### The Philippines Country Environmental Analysis

# Land Degradation and Rehabilitation in the Philippines

## FINAL REPORT

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Prepared by:
Roehlano M. Briones, Consultant
Senior Research Fellow
Philippine Institute for Development Studies

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## Executive summary

While the Philippines' resource endowment can support vast farmlands, the majority of its land area consist of uplands for which temporary crop cultivation may not be sustainable. Originally these uplands were forested; with timber extraction, population expansion, and rapid agricultural growth, came the spread of crop farming by upland settlers. A growth slowdown came in the 1980s, which was accompanied by stagnant productivity growth, for which agriculture-related land degradation may have played a role. Despite apparent market incentives towards diversification, allocation of resources away from existing cropping patterns has been slow. Protection of the resource base has become more urgent to sustain yield growth at high levels.

Land degradation in the lowlands is a result of intensive cultivation and can be offset by proper crop management practices. A more serious problem arises from land degradation in the uplands, which is primarily the result of soil erosion. The cost of erosion is accounted for mostly by the depletion in the stock of available soil nutrients. While short term effects of erosion are negligible, the long term cumulative effect is an irreversible decline in land quality. The costs of land degradation are even more serious when off-site costs are considered (though the quantification of impact for off-site costs is far less developed than for on-site costs). Despite variation in the estimates, and considerable uncertainty about the degradation parameters, a conservative estimate of the cost of land degradation finds a large value, comparable at least to the annual investment in research and development of the public sector.

The long term benefit of soil conservation technologies, or shifting away from erosive land use, is the avoidance of this soil loss. Direct interventions, such as promotion of soil conserving farm technologies, typically involve investments and running costs. Some studies indicate that soil conservation technologies are worthwhile investments based social benefit-cost analysis.  However when the credit market is segmented, farmers set short planning horizons (say under insecure tenure), and face liquidity constraints, then profit-maximizing farmers may forego these investments.

Meanwhile indirect interventions alter the incentive structure of technology adoption and land use, which in turn affect the rate of soil erosion. Tenure reform has an ambiguous effect, while removal of domestic protection of corn has a positive effect on soil conservation. As upland farmers, including the large population of subsistence corn growers, are among the poorest segments of the rural population, the analysis suggests increasing and widening incentives for adoption of soil conservation and permanent tree

crops through extension and improved tenurial measures, while ensuring that trade adjustment be accompanied by adequate social protection.

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## 1. Introduction

The traditional strategy of agricultural development neglected protection and management of natural resources, focusing rather on intensification. This involves the application of more inputs per unit land to increase yield, based on modern technology such as genetically improved “Green Revolution” varieties. In the past few decades however, the problems of the traditional strategy became increasingly evident. As farming extended into areas with a limited and fragile resource base, it wrought havoc on local ecosystems and land resources, while reaping limited benefits from Green Revolution technologies (World Bank, 2008). Land degradation is now widely recognized as a serious threat to agricultural productivity worldwide (Eswaran, Lal, and Reich, 2001).

Land degradation in the Philippines is likewise seen as a serious environmental problem. Agricultural practices and economic pressures have severely degraded the agricultural resource base, associated with accelerated soil erosion, siltation of irrigation systems, flooding, and water pollution (Briones, 2005). The country’ research and agricultural development strategy is now orienting towards long term productivity growth through natural resource management or NRM (Rola, 2004).

There is a sizable literature and data on land degradation and rehabilitation, both globally and for the Philippines. There is however a need to compile and synthesize the statistics and estimates from various sources towards a coherent review and assessment of status, trends, impacts of human activity, environment and resource management interventions, and welfare impacts on poor households. Hence, this review aims to:

(i) Analyze the characteristics of the crop production sector;
(ii) Synthesize existing estimates of the costs of land degradation;
(iii) Analyze the costs and benefits of a few priority interventions to protect soil resources;
(iv) Assess distributional impacts of environmental costs, as well as interventions.

The rest of the paper is organized as follows: Section 2 provides a conceptual and methodological framework for the assessment of land degradation and rehabilitation. Section 3 reviews the background of land degradation within the context of Philippine agriculture. Section 4 deals with the impacts and costs of land degradation. Section 5 evaluates land rehabilitation interventions, based on cost, benefits, and incidence of impact. Section 6 concludes.

## 2. Conceptual framework

### 2.1. The agricultural system

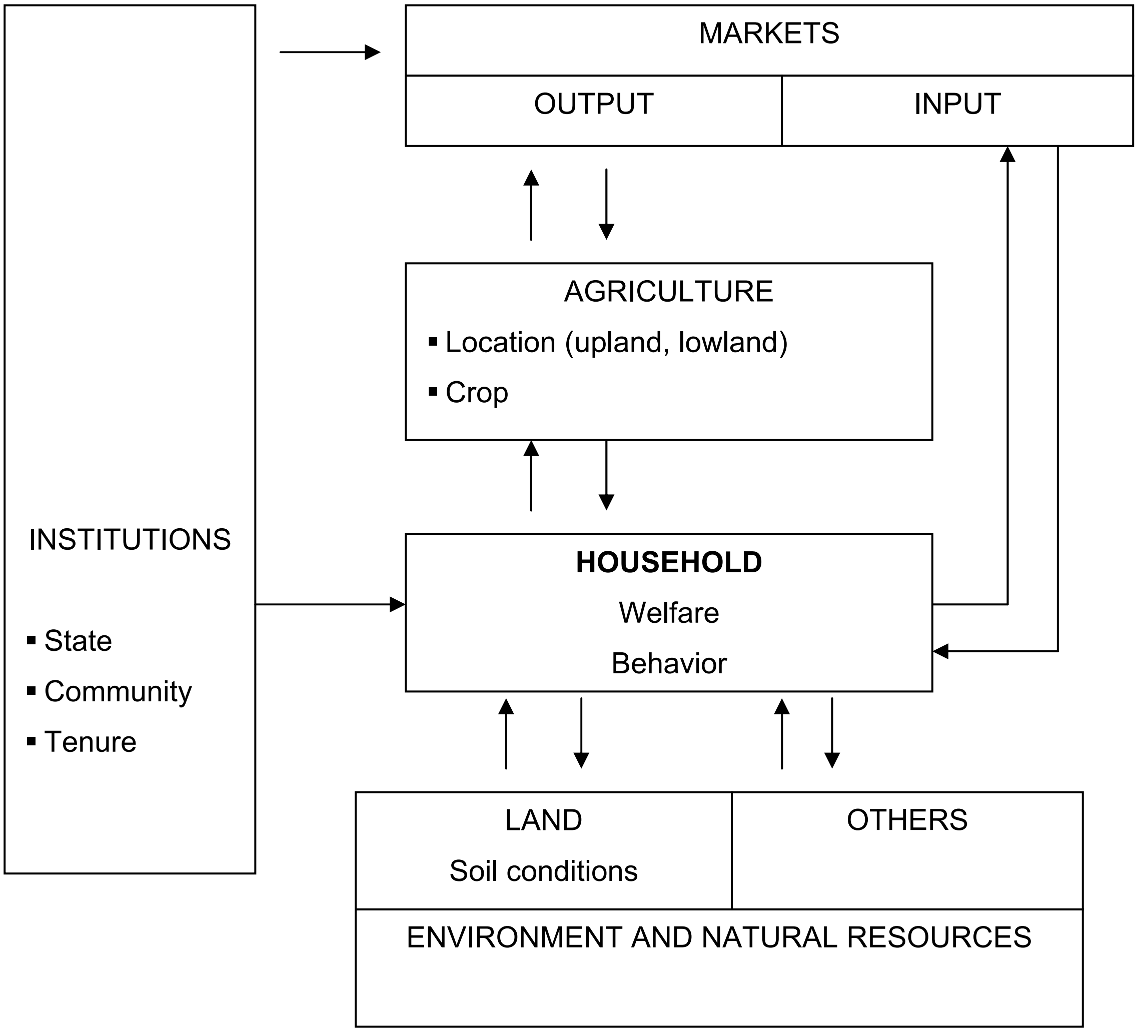
In this study we focus on the land degradation in the context of agriculture (Figure 1).[1] At the core of the analysis is the household, whose welfare improvement, now and in the future, is the primary evaluation criterion. In standard economic theory, household behavior is rationalized in terms of maximization of some pay-off function subject to constraints. Households have in their possession endowments of labor and assets. Productive factors, including land, are combined by households to produce outputs. The focal household activity is agriculture, which can be distinguished by location (upland, lowland) and crop grown. Agricultural activity in turn can depreciate natural capital, i.e. through land degradation. Output is sold to the market and returns income to households; households also obtain other agricultural inputs at a price, while selling their endowment (e.g. labor) to the factor market.

