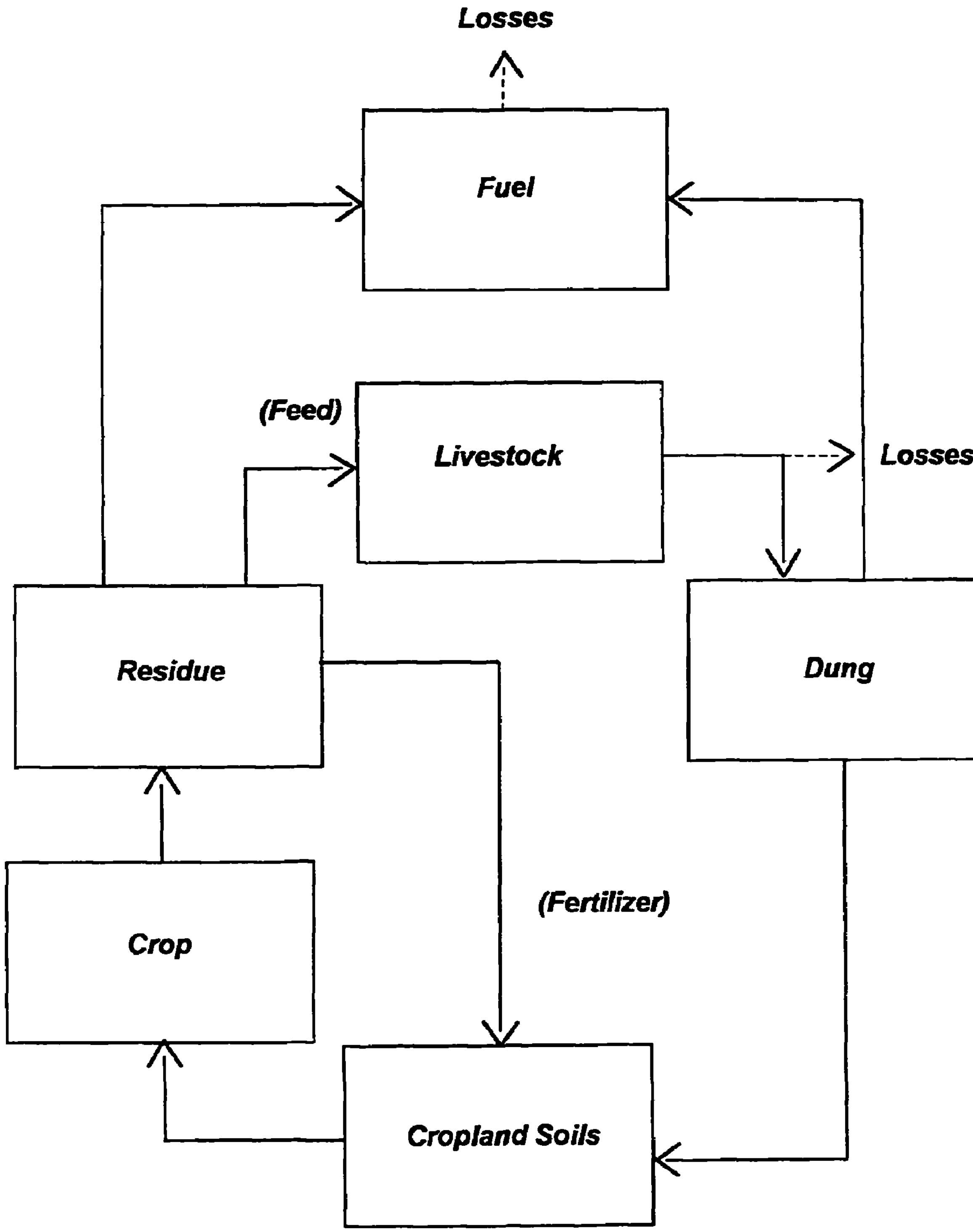
Since land degradation is a cumulative process, in which each year's erosion and nutrient removal is followed by another, layers of costs are added on top of each other. The size of this accumulation will depend very much on the point of reference or base year chosen for the analysis. Logically, the GDCL is one measure to be put against potential investments in combating land degradation; it is the potential benefit side of successful soil conservation.

