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Land Degradation

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1 Definition

"'Land degradation' means reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

(i) soil erosion caused by wind and/or water;
(ii) deterioration of the physical, chemical and biological or economic properties of soil; and
(iii) long-term loss of natural vegetation." [29]

Disregarding the issue of long-term loss of natural vegetation (which will be covered in this project under the headings of deforestation and biodiversity), land degradation primarily relates to a reduction in soil quality and quantity as an input to the production of agricultural crops. But there are also off-site effects, such as loss of watershed function.

Soil quality relates to the chemical, physical and biological properties of the soil, and how these are distributed throughout the soil profile. Scientists use an array of indicators to describe soil quality: pH, organic matter content, plant-available nutrients, porosity, grain size distribution, water permeability and retention capacity, topsoil depth, presence of chemicals toxic to plants or plant consumers, etc. These properties vary vertically within the soil profile and horizontally from site to site. They also interact. Therefore, soil quality cannot easily be described by one variable or an index. Crop yields alone are not a good proxy as they depend on water, fertilizer, seed variety, and crop management practices in addition to soil quality. However, measuring yield *trends* while controlling for other inputs and management can provide an observable and credible measure of *trends* in soil quality.

Agricultural practices fundamentally influence soil characteristics over time. Farmers improve soil nutrient levels by adding manure or fertilizer; reduce acidity by adding lime; and optimize water availability through drainage or irrigation. However, agriculture also entails degradation processes:

- Soil erosion: Clearing of natural vegetation, weeds, and previous crop remains for seedbed preparation leaves the soil with sparse plant cover or root mass to protect it from wind and rainwater impact and surface water flows. The result is more loss of topsoil and

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plant nutrients than would be the case were the land not cleared, or were it under a cropping system with perennial crops or dense plant cover. Intensive grazing may also reduce vegetation and increase erosion.

- Soil compaction and crusting can result from cultivation with heavy machinery and/or depletion of soil organic matter.
- Nutrient depletion or nutrient mining results from removal of plant nutrients with crops removed from fields without replacement through manure or fertilizer. Removing plant residues also reduces soil organic matter content.
- Salinization occurs on irrigated land under arid conditions, when salts are added by irrigation water and not washed away by rainfall.
- Waterlogging may result from irrigation with poor water control.
- Pollution, acidification, alkalization, and water-logging are often important locally.

Soils vary in their resilience to these forms of degradation depending on characteristics such as slope, soil texture, climate, and cropping pattern. Some aspects of land degradation are less easily reversed than others. Thus, terrain deformation by gully erosion, or total topsoil loss from erosion, or the wiping out of native soil fauna is more irreversible than a negative nutrient balance, or surface sealing and crusting.

Off-site and downstream effects include siltation of dams and waterways, nutrient runoff causing eutrophication, and pesticide runoff. In some locations, wind-blown soils inflict damage on wide areas. Reduction of soil organic matter also releases CO_2 and CH_4 to the atmosphere, contributing to global warming.

2 Extent and trends of land degradation

During the last half-century the global extent of agriculture has increased vastly at the expense of natural forests, rangelands, wetlands, and even desert. Some of the increased land degradation associated with this expansion is compensated by farmers' investment in soils, such as fertilization, terracing, and tree-planting. New soil formation also occurs through natural processes, but in general these proceed too slowly to compensate for human-induced degradation.

No developing country has installed a system for monitoring soil quality at a national scale. Existing assessments are based on consultation with experts, extrapolation from case studies, field experiments and other micro studies, or inferences from land use patterns [24]. While little is known about current status, even less is known about trends, and to what extent the degradation processes are human-induced.

The most influential assessment of aggregate land degradation has been the GLASOD study, in which 250 experts contributed assessments of land degradation in their countries since the mid 1940s [21]. The results suggest that about 560 million ha of farmland had been degraded – or 38% of the total. Permanent loss of farmland due to human-induced land degradation was estimated to be 5–6 million ha per year, or about 0.3 to 0.5 % of the world's arable land area. However, since this was based on expert judgment, it may "reflect unsubstantiated biases and assumptions" [24]. Thus, Lindert [20] found clear evidence of overstated soil degradation in

GLASOD for China and Indonesia, as well as confusion between soil quality in general and human-induced degradation.