Exogenous to the framework are institutions, primarily the state, the community, and tenurial relations. Tenure can be formal or informal – if the latter, this presumes tacit acceptance within the wider community. Likewise communities, through norms and social interaction, may encourage households to act in concert to maintain the resource base. Finally, the state can implement programs to encourage resource conservation, provide the legal framework for tenurial instruments, as well as impose formal policies that affect markets, such as regulations, taxes, or tariffs.

### 2.2. The agriculture-degradation link

The central concern of this paper is the agriculture-degradation link. Degradation occurs through: i) actual removal of the soil, through erosion; ii) changes in the chemical, biological, and physical endowments of soil, such as nutrient loss, salinization, acidification, and compaction (Cummings, 1999). Erosion is a natural process from the action of water and wind, but it can be accelerated by human activity, primarily by land clearing. Other factors equal, steeper land is more erosion prone. It should be noted that soil “loss” is a location-specific concept; soil eroded from one area is deposited elsewhere, and depending on the deposition site, may still be useful for agriculture. Nutrient loss is a related problem, as runoff causes nutrient leaching. In turn, upstream erosion, nutrient loss, and salinization can cause downstream damages through sedimentation, eutrophication, and saline seep.

**Figure 1: Conceptual framework**



Bojö (1996) lists the the most common methods for computing the cost of land degradation. For on-site costs there are: (i) macro-level assessments using production functions to derive land degradation coefficients; (ii) micro-level assessments using plot-level data on land degradation impacts on yield that are scaled up; (iii) replacement cost approaches calculating the cost of replacing nutrients "lost" to soil, based on fertilizer prices. Note that (i) requires a detailed cross-section and/or time series data on soil erosion and possible explanatory variables, which may not be available. Meanwhile (ii) can based on experimental plot data or crop simulation analysis.[2] Finally, (iii) is the simplest and easiest approach, but is prone to error; aside from the uncertainty of soil loss estimate, there is the upward bias from the fact that *current* plant nutrient uptakes may be unaffected – rather it is the long term nutrient supply that is affected by soil degradation. A final set of costs are off-site impact calculations pertaining to lost capacity for irrigation and/or hydro-power, dredging costs, etc. (see e.g. Grohs, 1994).

## 3. Crop Production Sector

### 3.1. Geography and climate

*While the Philippines' resource endowment permits a significant amount of land that can support farming, the larger share of its land area is unsuitable for annual crop cultivation.*

Concepcion (2004) profiles the country's geographic features and land endowment based on data from the Bureau of Soil and Water Management (BSWM). The country is an archipelago of about 30 million ha, formed out half-submerged mountains, pushed up from the sea floor due to tectonic pressures. The island groups are Luzon (14.1 million ha), Visayas (5.7 million ha), and Mindanao (10.2 million ha), respectively at the north, central, and southern parts of the country. The most mountainous group is Luzon, whereas Visayas is a more fragmented group of islands and islets. Mindanao's terrain is diverse, including volcanic peaks, fault block mountains, plateaus, and low flat basins.

The climate is tropical, with an average humidity of 80% and an annual average rainfall ranging from 80 to 450 cm. Seasonal winds are referred to as the northeast monsoon, southwest monsoon, and north pacific trade winds. Both Luzon and Visayas lie within the typhoon belt, which is visited by twenty or so typhoons annually. Nearly half of annual rainfall is brought by these typhoons, while a small proportion (7%) are brought by monsoons; the remainder is brought by the intertropical convergence zone, and assorted rainfall-inducing weather patterns.

The Philippines' land area can be divided into nine capability categories, based on soil type and slope gradient (Box 1). The shares in total area by land capability category are shown in Figure 2. The majority of the country's land area is classified as steep land unsuitable for cultivation (i.e. of temporary crops). Only 8.3 million ha (about 27.5% of land area) is classified as at least fairly suitable for cultivation. About 17% of total area are classified as very steep slopes (>30%), and another 66% as steep slopes (between 8-30%), making them prone to erosion.[3] In fact however the country's agricultural area covers over 12.2 million ha, suggesting that a large extent of farming is occurring in steep lands.

**Box 1: Land capability categories**

Class A (Very good land): can be cultivated safely under simple management.

Class B (Good land): can be cultivated safely and requires easy conservation practices.

Class C (Moderately good land): must be cultivated with caution under careful management and intensive conservation practices.

Class D (Fairly good land): must be cultivated with caution under very careful management and complex conservation practices. More suitable for pasture or forest.

Class L (Level to nearly level land): too stony or too wet for cultivation. Limited to pasture or forest use with good soil management.

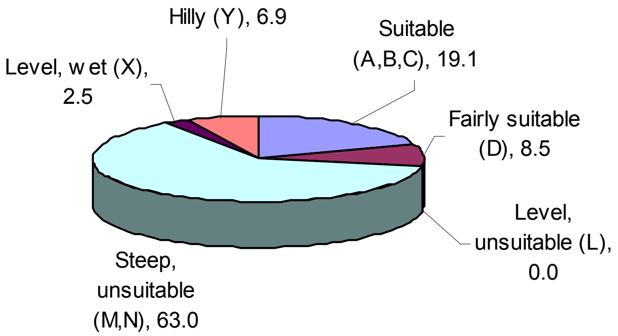
Class M (Steep land): easily eroded and too shallow for cultivation. Requires careful management to be used for pasture or forest.