First, consider the impact of soil erosion. Using the previously defined decline rate of 0.4 percent per year in a spreadsheet, the declining stream of crop yield is projected 100 years ahead, deducted from a hypothetical "without" land degradation stream, and multiplied with a constant real price (1994) of EB1,431 to produce an annual loss figure. This figure is discounted back to a present value in 1994, using a rate of 10 percent. The resulting present value is about EB3.4 billion (US$566 million).

Second, consider the impact of nutrient losses. In Sutcliffe (1993, p. 14), growth in the use of dung and residue of about 2.5 percent per annum is assumed.

Using the same basic model as Newcombe (1984) and Sutcliffe (letter to the authors, June 7, 1994, p. 10), a scenario can be constructed using (as for the GAIL) functions relating dung removal to nutrient loss and nutrient loss to yield loss. Furthermore, we add a dung removal growth assumption roughly along with the population growth loss increases in efficiency and same fuel substitution (2.5 percent). Since the livestock herd and its dung production cannot grow without limit and since there are limits to what can reasonably be collected and returned to cropland, a cap of 20 million tons (about five times the current amount) was imposed. This is slightly lower than the total dry matter dung prediction in 1981–82 (Newcombe 1984). Using a time horizon until the year 2100 and a discount rate of 10 percent, the result is a present value of some EB8.3 billion.

The Nutrient Cycle



APPENDIX 2:
Redeposition: the Neglected Variable

Redeposition of soil lost from a particular area is clearly of great importance when calculating the total losses from a larger system. Information on this point is extremely scarce and forms a high priority area for further land degradation research. Many observers have merely noted the scarcity of data and evaded the issue by assuming a zero rate of redeposition. This paper argues that this is generally far from the truth and that it is better to attempt an assessment of the real order and test the sensitivity of results with respect to assumptions made on this point. The importance of this approach will be illustrated below.

Empirical results from one watershed cannot be uncritically applied to another; the variables influencing sediment delivery ratios may vary considerably.[22] Nevertheless, it is important to observe what empirical evidence there is and assess what a reasonable interval of assumptions could be for Ethiopia.

With all the efforts that went into the *Ethiopian Highlands Reclamation Study* (EHRS) (FAO 1986b), it is disappointing to find so little by way of addressing the issue of redeposition of eroded material. Barber (1984, pp. 22–23) deals only briefly with this issue but quotes estimates showing sediment delivery ratios[23] in some watersheds of 2.5–5 percent of estimated soil losses from hill slopes derived by the Universal Soil Loss Equation.

The main text of the EHRS (FAO 1986b, p. 207) postulates a redeposition rate of 90 percent and assumes this to take place in proportion to the area coverage of different types of land use (cropland, grazing, and forest). There are little data to support this, but reference is made to an FAO study in 1965 showing average sediment loads of between 1 and 3.5 tons per hectare per year at different points in the Awash river basin.[24] The link to the EHRS is that the gross loss is assumed to be 35 tons per hectare per year for all types of land; if 10 percent of this is lost to rivers, it would correspond, roughly to the measurements quoted.

A search for other Ethiopian studies detects two related to the Soil Conservation Research Project (SCRP). First, Hurni (1985b, p. 14 and p. 17) reports two watershed studies over four years (89 hectares and 116 hectares in area) with measured sediment delivery ratios of approximately 4 and 30 percent respectively.

Second, Hurni (1983, p. 136) reports results from a study in Ethiopia in which the USLE was used to estimate a gross soil erosion rate of 120 tons per hectare per year. Sediment measurements in a 30-square-kilometer watershed area indicated a net loss of only 20 tons per hectare per year. This implies a sediment delivery ratio of about 17 percent.

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[22] Jansson (1982) reviews a large number of sediment yield and delivery ratio equations. Among factors that influence sediment delivery are precipitation, rainfall intensity, temperature, gross erosion, relief, channel length, soil type, and so on.