Within specific agro-ecological environments, experimental data from plot and field scale allow soil degradation processes to be observed with greater precision. Long-term data series indicate that intensive farming can cause yield reductions of 50% and more in some environments [13]. Even under best varietal selections and management practices, yields have stagnated and even fallen under long-term intensive monoculture for irrigated rice [6] and rainfed corn [19]. The data underlying these results are, however, limited to a few experimental plots, and the basis for extrapolation to farmers' fields is weak.

A review [24] of 16 studies to assess the global extent, rate, and effects of soil degradation concluded that soil quality on three quarters of the world's agricultural lands has been fairly stable over the last fifty years, but that on the remaining share land degradation is widespread and has accelerated. Productivity has declined substantially on about 16% of agricultural land in developing countries, especially crop land in Africa and Central America, pasture in Africa, and forests in Central America. Land areas of 5 to 8 million hectares have gone out of production each year. These are primarily lands at the margin of cultivation, especially at desert margins and in steeply sloping and high-altitude areas.

Soil nutrient mining is particularly acute in Africa. In 2002/2004 about 85% of African farmland had nutrient mining rates at more than 30 kg nutrients (NPK) per hectare per year, and 40 % had rates greater than 60 kg/ha yearly [18]. Partly as a consequence, Sub-Sahara African cereal yields are the lowest in the world, averaging about 1 ton per hectare – about the same as 20 years ago.

Patterns of degradation vary according to agro-ecological conditions, farming systems, levels of intensification, and resource endowments, but these also interact in important ways with social and economic systems. Temperate lands, for example, are generally more resilient to degradation, but are also associated with societies that have more resources for investing in maintaining and rehabilitating land quality – and for developing alternative sources of livelihood for their citizens. Thus, the areas for prime concern are the tropical and subtropical marginal lands, which have low physical resilience to land degradation, and are also associated with societies in which property rights are weakly defined, information systems are weak, and managerial capacity is low. For poor people, income from land accounts for a larger share of total income, thus making them more vulnerable to degradation. They also have fewer resources for alleviating degradation, and are especially susceptible to the credit market failures and land tenure insecurity, which can raise time discount rates and reduce planning horizons, leading to faster soil mining.

World agriculture is likely to expand in area to cater for population growth and increased demand for food and industrial crops. FAO [5] estimates that the area for arable agriculture will expand by 8 % over the next quarter century, with most of the expansion occurring in developing countries, and much of it from clearing of tropical forests. Continued degradation of existing lands will also raise the land clearing rate. Under current technologies and practices this will have high local costs, but is less likely to lead to large agricultural commodity price increases – or to threaten global food supplies within the next couple of decades [24].

3 What can be achieved and what does it cost?

The main environmental principles for reducing land degradation are to maximize vegetation cover to prevent erosion; replace nutrients removed; prevent accumulation of harmful substances; and put in place structures (terraces, bunds, vegetation strips) to reduce the speed and volumes of water flow over the soil. From this perspective tree crops and perennial crops are preferred, as are intercropping and reduced-tillage systems. High-yielding crops cover the soil better than low-yielding crops [25]. Moreover, obtaining high yields on the best lands reduces the profitability of cultivating marginal lands, leaving more land to be returned to nature (when crop prices decline in response to the increased production).

Most land users exert efforts to maintain future productivity of the land. Our knowledge of what these efforts result in, in terms of degradation and yield losses avoided, is very incomplete. There is limited knowledge of how differences in land use influence land degradation, and of how land degradation in turn influences current and future yield [13]. Our understanding of how changed policies will affect land-use decisions by land users is also incomplete. Land management is the result of decisions of millions of small-scale and large-scale land users. It is therefore extremely expensive to attempt to alter land degradation through direct interventions at the farm or community scale, since the interventions must be replicated many times over to effect large aggregate changes. However, farmers' decisions are shaped by economic incentives, and thus to the extent that markets are pervasive, the decisions of many land users can simultaneously be influenced by policies that alter prices.

In the following, we rank interventions broadly according to increasing cost of wide-scale implementation.

3.1 Price and trade policy reforms

Many countries explicitly or implicitly subsidize practices that increase land degradation, or tax activities that tend to reduce degradation. Examples are subsidies on cultivation of upland crops that drive expansion into the marginal lands; subsidies on water and energy in irrigation schemes; tariff protection for land-degrading crops; and export taxes on more environmentally benign crops. Reversal of these policies will have very high benefit-cost ratio, since their net cost is low, zero, or even negative – as long as political costs are disregarded. Examples include U.S. sugar import quotas, which promote farmland expansion in areas like the Florida Everglades, and developing-country corn import barriers, which have contributed to land expansion and increased intensity of cultivation in ecologically fragile upper-watershed areas of countries like India and the Philippines. Developing countries in particular have undertaken extensive reform of trade policies in manufacturing sectors, driven both by unilateral goals and by the need to conform with international obligations as signatories to regional and multilateral trade agreements. Agricultural trade reform has lagged behind this process, with the result that average agricultural tariffs are now equal to or greater than those on non-agricultural goods in developing countries (Anderson 2006, table 1).