Class N (Very steep land): too shallow and rough or dry for cultivation and easily eroded. Can be used for grazing or forestry.

Class X (Level land): very often wet is suited for fishpond, e.g. mangrove swamps.

Class Y (Very hilly and mountainous): barren and rugged, suitable for recreation or wildlife.

**Figure 2: Shares in total land area by land capability category, in percent**



Source: BSWM.

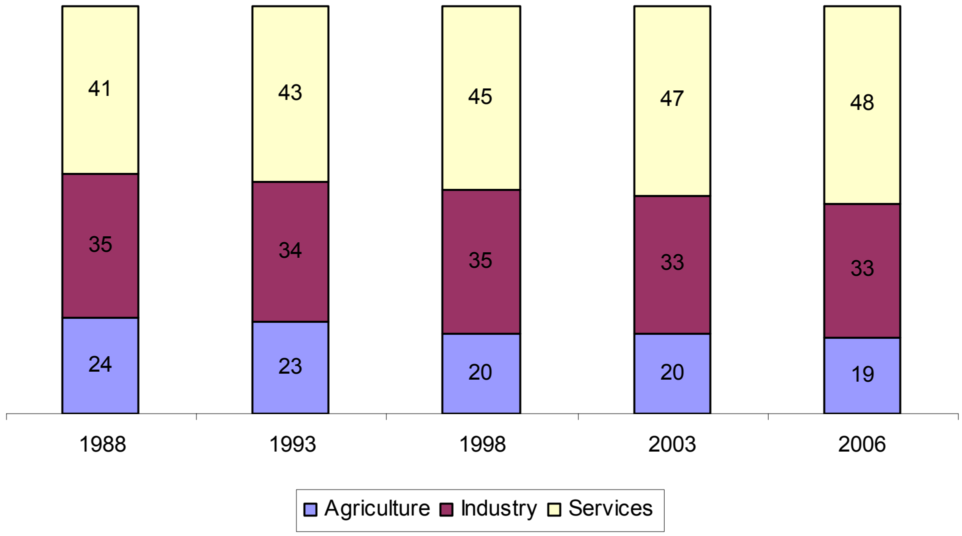
In terms of soil quality, “problem soils” are estimated to cover an area of about 22.6 million ha (74.9% of total area), resulting from both natural and anthropogenic processes. The big bulk of this area (12 million ha) are classified as having fertility limitations. Of the remaining amount (10.6 million ha), about 11.7% are characterized by physical problems (i.e. cracking clays, coarse texture, etc.), while another 4.6% have chemical constraints, such as high salinity (400,000 ha).

### 3.2. Patterns and trends in Philippine agriculture

*The Philippines has followed the stylized pattern of structural change, in which the economic importance of agriculture declines over the course of economic development*.

Agriculture accounted for nearly a third of GDP in 1970, but now accounts for just under a fifth.[4] In recent years, the declining output share of agriculture has been accompanied by the rising output share of services, even as the industry share has remained stable (Figure 3).

**Figure 3: GDP shares by sector, Philippines, 1988-2006 (At constant 1985 prices)**



Source: National Economic Development Authority Quickstat online (accessed 11/30/2007)

*Agricultural growth was respectable within the period 1965 – 1980, a period of area expansion, intensification, and technological change.*

The declining share of agriculture has not always been due to weak sectoral growth. In fact growth was respectable from the latter half of the 1960s and in the 1970s, when it exceeded the averages for developing monsoon Asia countries, and compared favorably with those of Thailand and Indonesia (Balisacan, 1993a). In the 1970s, above-average agricultural growth was accompanied by rapid expansion in land area for arable land and permanent crops, as well as in total population (Table 1). However there was a marked slowdown in agricultural growth in the 1980s, which lasted until the 1990s. This was accompanied by a sharp deceleration in the growth of arable land area. However population growth kept its momentum throughout, consistently staying above an annual rate of 2%.

**Table 1: Growth rates of agricultural output, arable land, and total population, in percent (annual average)**

| | 1971-75 | 1976-80 | 1981-85 | 1986-90 | 1991-95 | 1996-00 | 2001-05 |
|---|---|---|---|---|---|---|---|
| Agriculture GVA | 3.1 | 5.1 | -0.4 | 2.7 | 1.5 | 2.3 | 3.1 |
| Arable land | 2.3 | 2.9 | 0.3 | 0.3 | 0.0 | 1.5 | 0.1 |
| Population | 2.8 | 2.7 | 2.4 | 2.4 | 2.3 | 2.1 | 2.1 |

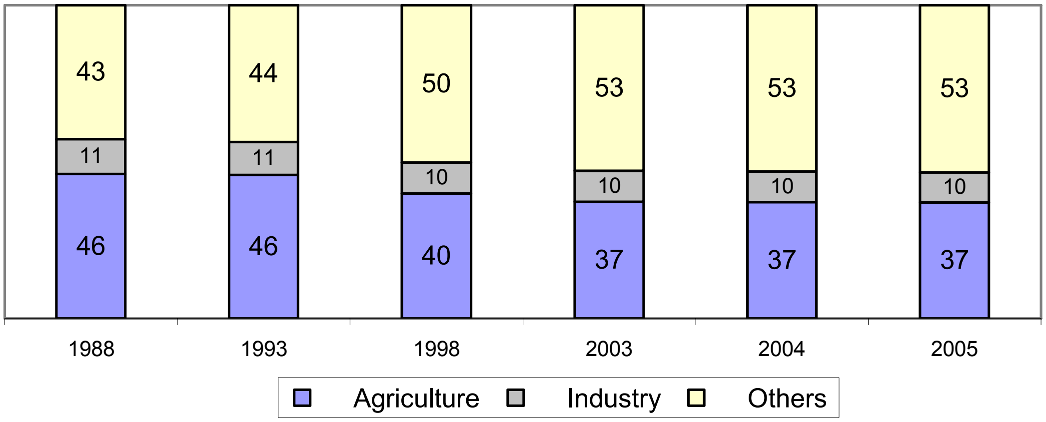
Sources: World Development Indicators for agricultural value added; FAOStat for arable land and population.

To meet the food requirements of a rising population, expansion of cultivated area or “extensification” played an important early role. As the expanding population reached the land frontier, agricultural growth would have to be achieved by raising land productivity, i.e. through intensification. Intensification occurred in parallel with the Green Revolution. Irrigated area rose from just 0.83 million ha in 1970 to 1.43 million ha by 2007. Over the same period, fertilizer usage rose steadily from 25 kg/ha in to over 60 kg/ha in 2002, while agricultural mechanization proceeded very rapidly, as the number of tractors increased nearly fifteen-fold.[5]

*The growth slowdown in the 1980s was accompanied by stagnant productivity growth, both in terms of labor and total factor productivity.*

A change in the structure of output may be expected to correspond to a change in the structure of employment. In fact, employment composition follows the same trend as the output composition (Figure 4). However the decline in employment share has lagged behind that of the output share; the ability of the nonagricultural sectors to grow faster than agriculture have exceeded their ability to absorb labor from agriculture. This implies that labor productivity in agriculture has failed to keep pace with productivity growth in the nonagricultural sectors. Growth in labor productivity, measured as value added in agriculture per agricultural worker, has in fact stagnated since the 1990s (Figure 5), growing at only an average annual rate of about 1.5%. An important factor was the El Niño shock of 1997-1998, which largely accounts for the drop in labor productivity in 1998, and from which productivity recovered to 1997 levels only by 2001.