[23] Sediment delivery ratio is the ratio of sediment yield to gross erosion, often expressed as a percentage. The sediment yield is the sediment flow past a given cross section in a stream channel or a river. It is generally expressed in weight per unit of time (Jansson 1982, p. 43).

[24] A second reference is made to an unlisted study by McDougall in 1975 but which gives a value of "up to 5 tons per hectare per year" (FAO 1986b, p. 209). If this is a maximum figure, it is not useful for our purposes.

There is no attempt to systematically review the large international literature on the subject here, but Larson, Pierce, and Dowdy (1983) have presented a study of five different watersheds in Minnesota, which illustrates the great variation of sediment delivery ratios across drainage areas: from less than 1 percent to about 27 percent. There was no simple correlation with watershed size or field erosion rates.

However, although there is a wide band of uncertainty surrounding the sediment delivery ratio, it is misleading to simply assume 100 percent delivery rather than say 1–30 percent, with 10 percent as a "best guess." Furthermore, the actual deposition patterns can have a considerable influence on rate of net soil loss from various classes of productive lands. Ultimately, it could perhaps be assumed that all sediment will be deposited on lower slope areas or riparian zones and be removed from production; however, the time frame in which these processes occur is currently unknown.

The question of redeposition illustrates some of the limitations of reliance on the Universal Soil Loss Equation for conservation planning. The USLE was derived from statistical analysis of a vast body of experimental data from soil loss plots chiefly in locations in the northern midwest in the United States. There is, however, considerable uncertainty with regard to its universality, given in particular its reliance on correlations between annual rainfall and erosion. In many tropical, subtropical, arid, and semiarid environments, soil erosion is an event-based process with significant variations in relation to the nature of storm events and prestorm soil conditions.

Viewed as a data summary with predictive potential, the USLE is now widely recognized as not being universal; as a result there is growing recognition of the need for a more general concept of a probability distribution of soil loss. Rose (1984, p. 151) has noted that despite the most useful contribution made by the USLE to the prediction of erosion, the need remains to investigate approaches that attempt to represent the processes of erosion, transport, and deposition more explicitly. The USLE represents only erosion, not explicitly deposition at all; it has no capacity, therefore, to indicate where eroded material might be deposited elsewhere in the landscape.

Although no empirical data are available on deposition patterns in relation to geomorphic parameters in Ethiopia, the potential significance of redeposition can be seen from the hypothetical tables presented in this appendix. These tables show the results of varying the assumptions on this point. A matrix has been constructed that allows both the overall sediment retention ratio (or the inverse, "sediment export") and the land-use specific retention rate to be inserted. It is shown in the tables below that even a generous allowance for the inter-land-use transfer of sediment and for the "export" of soil into rivers will leave considerable potential for redeposition on cropland—the major focus of concern here.

We recognize that much of the soil retained within the cropland category will be redeposited on marginal areas, such as along grass strips and natural field boundaries. Depositions may also occur on land with a soil depth that is already sufficient to support unconstrained plant growth. Research done by the SCRP has confirmed this pattern (Hurni, letters to the authors, June 15, 1994, p. 5 and June 16, 1994, p. 1). We do not, however, assume any productivity *increase* in any land category due to deposition, although such soil depositions will prolong the period of agricultural use. What we are maintaining is that the net rate at which the soil is lost to agriculture is lower than the gross rate of soil erosion as estimated by even the more rigorous geomorphic applications of USLE-type calculations (Sutcliffe, letter to the authors, June 7, 1994, p. 13). *Hence, there is reason to adjust previous calculations of the rate of soil loss down even further than suggested by the National Conservation Strategy Secretariat.*

Further investigation of sediment deposition processes in Ethiopia is clearly warranted both to improve estimates for soil conservation planning and to help develop locally appropriate conservation measures. Erosion deposition is a differential process with the coarser, nutrient-poor particles being deposited first, followed by sands, and finally by the more nutrient-rich particles (Moss 1984). Ethiopian farmers clearly understood these processes when they plowed in the nutrient-rich soil trapped in soil conservation bunds in the period immediately following the collapse of the Derg regime (see discussion page 31). Although such practices would be destructive if not followed by new conservation efforts, they also suggest that there may be merit in devising low-cost, more dynamic soil conservation measures that would allow farmers to both trap and redistribute eroded sediments. Understanding sediment erosion, transport, and deposition processes would clearly be of assistance in the design of dynamic farmer-oriented systems.