In general equilibrium simulation experiments, implementation of a mid-1990s package of trade liberalization measures in the Philippines, including a modest reduction in cereals prices, is found to exert a substantial effect on land use. The price of corn, the major annual crop grown in uplands, falls in these experiments by about 0.55%; this fall, along with rises in wages and some input prices, causes a contraction of about 0.5% in demand for upland land for seasonal crops. If corn land is primarily responsible for erosion from upland fields [8] and the base annual soil loss from upland farms is 74-81 million t./yr [16], then the trade reforms could save about 407,000 – 445,000 tons per year once permanent ground cover is reestablished—assuming that this is what happens after corn production ceases. Earlier Philippine studies valued the nutrients lost in soil erosion at $0.60/ton; adopting that as a very conservative indicator of the total value of soil lost, the experiment yields a direct, on-site gain of roughly $250,000—in addition to the other benefits that trade liberalization brings to the economy.

The effects of global trade reform are potentially far higher than can be achieved by this modest trade reform. The Philippines is the world's 11th-ranked country by corn area, with 1.55% of the total harvested area [15]; its average agricultural tariff was 47% in 2001 [3]. The scope for trade policy liberalization is large. India is another relevant case; it has nearly 5% of the world's corn area (7.8 m. ha), and an average tariff on cereals of 21.5% in 2005 [23]. If we assume an elasticity of area planted with respect to price of 1.0, eliminating the tariff will reduce area planted by about 15.6 m.ha. Supposing that the average erosion from corn land is 75 t/ha/yr valued at $1/ton in nutrient losses alone, and that this falls to 25 t/ha/yr under an alternative land use, the policy change would generate immediate savings of $7.8m plus the value of any off-site savings, and about $100m in direct savings over a 30-year period, using a discount rate of 6%.

In these and similar tropical economies, substantive trade liberalization will result in major land use changes. Relaxing protectionist policies on crops which contribute to land degradation in the tropics will shift their production to countries and environments where they can be grown at lower environmental cost [9]. In the case of subsidies, their relaxation creates fiscal savings that provide an opportunity to compensate upland farmers, who are often extremely poor. For environmental taxes, e.g. on activities that lead to downstream siltation, the challenge is to monitor and assess such widely dispersed activities.

Addressing policy-induced distortions that operate through markets to promote land-degrading activities is the most efficient single means to address land degradation in large areas of the developing world. The success of policy reforms, however, relies on the pervasiveness of markets and the feasibility of market-based instruments. Nor are trade policy reforms on their own a panacea for environmental damage; in countries with comparative advantage in land-degrading crops, greater trade openness without complementary environmental protection policies may lead to rapid worsening of land degradation.

3.2 Capital market failures

Liquidity constraints under imperfect credit markets prevent landowners from undertaking otherwise profitable conservation investments.

For poor rural households, financial market failures are pervasive. They face severe liquidity constraints and have very high discount rates. Most estimates of the discount rates of rural poor in developing countries indicate that these rates are far higher than 6%. We can therefore surely say that the "business as usual trend" scenario implies land degradation rates that are higher than would be optimal from a social point of view (as reflected in discount rates of 3% or 6%).

A rough estimate of the marginal rate of return on conservation activities might be obtained by assuming that land users carry out those projects where the expected rate of return is higher than their reservation rate of return, i.e. their discount rate. Assuming that rural households order their investment projects according to expected private returns, and also that households do undertake some land conservation or investment activities, this implies that the marginal land conservation or improvement investment has a return roughly equal to their discount rate. Typical estimates of rates of return for poor rural households in developing countries are surprisingly high: 60% in rural Ghana [28], for example, while a recent survey of empirical studies from South Asia and Africa finds rates varying over a range of 22% to 100% [4]. The primary explanation for these high rates of return are "financial market imperfections that hinder flows of capital into the informal sector" [28].

Analyzing the consequences of an economy-wide easing of capital-constraints for the rural poor certainly requires general equilibrium models. Production costs would decline, leading to expanded output, which would likely lead to lower prices and a dampening effect on supply response. The net effect on land use is ambiguous.