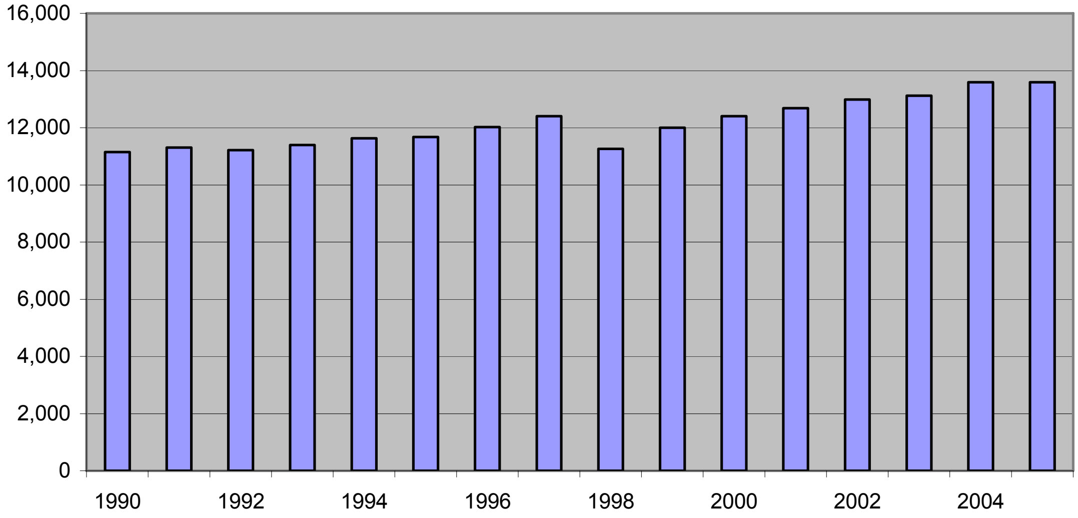
**Figure 4: Employment shares by economic sector, 1988-2005**



Source: ADB Key Indicators (2007).

Thus far we have been dealing with partial productivity measures. A more comprehensive measure is total factor productivity (TFP). A number of studies have been examining TFP growth in Philippine agriculture, whether singly or within a cross-country analysis, based on a variety of empirical techniques. Even with TFP measure, a similar pattern emerges: productivity growth declined in the 1980s and 1990s, contributing to the slowdown of overall growth (Table 2). The slump is even more marked when compared to other countries in the region, which have posted robust TFP growth during that period, e.g. in East Asia (China, Viet Nam) and South Asia (Pakistan).

**Figure 5: Labor productivity in agriculture, in pesos/worker (1985 prices)**



Source: BAS and FAOStat.

**Table 2: Estimates of TFP growth for selected Asian countries, 1981-2001**

| | 1) | 2) | 3) | 4) |
|---|---|---|---|---|
| Philippines | -0.3 | 0.4 | -1.3 | 0.1 |
| Bangladesh | 1.3 | 1.1 | | |
| India | 2.4 | -1.1 | | |
| Pakistan | 2.5 | 2.7 | | |
| Cambodia | 2.0 | | | |
| Indonesia | -0.4 | -1.1 | | 1.5 |
| Laos | 2.5 | | | |
| Malaysia | 1.4 | 1.5 | | |
| Thailand | 1.1 | 1.4 | | 0.9 |
| Vietnam | 3.3 | 1.0 | | |
| China | 4.8 | 3.6 | | |

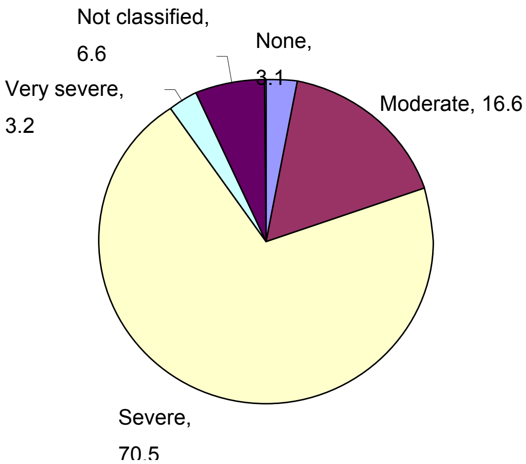
Sources:1) Avila and Evenson (2004): 1981 – 2001; 2) FAO (2004): 1980-2000; 3) Cororaton and Caparas (1999) 4) Mundlak, Larson, and Butzer (2002): Philippines 1980-1998; Indonesia 1981-1988; Thailand 1981-1995

*Land degradation is a pervasive problem in the country's farmlands, and may have played a role in the slowdown of productivity growth in agriculture.*

While land endowment, topography, and climate are a limiting factor to agriculture, land resources have also felt the strong impact of agricultural activity. Based on a classification by the Global Assessment of Soil Degradation (GLASOD), over 70% of the country's land area has been severely degraded due to soil erosion (Figure 6).[6] Forests, which used to blanket the uplands, have now been largely cleared. According to the Department of Environment and Natural Resources (DENR, 2005), the country's forest cover in 1900 was 21 million ha (70% of land area); by 2005, this was down to 7 million ha (23%). However removal of primary forests should not be largely attributed to extensification; rather, logging was initially responsible for the degradation of primary to secondary forests and grasslands. This opened up forest land to shifting cultivation and, much later, to intensive agriculture (Cramb, 2000).

Economic development in the uplands basic outlines of Boserup (1965): before modern economic development, forestlands were primarily subjected to long-phase, forest-fallow rotations, for subsistence farming, under customary tenure. Ultimately migration to the frontier and agricultural modernization transformed this into a more intensive, commercially oriented system under private land rights. The process displaced traditional land resource use institutions, by direct occupation (*de facto*), or even by legal action (*de jure*), i.e. the state's assertion of ownership over uplands, and the introduction of private land titles. However the demise of traditional tenure left a vacuum, resulting in a virtual open access regime that coincided with high commodity demand, leading to rapid resource degradation (Rola and Coxhead, 2005). Furthermore, expansion into the uplands was in part due to declining productivity in lowland agriculture (Rola et al, 2008). Conversely, increased intensification and technological change in lowland farming can reduce both deforestation (Shively, 2001) and expansion in farm area (Coxhead and Shively, 2006). Finally, the agriculture-degradation link can be found in the lowlands as well; while soil erosion is less of a problem, loss of soil organic matter and soil nutrient imbalance (owing to nutrient mining and inappropriate fertilizer management) have been observed in intensively cultivated farms (Rola, 2004).

**Figure 6: Degree of land degradation**



Source: http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp?country=PHL&search=Display+map+!National. Accessed October 2008.