ETHIOPIA: SOIL TRANSFER MATRIX

			RECIPIENT LAND CATEGORY								
FROM:	SHARE(%)	T/HA/Y	GRAZING	UNCULT.	CROPL	WOODL	UNPROD	FOREST	PERENN	EXTERN
GRAZING	47.2	5	2.50	0.71	0.50	0.31	0.14	0.14	0.06	0.50
UNCULTIV	18.7	5	1.16	2.50	0.32	0.20	0.09	0.09	0.04	0.50
CROPLAND	13.1	42	9.12	3.62	21.00	1.57	0.73	0.70	0.33	4.20
WOODLAN	8.1	5	1.03	0.41	0.29	2.50	0.08	0.08	0.04	0.50
DEGRADE	3.8	70	13.74	5.44	3.81	2.36	35.00	1.05	0.49	7.00
FOREST	3.6	1	0.20	0.06	0.05	0.03	0.02	0.50	0.01	0.10
PERENNIA	1.7	8	1.54	0.61	0.43	0.26	0.12	0.12	4.00	0.80
TOTAL	96.2	12	29.26	13.36	26.40	7.23	36.19	2.66	4.97	1.20
NET LOSS			-24	-8	16	-2	34	-2	3	-1

Sediment retention fraction within each land use category: 0.5

Sediment export fraction from entire land use system: 0.1

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REFERENCES

Abebe, F. 1992. "Ethiopian Land Use Issues." *Tropical Agrisystems* 3: 3–4.

Aggrey-Mensah, W., P. de Keizer, G. Possio, K. Lakew, S. Adebo, and Y. Hagos. 1984. *Degradation of the Ethiopian Highlands and Actions to Combat it: Social and Economic Implications Costs and Benefits*. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Aggrey-Mensah, W., P. de Keizer, G. Possio, K. Lakew, and S. Adebo. 1985. *Cost-Benefit Analysis of Alternate Strategy Proposals for Reclaiming and Developing the Highlands*. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Ahmad, Y. J., S. El Serafy, and E. Lutz. 1989. *Environmental Accounting for Sustainable Development*. Proceedings of a UNEP-World Bank Symposium. Washington, D.C.: The World Bank.

Archer, A. C. and Solomon Kebede. 1984. *An Assessment of the Current Grassland and Forestland Situation*. Working Paper 10. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Aregay, M. W. 1986. "Land Tenure and Agricultural Productivity." *Proceedings of the Third Annual Seminar*. Addis Ababa: Department of History, University of Addis Ababa.

Barber, R. 1984. *An Assessment of the Dominant Soil Degradation Processes in the Ethiopian Highlands: Their Impacts and Hazards*. Working Paper 23. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Bekele-Tesemma, A., A. Birnie, and B. Tengnas. 1993. *Useful Trees and Shrubs for Ethiopia: Identification, Propagation, and Management for Agricultural and Pastoral Communities*. Nairobi, Kenya: Regional Soil Conservation Unit (RSCU), Swedish International Development Authority.

Belete, Abenet, John L. Dillon, and Frank M. Anderson. 1991. "Development of Agriculture in Ethiopia since the 1975 Land Reform." *Agricultural Economics* 6: 159–75.

Bruce, J. W., A. Hoben, and D. Rahmato. 1993. *After the Derg: An Assessment of Rural Land Tenure Issues in Ethiopia*. Draft Discussion Paper presented to a Workshop on Rural Land Tenure Issues in Ethiopia, August 27–29, 1993, Addis Ababa.