Improving the functioning of financial markets will facilitate land-conserving investments, but may also increase total agricultural investment, leading to an expansion of cultivated area. The net effect of capital market development on land degradation is therefore ambiguous.

3.3 Property rights, land tenure, market failures and externalities

If security of land tenure is weak or absent, land is treated as an open-access resource. It is then difficult to reclaim or to bequeath the value of soil improvements or conservation measures, so land users lack incentives to invest in maintaining long term soil productivity (Barbier 2005). In areas of low population density, land is abandoned when it has been degraded, and farmers move on to clear new land, leaving the degraded land as a negative externality.

Some current research indicates that secure rights do indeed induce higher investment and productivity in developing countries [10-12, 26]. One source suggests that more secure land rights in Ethiopia might induce investments (e.g. in terracing) that increase the value of the land by 5% [12], while land-titling in Ethiopia has been conducted at a cost of only about $US 3.50 per household. In some cases of communal or open-access land tenure, however, there may be strong incentives for investing in the land, since such investments can be a means of obtaining permanent private use rights [27], meaning that investment in tree planting or terracing might actually be higher under less secure tenure. Clearly, the effects on land investment from securing and formalizing land tenure are highly dependent on other aspects of institutions.

Land use rights need not be assigned to individuals in order to capture the benefits of secure tenure. In drylands, reducing grazing intensity can be necessary to halt land degradation. This has in some cases been achieved through empowering local communities to manage rangelands as commons, in others through assigning individual land use rights. Impediments to developing and enforcing tenure regimes that give incentives for sustainable land management are primarily political, but poor capacity in public administration frequently contributes.

Assigning property rights can increase investment in land [12], but is not a sufficient condition for sustainable land use. Soil quality is hard to observe and may therefore be poorly captured in land transactions, reducing the return to such investments relative to more easily observable investments. There are also limits to what property rights can do to prevent land degradation as long as soil generation processes work slowly and land users have a positive time preference for consumption [17]. Finally, the success or otherwise of any efforts to confer more secure property rights in land are entirely dependent on the robustness of national legal systems, without which a certificate of land title has no practical meaning.

3.4 Technology development and productivity growth

The costs of conservation agriculture and nutrient replacement practices may be reduced, and adoption increased by developing new technologies that raise returns to nutrient inputs, or reduce the costs of conservation practices. There is a particularly important role for international and national agricultural research to develop farming systems that conserve or improve soil quality, while being attractive to farmers. Past agricultural research has yielded very high returns [14]. While fixed costs of research can be high, results are often widely applied at very low marginal cost. A meta analysis of 289 studies of rates of return [1] reported mean rates of return of 47% for agricultural research and extension combined. However, the authors express skepticism to the validity of these estimates, worrying that they are overestimated [2]. To be on the safe side, we will therefore assume that mean returns are only half of what was found in these studies. Of course, most of these returns have been related to the value of increased productivity and the concomitant reduced price of food. But pervasive yield increases imply that the current global crop can be grown on a smaller land area than would have been needed to grow the same amount of produce with lower average yields. In this sense, increases in yields have also contributed to sparing land for nature [30] – preserving the land from the degrading effects of agriculture.

Nor is this phenomenon limited to agricultural productivity increases. Thailand's transition from agrarian to industrialized economic structure due to a boom in domestic and foreign investment directed at labor-intensive manufacturing sectors was associated, over the decade 1985-95, with a 17% reduction in the size of the agricultural labor force. This enormous migration, a response to higher labor productivity and thus wages in the manufacturing sectors, resulted in the retirement of large areas of marginal agricultural land previously used for subsistence cultivation [7].

3.5 Direct land use interventions

Many countries have tried measures such as set-aside programs, land use zoning and establishment of conservation areas, bans on "degrading activities" and public reforestation projects. China's Sloping Land Conversion Program, which with a target area of almost 15 million hectares and a budget of $US 40 billion is the world's largest and most ambitious land conservation program. Its 2010 target is an increase in China's forested area by 10-20% and an

11% decrease in cultivated area. The current program, however, lacks "voluntarism" in participation, and therefore suffers from low cost effectiveness and high cost of performance monitoring and evaluation [32]. In general, it is very difficult and costly to police and enforce bans against common and widely dispersed practices when these practices are profitable to land users – or perhaps even necessary for survival. Still, in some cases they may be the only practical approach [31].