### 3.3. Profile of the major crops

*Land use in Philippine agriculture has been dominated by a few traditional crops. Despite apparent market incentives towards diversification, allocation of resources away from existing cropping patterns (which may contribute to degradation) has been slow.*

Based on area planted/harvested (Table 3), the major crops in the Philippines are palay (paddy rice), corn, coconut, sugarcane (the traditional export crops), and banana (a high value export crop). These crops have been the mainstays of Philippine agriculture, accounting for 90% of total agricultural area in 2007. In fact the top three (palay, corn, and coconut) already account for 85% of the total area. Palay area is by far the biggest, covering 4.3 million ha in 2007. Palay area has been growing both in absolute terms and as a share in total; shares of banana and sugarcane have also been growing since 1990. However, that of coconut has remained stable, whereas the both the share and absolute area of corn has been shrinking until the 2000s.

**Table 3: Area harvested by crop ('000 ha), Philippines, 1988-2006**

| | Area harvested/planted ('000 ha) | | | | | Area shares (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2007 | 1990 | 2007 |
| Palay | 3,319 | 3,759 | 4,038 | 4,070 | 4,273 | 28.1 | 33.4 |
| Corn | 3,820 | 2,692 | 2,510 | 2,442 | 2,648 | 32.3 | 23.9 |
| Banana | 312 | 339 | 382 | 418 | 437 | 2.6 | 3.0 |
| Coconut | 3,112 | 3,095 | 3,144 | 3,243 | 3,360 | 26.3 | 27.5 |
| Sugarcane | 235 | 302 | 384 | 369 | 383 | 2.0 | 2.7 |
| Other | 1,018 | 1,069 | 1,029 | 1,058 | 1,116 | 8.6 | 9.5 |
| TOTAL | 11,815 | 11,256 | 11,487 | 11,600 | 12,216 | 100.0 | 100.0 |

Source: FAOStat

The pattern of contribution to value added contrast to that of area shares (Table 4). While palay has a value added share roughly corresponding to its area share, corn and coconut have shares far below their respective area shares. In fact palay value added was nearly thrice that of corn, and more than five times that of coconut. This suggests that land for these crops are found in the more marginal areas (e.g. uplands). Other crops accounted for more than two-fifths of total value added in 1990; however with the expansion of palay value added, the share of other crops receded to 37% in

2007, as did the share of banana. Both corn and coconut maintained their respective contributions to agricultural value-added.

Under the assumption of frictionless competitive markets, land should move from low-return to high-return crops, with rates of return converging across different type of land use (holding land quality constant). Land use change may in turn alter the rate of land degradation. In fact however, the patterns of area allocation appear to exhibit strong inertias to differences in net return per ha; in particular there seems to be insufficient diversification away from traditional, low value crops towards new, high value crops.

**Table 4: Gross value added of major crops, 1990 – 2007**

| | Gross value added (millions of pesos) | | | | | Shares in total (%) | |
|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2007 | 1990 | 2007 |
| Palay | 24,873 | 28,189 | 33,132 | 39,051 | 43,429 | 29.0 | 34.3 |
| Corn | 10,950 | 9,837 | 10,751 | 12,518 | 16,054 | 12.8 | 12.7 |
| Banana | 7,084 | 7,380 | 7,173 | 8,226 | 8,244 | 8.2 | 6.5 |
| Coconut | 3,652 | 3,964 | 4,642 | 5,691 | 5,463 | 4.3 | 4.3 |
| Sugarcane | 2,698 | 2,808 | 4,492 | 5,740 | 6,819 | 3.1 | 5.4 |
| Other | 36,613 | 40,759 | 40,418 | 43,510 | 46,608 | 42.6 | 36.8 |
| TOTAL | 85,870 | 92,937 | 100,608 | 114,736 | 126,617 | 100.0 | 100.0 |

Source: BAS.

This can be seen in cost and returns data for two traditional crops and two high value crops (Table 5), from the Bureau of Agricultural Statistics (BAS). Here the estimates are given in annual terms, i.e. adjusting for seasonal or perennial production cycles. [7] The data set also provides information on the component of cost paid out-of-pocket, i.e. “cash costs”, which may act as constraints on farmers with low and erratic cash flow. Return per ha for the high valued crops is more than double that of irrigated rice. Meanwhile the returns to corn farming are highly variable, though still within the range of returns to rainfed and irrigated rice. Mango farming is even more profitable than pineapple farming. The contraction in corn area makes sense based on these figures, but not the expansion of palay area, nor the overall failure to allocate land to high value crops.[8]

Net return is of course not the sole indicator for land allocation; land quality, gestation period, and risk also matter for crop choice. Nevertheless these persistent discrepancies may be resulting from entry barriers in the high value sector, such as high working capital requirement (i.e. cash cost) combined with an imperfect credit market.

The failure of the Philippine crop sector to diversify is one major reason for its low productivity in the aggregate, and may in turn be strongly influenced by incentives and the policy regime (World Bank, 2007).

**Table 5: Annual real cost and returns per ha for selected crops, Philippines, 2002 – 2006, (2007 prices)**

| | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Irrigated rice | | | | | |
| Returns | 17,413 | 21,380 | 22,657 | 25,299 | 24,195 |
| Cash cost | 27,375 | 26,346 | 28,043 | 29,127 | 28,066 |
| Rainfed rice | | | | | |
| Returns | 7,598 | 9,472 | 11,523 | 11,591 | 13,248 |
| Cash cost | 16,273 | 17,180 | 17,992 | 18,451 | 17,781 |
| Corn: | | | | | |
| Returns | 10,380 | 12,189 | 23,645 | 10,271 | 21,067 |
| Cash cost | 21,793 | 22,075 | 24,391 | 25,083 | 24,767 |
| Pineapple | | | | | |
| Returns | 38,782 | 46,537 | 41,929 | 43,708 | - |
| Cash cost | 29,668 | 35,882 | 32,154 | 33,850 | - |
| Mango | | | | | |
| Returns | 82,578 | 83,339 | 91,151 | 83,719 | - |
| Cash cost | 30,316 | 31,159 | 32,244 | 33,169 | - |

Source: basic data from BAS.

*Land productivity or yield has been growing in the past few decades; however yield growth has not been consistent, and a growth slowdown in some major crops was evident in the 1990s. Protection of the resource base has become more urgent to sustain yield growth at high levels.*

Some of the major crops have registered significant Increases in yield (Table 6). In 1960 annual palay yield was only 1.1 t/ha (de Leon, 2005). Within twenty years this had been doubled in the aftermath of the Green Revolution; yields have continued to climb to its current level of 3.7 t/ha. Even more impressive is the growth in corn yield. However, yield in the traditional export sector has stagnated and (in the case of sugarcane) even declined. On the other hand, spectacular yield growth was achieved by the new cash crops.