Bruijnzeel, L. A. 1990. *Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review*. Paris: Humid Tropics Programme, UNESCO.

Campbell, J. 1991. "Land or Peasants? The Dilemma Confronting Ethiopian Resource Conservation." *African Affairs* 90: 5–21.

Carucci, V., M. Zeleke, T. Alemu, and A. Yirga. 1993. *How to Make a Community Forestry and Soil Conservation Work Plan (Local Level Participatory Planning Approach)*. Addis Ababa: Ministry of Natural Resources Development and Environmental Protection, Government of Ethiopia.

Cassells, D. S., M. Bonell, L. S. Hamilton, and D. A. Gilmour. 1987. "The Protective Role of Tropical Forests: A State-of-Knowledge Review." In N. T. Vergara and N. D. Briones, eds. *Agroforestry in the Humid Tropics: Its Protective and Ameliorative Role to Enhance Productivity and Sustainability*. Honolulu, Hawaii: Environment and Policy Institute, East-West Centre.

Christophersen, Kjell. 1992. *Ethiopia Forestry Action Plan: Forest Economics Technical Report*. Washington, D.C.: EFAP Secretariat and World Bank.

Cloutier, P., G. Posio, and D. Alemayehu. 1984. *Agriculture: Strategies for Reclamation and Development*. Working Paper 14. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Constable, M. 1984. *The Degradation of Resources and an Evaluation of Actions to Combat It*. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Dewees, P. A. 1989. "The Wood Fuel Crisis Reconsidered: Observations on the Dynamics of Abundance and Scarcity." *World Development* 17: 1159–72.

Egziabher, T. B. 1991. "Management of Mountain Environments and Genetic Erosion in Tropical Mountain Systems: The Ethiopian Example." *Mountain Research and Development* 11(3): 225–230.

Ethiopia, Ministry of Agriculture. 1988a. *Study of Traditional Conservation Practices*. Addis Ababa: Tahal Consulting Engineers, Ltd.

Ethiopia, Ministry of Agriculture, National Fertilizer and Inputs Unit (NFIU). 1988b. *Results of the 1986–87 FTS Factorial Fertilizer Trials and Its Partial Factorial Fertilizer Trials*. Working Paper No. 29. Addis Ababa.

Ethiopia, Ministry of Natural Resources Development and Environmental Protection. 1993. *Ethiopia Forestry Action Program, Draft Final Report*. Volume II. *The Challenge for Development*. Addis Ababa.

Ethiopia, 1994a. "Toward a Strategy of Economic Development in Ethiopia." Mimeo of extracts from *Overall Development Strategy and Agricultural Sector Strategy for Ethiopia*. Addis Ababa.

Ethiopia, Ministry of Planning and Economic Development, National Conservation Strategy Secretariat. 1994b. *National Conservation Strategy*. Volume I, *The Resource Base, Its Utilization and Planning for Sustainability*. Volume II, *National Policy Framework*. Addis Ababa.

Food and Agriculture Organization (FAO) of the United Nations. 1979. *A Provisional Methodology for Soil Degradation Assessment*. Rome.

———. 1986a. *Early Agro-Meteorological Crop Yield Assessment*. FAO Plant Production and Protection Paper 73. Rome.

———. 1986b. *Highlands Reclamations Study: Ethiopia*. Final Report. Volume I.

———. 1986c. *Highlands Reclamations Study: Ethiopia*. Final Report. Volume II.

Glantz, Michael and Nicolai S. Orlowski. 1986. "Desertification: Anatomy of a Complex Environmental Process." *Natural Resources and Its People: Conceptual Issues in Interdisciplinary Research*. Boulder: Westview Press.

Goering, T. J. 1990. *Conservation-Based Rural Development in the Context of the National Economy: Macro-Economic Constraints*. Paper submitted to the Conference on the National Conservation Strategy, May 22–25, Addis Ababa. Addis Ababa: Office of the National Committee for Central Planning, Government of Ethiopia.