Project-based payment for environmental services (PES) schemes provide a means to influence land use by paying compensation (i.e. bribes) to farmers for desisting from environmentally undesirable activities [22]. But since there is no internal mechanism for decreasing-cost replication of PES measures, in benefit-cost terms these are expensive interventions if they are to be widely applied – even before counting the costs of contract enforcement and monitoring.

Preventing or reversing waterlogging and salinization on irrigated areas requires improved water management and, in some cases, installation of drainage systems. Correcting design and engineering mistakes, and ending water and energy subsidies that encourage waste of water are good first steps. The costs of drainage systems are, however, very high.

4 Summing up benefits and costs

To attempt a benefit-cost analysis of the above remediation measures is strictly futile due to the heterogeneity of the projects according to place, time, nature and extent of implementation. There are no "typical" numbers. Option 3.1, removing subsidies that promote land degradation, could have B-C ratios that are infinite, as already argued—if the political costs are disregarded. Option 3.2, assigning and extending private land rights, involves administrative costs, but the benefits are highly uncertain.

In the discussion above we have presented rates of return rather than B-C ratios for actions to reduce land degradation. Measures to counteract land degradation do not lend themselves to be organized as projects, where total project costs and benefits can be assessed. However, rates of return can be recalculated as B/C ratios. E.g. a rate of return of 20% is equivalent to a B/C ratio of 3.32, if we assume equal annual returns, a discount rate of 6%, and a time horizon of 100 years.

Rough estimates of rates of return are given in Table 1. These are recalculated as Benefit Cost ratios in Table 2.

5 Conclusion and broader discussion

Problems of valuation, and even of assigning causality, make it impossible to compute accurate benefit-cost ratios for reducing land degradation. This does not, however, mean that nothing should be done. A precautionary approach, taking account of the relative magnitude of the problem, the relative importance of land degradation to the poor, and the relative weakness of existing institutional and market-based mechanisms to deal with on-site degradation and externalities, indicates that efforts to reduce land degradation should focus on sloping lands and forest/desert margin areas in developing countries, and should depend mainly (though not exclusively) on market-based instruments, accompanied by efforts to ease capital constraints, to assign and protect property rights in land, and to increase investment in the development of technologies for sustainable agriculture.

We conclude with two points that link land degradation to broader issues. First, as noted above, land degradation is proportionally and absolutely most severe in the tropics, where it represents a loss of long-run earning power for farmers and negative externalities for larger rural populations. Monetary values aside, therefore, the problem of land degradation becomes more acute when the welfare of the poor is given higher priority.

Second, it is important to note that the same policy instruments (economic policy reforms, strengthening property rights) that we have advanced as the best means to alleviate land degradation are also components of reform packages with much broader economic development aims. In this sense our land degradation proposals are "bundled with" measures that deliver gains that extend well beyond the environment. Recent policy initiatives in China, where in early 2007 the national legislative body began considering proposals for a broad strengthening of property rights in land, give hope for a closer match between the pace of economic growth and that of institutional reform in fast-growing developing countries. Such institutional strengthening is essential if exploitation of new market opportunities by the poor, whose rate of time discount is high, are not to worsen existing rates of land degradation.

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Table 1. Rates of return on activities[a] to reduce land degradation*

Opportunity or solution	Rate of return
Price and trade policy reforms reducing subsidies on land-degrading crops	Infinite (only benefits, no cost[b])
Correcting credit market failures	> 20%
Property rights formalization in land tenure and turning open access pastures into commons	Wide range
Technology development and dissemination	>20%
Direct land use interventions	Wide range

[a] Activities additional to business-as-usual trends.
[b] When disregarding political costs. Example: Corn trade liberalization in India, 15.6m ha land reverts to less erosive use

Table 2 Benefit Cost Ratios of approaches[a] to reducing land degradation

Opportunity or solution	Discount rate LOW	Discount rate HIGH
Price and trade policy reforms	Infinite (only benefits, no cost[b])	Infinite (only benefits, no cost[b])
Correcting credit market failures	> 6.3	>3.3
Property rights formalization in land tenure, turning open access pastures into commons	Wide range	Wide range
Technology development and dissemination	>6.3	>3.3
Direct land use interventions	Wide range	Wide range

Based on a 100 year time horizon, "Low rate" is 3%, "High rate" is 6%
[a] Activities additional to business-as-usual trends
[b] When disregarding political costs. Example: Corn trade liberalization in India, 15.6m ha land reverts to less erosive use.