In the 1990s except for banana and pineapples, yield growth tapered off for the major crops. Yields even declined for sugarcane; this coincided with low prices in and declining quantity of the US quota market, historically the most lucrative market segment for the sugar industry. The cereals meanwhile exhibited yield growth recovery in the 2000s; in the case of corn this was due to the spread of yellow corn varieties to meet feed demand, while areas planted to white corn in marginal lands declined (David, 2003). In the case of rice, production growth may have been due in part to an expansion in privately irrigated rice growing areas (Barker and Innocencio, 2007), as well as production incentives (mainly seed and fertilizer subsidies) given by the government.

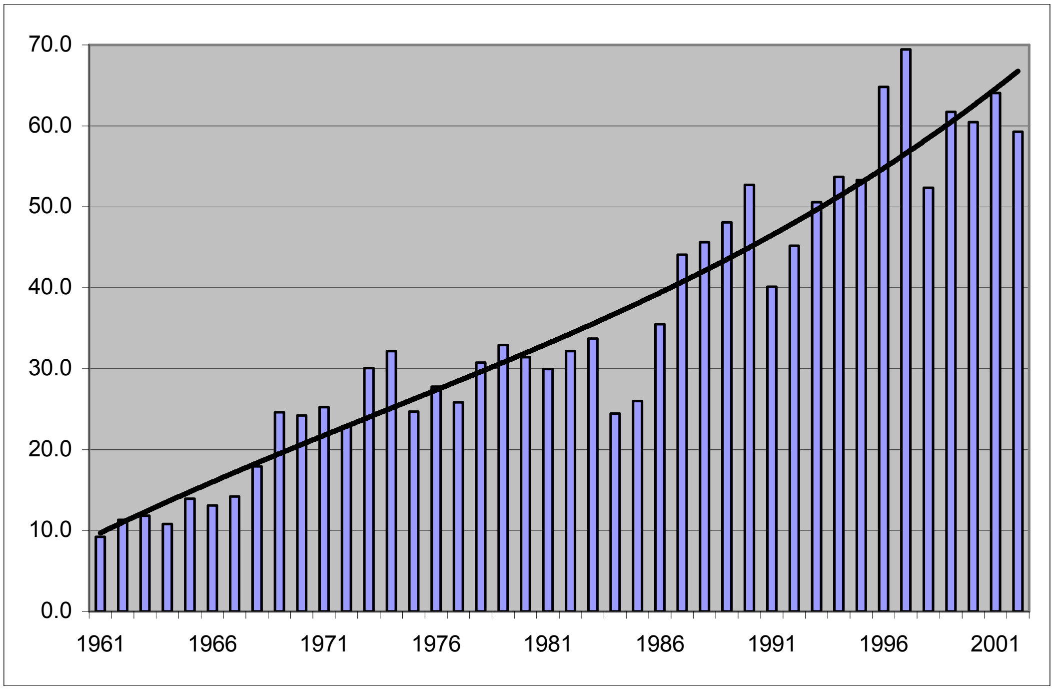
**Table 6: Yield of major crops, Philippines, 1970-2006, in t/ha/yr**

| | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2006 | Annual growth, % |
|---|---|---|---|---|---|---|---|---|---|
| Paddy rice | 1.7 | 1.7 | 2.2 | 2.6 | 3.0 | 2.8 | 3.1 | 3.7 | 3.1 |
| Maize | 0.8 | 0.9 | 1.0 | 1.1 | 1.3 | 1.5 | 1.8 | 2.4 | 5.2 |
| Coconuts | 3.0 | 4.0 | 2.8 | 2.6 | 3.5 | 4.0 | 4.2 | 4.5 | 1.3 |
| Sugar cane | 71.4 | 66.9 | 72.8 | 62.0 | 80.0 | 65.6 | 62.0 | 62.1 | -0.4 |
| Bananas | 4.5 | 8.9 | 12.9 | 11.6 | 9.7 | 10.9 | 15.0 | 15.8 | 7.1 |
| Pineapples | 8.1 | 13.9 | 16.0 | 17.8 | 19.4 | 21.0 | 36.3 | 36.8 | 9.9 |

Source: FAOStat

The consistent climb of yield growth may be due to intensification. Figure 7 shows fertilizer application rates since the 1960s, to which we have added a trendline.[9] Clearly fertilizer application has been generally on an upward trend particularly with the onset of the Green Revolution in the late 1960s and 1970s. Unfortunately, this may well be masking weak supply fundamentals, i.e. slow technological progress, inadequate infrastructure, and a deteriorating natural resource base, as may be expected from a history of severe soil erosion. As discussed earlier, TFP, a broader productivity measure which adjusts for input application, has generally been on a slowdown since the 1980s. At the crop level, there is however limited analysis of TFP; in the case of rice, one study covering the 1971 – 1990 period is available (Umetsu, Lekprichakul, and Chakravarty, 2003). This study suggests that TFP rose in the late 1970s owing to the introduction of modern varieties, but declined in the late 1980s as a result of intensification and weak technical change, particularly in regions where investments in infrastructure, education, and mechanization were lower, and where the agroclimatic condition was poorer.

**Figure 7: Fertilizer application rates in kg/ha, Philippines, 1961 - 2002**



# 4. Land degradation cost estimates

## 4.1. Physical effects of land degradation

*Degradation in the lowlands*

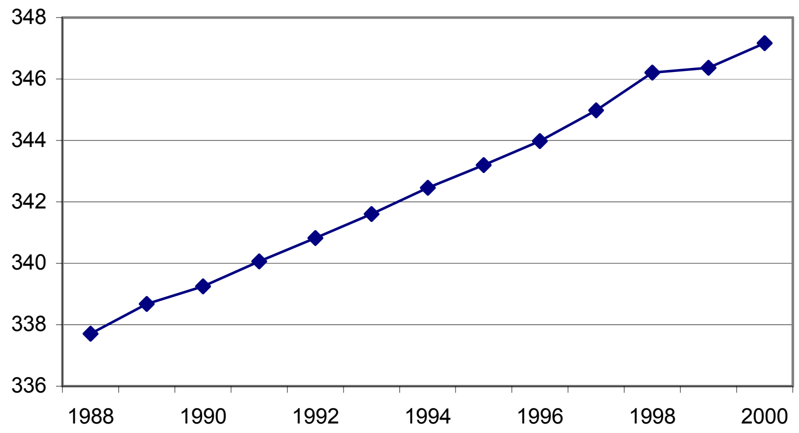
In lowland agriculture, intensive cultivation and high yield accelerates removal of nutrients and alteration of physical and chemical properties of soil. Sustainability of rice systems have been well-studied: it is possible that continuous cropping, extensive submergence, and high chemical usage may lead to soil degradation. These are indicated by: declining organic matter content and nutrient-supplying capacity, nutrient imbalance, water logging, soil salinity and alkalinity, and forming of hardpans at shallow depths (Reichardt, Doberman, and George, 1998; as cited in Badayos and Calalo, 2007). Following the Green Revolution was the spread of micronutrient deficiencies in intensively cropped Asian soils, particularly with regard to zinc, boron, iron, manganese, and sulphur (Singh, Woodhead, and Papademetriou, 2002). For the Philippines, soil nutrient imbalance as well as decreasing nitrogen productivity have been implicated in the slowdown of yield growth in rice (Cassman and Pingali, 1995, as cited in Rola, 2004). In the case of intensive banana plantations, reductions in yield have attributed to changing nutrient ratios in the soil (Sadasa et al, cited in Rola, 2004).