Gretterud, Sverre. 1994. *Population-Environment Links: Testing a Soil Degradation Model for Ethiopia*. Divisional Working Paper No. 1994-46. Washington, D.C.: Pollution and Environmental Economics Division, Environment Department, The World Bank.

Griffiths, J. S. and K. S. Richards. November 1988. "Application of a Low-Cost Data Base to Soil Erosion and Soil Conservation Studies in the Awash Basin, Ethiopia." *Land Degradation & Rehabilitation* 1: 241–62.

Grohs, Florian. 1994. *Economics of Soil Degradation, Erosion, and Conservation: A Case Study of Zimbabwe*. Institute for Agro- and Socio-Economics. Kiel: University of Hohenheim.

Grunder, M. 1988. "Soil Conservation Research in Ethiopia." *Mountain Research and Development* 8: 145–151.

Helldén, Ulf. 1987. *An Assessment of Woody Biomass, Community Forests, Land Use, and Soil Erosion in Ethiopia*. Final report of a feasibility study on the use of remote sensing and GIS-analysis for planning purposes in developing countries. Lund: Swedforest Consulting AB.

Hudson, Norman. 1986. *Soil Conservation*. London: BT Batsforth, Ltd.

Hurni, Hans. 1983. "Soil Erosion and Soil Formation in Agricultural Ecosystems Ethiopia and Northern Thailand." *Mountain Research and Development* 3(2): 131–42.

———. October 1985a. *Soil Conservation Manual for Ethiopia*. Addis Ababa: Ministry of Agriculture, Government of Ethiopia.

———. November 1985b. *Erosion-Productivity-Conservation Systems in Ethiopia*. Paper presented for Fourth International Conference on Soil Conservation. Berne.

———. 1988a. "Degradation and Conservation of the Resources in the Ethiopian Highlands." *Mountain Research and Development* 8(2–3): 123–30.

———. 1988b. *Ecological Issues in the Creation of Famines in Ethiopia*. Berne: University of Berne.

———. 1990. *Toward Sustainable Development in Ethiopia*. Paper presented at Group for Development and Environment. Berne: Institute of Geography, University of Berne.

Jansson, M. B. 1982. *Land Erosion by Water in Different Climates*. Published as part of a series. UNGI Report No. 57. Uppsala: Department of Physical Geography, Uppsala University.

Krauer, J. 1988. *Rainfall, Erosivity, and Isoerodent Map of Ethiopia*. Research Report 15. Berne: Institute of Geography, University of Berne in association with the United Nations University.

Larson, W. E., F. Pierce, and R. Dowdy. February 1983. "The Threat of Soil Erosion to Long-Term Crop Production." *Science* 219: 458–65.

Melese, B. 1992. "Integrated Planning and Rehabilitation of Arable Lands: The Case of Sirinka Catchment (Ethiopia)." In *Proceedings of the Second International Symposium on Integrated Land Use Management for Tropical Agriculture*. Brisbane, Australia: Queensland Department of Primary Industries.

Mercer, D. E. and J. Soussan. 1992. "Fuelwood Problems and Solutions." In N. P. Sharma, ed. *Managing the World's Forests: Looking for a Balance Between Conservation and Development*. Dubuque, Iowa: Kendal/Hunt Publishing Company.

Mesfin, Wolde-Mariam. 1992. "Vertical Distribution of Human and Animal Populations in North-Central Ethiopia." *Mountain Research and Development* 12 (4): 357–362.

Moss, A. J. 1984. "Sediment: Redeposition of Soil Materials" In *Soil Erosion Research Techniques*. Conference and Workshop series QL 84001. Brisbane, Australia: Queensland Department of Primary Industries.

Newcombe, K. 1989. "An Economic Justification for Rural Afforestation: the Case of Ethiopia." In G. Schramm and J. J. Warford, eds. *Environmental Management and Economic Development*. Prepared for the World Bank. Baltimore: Johns Hopkins University Press.

Place, F. and P. Hazell. 1993. "Productivity Effects of Indigenous Land Tenure Systems in Sub-Saharan Africa." *American Journal of Agricultural Economics* 75: 10–19.