However there is no evidence that such degradation is irremediable; a number of long term experiments of continuous rice cultivation do find sustainable yields under intensive farming with chemical inputs. Kaosa-Ard and Rerkasem (2000) note that for Asian agriculture, irrigated land, and rainfed areas with good soil and reliable rainfall, have yet to demonstrate the effects of degradation – and these are lands which have contributed most to agricultural growth. In Karnal, India, soil analysis over the past 15 years show no major deterioration in yields, despite declining soil nutrients, under proper crop and soil management. Long term experiments in the Philippines show that continuous cultivation of irrigated rice with balanced fertilizer and submerged soils can maintain or slightly increase soil organic matter, and maintain soil nitrogen-supplying capacity (Pampolino et al, 2008). Furthermore over a wide range of rice-based cropping systems, plots under organic amendments have no significant yield advantage over plots managed with balanced application of inorganic fertilizers (Doberman and Dawe, 2008).

### *Degradation in the uplands*

Land degradation is a bigger problem in less favored areas (Kaosa-ard and Rerkasem, 2000); in the Philippines this takes the form of soil erosion in the uplands (Rola et al, 2008). Estimates of erosion rates are typically derived from micro-level assessments, and extrapolated nationwide. This method is adopted by official statistics on soil erosion (Figure 8). Over time, estimated soil loss due to erosion has been rising slowly but inexorably, from about 340 million t/yr in the late 1980s to nearly 350 million t/yr by the 2000s.

**Figure 8: Amount of soil eroded from agricultural soils, million t/yr, 1988-2000**



Source: NSCB (2006)

The ENRAP I project compiles estimates from various sources to arrive at erosion rates by land use. Land covered by tree crops or forests, as well as irrigated paddy rice (which is lowland), have the lowest erosion rates. The highest by far is for grassland or pastureland, followed by upland agriculture. Francisco (1994) takes a weighted average of these estimates to arrive at 1993 regional erosion rates (total and average per ha), reproduced in Table 7. Soil erosion is still mostly from grassland areas, both at the national and regional levels; it also has the highest rate of loss, at 174 t/ha/yr. Total loss from agriculture is under a third that of grasslands, and its rate of erosion per ha is 74% lower. The average figure reported for agriculture (63 t/ha/yr) is close to the figures obtained by plot experiments of Poudel, Midmore and West (1999). There is of course a large variation across studies depending on experimental site: Paningbatan et al (1995) reports figures in the high range, e.g. 140 t/ha/yr for moderately-sloped lands in Laguna province, planted to corn and mungbean; Rose (1999) as well as Presbitero et al (1995) meanwhile report figures in the low range, at 38-39 t/ha/yr, for mixed-crop corn up-and-down cultivation.

**Table 7: Gross and average erosion rates by land use, 1993**

| Region | | Gross erosion rate (million t/yr) | | | | Average (t/ha/yr) |
|---|---|---|---|---|---|---|
| | | Agriculture | Grassland | Woodland | Total | |
| Luzon | CAR | 6.0 | 131.7 | 2.5 | 140.3 | 82.4 |
| | I | 4.5 | 104.0 | 0.5 | 109.1 | 128.5 |
| | II | 18.2 | 99.5 | 3.9 | 121.6 | 56.5 |
| | III | 6.7 | 98.8 | 1.2 | 106.8 | 97.8 |
| | IV | 68.6 | 190.4 | 5.5 | 264.5 | 65.5 |
| | V | 51.0 | 73.6 | 0.7 | 125.3 | 84.7 |
| Visayas | VI | 39.0 | 136.2 | 0.7 | 175.5 | 105.8 |
| | VII | 36.5 | 118.2 | 0.3 | 154.9 | 114.0 |
| | VIII | 50.1 | 95.2 | 1.7 | 147.0 | 76.4 |
| Mindanao | IX | 42.1 | 110.8 | 1.0 | 153.9 | 92.6 |
| | X | 16.7 | 125.1 | 3.5 | 175.3 | 66.3 |
| | XI | 57.9 | 127.2 | 3.7 | 188.8 | 65.4 |
| | XII | 29.7 | 151.0 | 1.7 | 182.5 | 94.8 |
| **Philippines** | | 457.0 | 1561.8 | 27.0 | 2045.8 | |
| Average, t/ha/yr | | 61.8 | 173.7 | 3.0 | 80.6 | |

Source: Francisco and de los Angeles (1998).

Francisco (1994) also reports soil depletion horizons by region (Table 8). Average soil depth and density varies greatly across regions; for the country, the soil layer is slightly less than a meter and weights 1.2 gm/cm. Every cm of soil takes between 1 to slightly more than 2 years to deplete through erosion; hence the soil layer would take well over a century more to totally erode. Even if evaluation is limited only to the topsoil, which has the average depth of between 10 – 20 cm, then depletion would take about 20 – 33 years, after which sustaining plant growth will require costly amounts of inorganic fertilizer. Hence, except for the steepest slopes, the effects of soil depletion are intergenerational. Similarly, Schmitt (2007) has shown that in Negros Island (Visayas), the country's major sugarcane grower, nearly one-fifth of land area is eroding at rates exceeding 20 t/ha/yr; by 2050, 36% of the island's area would be unsuitable for agriculture.

**Table 8: Soil depletion horizon by region, 1993**

| | Soil depth (cm) | Density (gm/cc) | Years to deplete 1 cm | Soil depth |
|---|---|---|---|---|
| **Luzon** | | | | |
| CAR | 85 | 1.19 | 1.44 | 127 |
| I | 74 | 1.28 | 0.99 | 74 |
| II | 75 | 1.20 | 2.12 | 160 |
| III | 82 | 1.22 | 1.24 | 100 |
| IV | 57 | 1.15 | 1.76 | 103 |
| V | 117 | 1.19 | 1.4 | 169 |
| **Visayas** | | | | |
| VI | 96 | 1.25 | 1.16 | 114 |
| VII | 96 | 1.25 | 1.17 | 91 |
| VIII | 118 | 1.26 | 1.65 | 196 |
| **Mindanao** | | | | |
| IX | 139 | 1.04 | 1.13 | 157 |
| X | 103 | 1.09 | 1.65 | 169 |
| XI | 94 | 1.24 | 1.9 | 177 |
| XII | 120 | 0.91 | 0.96 | 115 |
| **Philippines** | 97 | 1.18 | 1.43 | 135 |

Source: Francisco and de los Angeles (1998).

Erosion by crop is quantified in several SANREM studies (Table 9). The three major crop categories are rice, corn, and other agriculture (the last of which combines both seasonal and perennial crops.) Corn occupies a bigger farm area of the uplands than rice, and more so in the steeper slopes. Corn is also a highly erosive crop, though less so than some vegetables (e.g. cabbage). However, corn farming, given its widespread practice in the steeper slopes, may be regarded as one of the most damaging land use of sloping upland soils in the country (Coxhead, 2002).