Repetto, R., W. Magrath, M. Wells, C. Beer, and F. Rozini. 1989. *Wasting Assets: Natural Resources in the National Income Accounts*. Washington, D.C.: World Resources Institute.

Rose, C. W. 1994. "Process Models of Hydrologic Soil Erosion and Deposition Processes." In *Soil Erosion Research Techniques*. Conference and Workshop Series QL 84001. Brisbane, Australia: Queensland Department of Primary Industries.

Sarin, M. 1990. "The Nada Chula Programme." In S. Joseph, K. Krishna Prasad, and H. B. van der Zaan, eds. *Bringing Stoves to the People: An Assessment of Impact*. Nairobi, Kenya: Foundation for Woodstove Dissemination.

Smiet, A. C. 1987. "Tropical Watershed Forestry Under Attack." *Ambio* 16: 156–158.

Soil Conservation Research Project (SCRP). 1991. *Eighth Progress Report (Year 1988)*. Volume 9. Berne: University of Berne in association with the Ministry of Agriculture, Government of Ethiopia.

Ståhl, M. 1993. "Land Degradation in East Africa." *Ambio* 22: 505–508.

Stocking, M. and A. Pain. 1983. *Soil Life and the Minimum Soil Depth for Productive Yields: Developing a New Concept*. Discussion Paper No. 150. Norwich, England: School of Development Studies, University of East Anglia.

Sutcliffe, J. P. 1993. *Economic Assessment of Land Degradation in the Ethiopian Highlands: A Case Study*. Addis Ababa: National Conservation Strategy Secretariat, Ministry of Planning and Economic Development, Transitional Government of Ethiopia.

Thomas, D. B. and Y. Adamseged. 1984a. *Soil and Water Conservation in the Ethiopian Highlands: An Assessment of Requirements and Evaluation of Activities*. Working Paper 13. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

———. 1984b. *Strategy Proposals for Soil and Water Conservation in the Ethiopian Highlands*. Working Paper 25. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

U.N. Environment Programme (UNEP). 1984. *General Assessment of the Progress in Implementation of the Plan of Action to Combat Desertification 1978–84*. Mimeo. A/35/396. Nairobi.

Wiersum, K. 1984. "Surface Erosion Under Various Tropical Agroforestry Systems." In C. L. O'Loughlin and A. J. Pearce, eds. *Proceedings of the IFRO Symposium on Effects of*

Forest Land Use on Erosion and Slope Stability. Honolulu, Hawaii: Environment and Policy Institute of the East-West Centre.

Wischmeier, W. H. and D. D. Smith. 1978. *Agricultural Handbook 537*. Washington, D.C.: U.S. Department of Agriculture.

Wood, A. and M. Ståhl, March 1990. *Ethiopia: National Conservation Strategy. Phase I Report*. Unpublished mimeo prepared for the Government of the Ethiopia with the assistance of the World Conservation Union (IUCN).

World Bank, Eastern Africa Department, Division of Agriculture and Environment. 1993a. *Rangelands*. Mimeo of technical notes. Ethiopia World Bank Environment Mission, June–July 1993.

———. 1993b. *World Development Report*. New York: Oxford University Press.

———. 1994. *World Development Report*. New York: Oxford University Press.

World Food Program (WFP) 1989. *Mid-Term Evaluation of Project 2488: Summary of Mission's Main Conclusions and Recommendations*. Addis Ababa.

Wright, C. and Y. Adamseged. 1984. *An Assessment of the Causes, Severity, Extent and Probable Consequences of Degradation in the Ethiopian Highlands*. Part of the Ethiopian Highlands Reclamation Study. Addis Ababa: Land Use Planning and Regulatory Department, Ministry of Agriculture, Government of Ethiopia, and FAO.

Young, Anthony. 1989. *Agroforestry for Soil Conservation*. Wallingford: C. A. B. International and International Council for Research in Agroforestry.

Zewde, B. 1991. *A History of Modern Ethiopia 1855–1974*. London: James Curry Press.