**Table 9: Area and erosion rates of selected upland crops (various sources)**

| Land use | slope grade, in % | | Erosion rate, in t/ha/yr | |
|---|---|---|---|---|
| | 18 - 30 | >30 | Mountains and upper slopes | Lower slopes and plains |
| Rice | 315,000 | 52,500 | | |
| Corn | 375,000 | 61,250 | 30.0 | 10.7 |
| Other agriculture: | 592,000 | 96,250 | | |
| Coffee | | | 35.0 | 25.0 |
| Cabbage | | | 55.0 | 30.0 |
| Average slope | | | 34.5 | 10.7 |

Source: Coxhead and Zelek (2002).

Erosion coefficients have so far been measured for direct farming activities in the uplands. Indirect effects through inter-industry linkages can also be gauged using input-output analysis. This obtains soil depletion multipliers shown in Table 10 (ENRAP Phase 3, 1996). The numbers are in tons of soil depleted per year, as a result of a Php 1,000 increase in final demand of a particular sector (equivalent to Php 2,800 in 2007 prices). The biggest multipliers are for agriculture itself, mainly due to the direct effect of an increase in demand on agricultural activity; however industries closely linked to agriculture have relatively large though indirect impacts, e.g resource-based manufacturing.

**Table 10: Soil depletion multipliers, in t/yr per Php 1,000 change in demand (1988 prices)**

| | Agriculture | Grassland | Woodland |
|---|---|---|---|
| Agriculture | 3.47077 | 0.00176 | 0.03035 |
| Fishery | 0.30108 | 0.00097 | 0.01671 |
| Forestry and hunting | 0.46796 | 0.08000 | 1.38279 |
| Mining and quarrying | 0.42894 | 0.00160 | 0.02767 |
| Resource-based manufacturing | 1.35209 | 0.00373 | 0.06454 |
| Other manufacturing | 0.43548 | 0.00162 | 0.02797 |
| Electricity and gas | 0.31137 | 0.00590 | 0.10193 |
| Waterworks and supply | 0.31393 | 0.00196 | 0.03390 |
| Construction | 0.49275 | 0.00366 | 0.06323 |
| Transportation | 0.43862 | 0.00152 | 0.02635 |
| Other services | 0.48486 | 0.00165 | 0.02861 |
| Households | 1.08909 | 0.00332 | 0.05734 |

Source: ENRAP Phase 2 (1996).

## 4.2. Costs of land degradation

*On-site costs: estimates*

For lowland agriculture, the evidence suggests that the "natural capital" inherent in land resources, is depreciated over the course of intensive farm operations; like physical capital, this natural capital can be protected and even enhanced by maintenance or management activities. Hence losses are internalized and valuation appears to be an inappropriate tool for understanding the allocative effects of degradation.

The uplands however may be a different case: soil erosion may involve a true loss to society as farmers fail to internalize the effects of resource degradation. This is most obviously true for off-site costs; however as seen in the above discussion of Table 8, this may also involve on-site costs of soil loss to future generations. Francisco and de los Angeles (1998) convert Francisco's (1994) soil loss estimates into monetary values based on replacement cost as of 1993 (Table 11). The nutrient values per ton of soil are very similar across land uses, in the range of Php 26.5/t – Php 30.4/t in 2007 prices, with agricultural land at about the middle. The major macronutrients are nitrogen, phosphorus and potassium; by far the greatest value per ton of soil is obtained from nitrogen.

**Table 11: Nutrient loss due to erosion per ha, quantity in kg and value (2007 pesos)**

| | Nitrogen | Phosphorus | Potassium | Total quantity | Total value |
|---|---|---|---|---|---|
| Quantity, national estimate (1993), average by land use | | | | | |
| Agriculture | 176.13 | 3.71 | 27.19 | 207.03 | - |
| Grassland | 434.60 | 12.17 | 81.70 | 528.47 | - |
| Woodland | 9.29 | 0.12 | 1.10 | 10.52 | - |
| Value, national estimate (1993), average by land use | | | | | |
| Agriculture | 1,584.5 | 24.0 | 214.5 | - | 1,823 |
| Grassland | 3,901.5 | 75.4 | 643.0 | - | 4,620 |
| Woodland | 81.6 | 0.8 | 8.8 | - | 91 |
| Quantity, Corn farming in Bondoc Peninsula (1998), by slope category (%) | | | | | |
| 3.1 – 8.0 | 88.00 | 0.84 | 3.12 | 91.96 | - |
| 8.1 – 15.0 | 186.00 | 4.65 | 23.49 | 214.14 | - |
| 15.1 – 35.0 | 295.60 | 3.28 | 63.76 | 362.64 | - |
| Value, Corn farming in Bondoc Peninsula (1998) , by slope category (%) | | | | | |
| 3.1 – 8.0 | 2,689.5 | 34.1 | 177.7 | - | 2,901 |
| 8.1 – 15.0 | 5,684.6 | 188.9 | 318.2 | - | 6,192 |
| 15.1 – 35.0 | 9,034.3 | 133.3 | 863.8 | - | 10,031 |

Sources: Derived from Francisco and de los Angeles (1998) for national estimates; Josue and Mendoza (2001) for Bondoc estimates. Values converted to 2007 prices using the official CPI.

Losses per ton of soil can be converted into losses per ha based on average erosion rates. Losses are by far highest for grasslands due to heavy erosion rates. For agricultural land, erosion loss per ha is only about Php 1,800/ha. Table 11 also reports plot-level evaluation of soil loss using belt transect method, conducted in Bondoc Peninsula of Luzon (Josue and Mendoza, 2001). Measured soil loss varied from 26 - 159 t/ha/yr for corn monocropping, and 17 - 183 t/ha/yr for fallow land, depending on the slope. Coconut monocropping led to a soil loss of at most 5.4 t/ha/yr on the steepest slopes (15 – 35% grade). Coconut-corn intercrop led to a dramatic increase of erosion loss; for the steepest slopes the loss reached nearly 90 t/ha/yr. Soil loss was then converted to nutrient loss and valued at fertilizer prices. As with Francisco and de los Reyes, most of the nutrient loss is due to nitrogen. Since erosion rate is faster for steeper slopes, the replacement cost likewise increases with slope. Nutrient loss value for the second slope category is more than double that of the first; the third is 62% above that of the second. At the last level, the value of loss virtually matches the net farm income per ha – an indication of upward bias in the replacement cost method.

The alternative is the yield loss method. Decena (1999) applies this on data from a PCARRD and IBSRAM study (respectively, Philippine Council for Agriculture and Natural Resources Research and Development; and International Board for Soil Research and Management). The study, conducted in upland farms in the provinces of Rizal and Batangas (both in Luzon), compared farmer's practice (up-and-down cultivation with no fertilizer) with soil conservation farming systems. The productivity difference between farmer's practice and conservation systems in Rizal was valued at Php 19,862 (compared to a replacement cost of only Php 11,568); in Batangas the yield difference was valued at Php 13,037, this time smaller than the replacement cost equal to Php 26,451 (which is rather an overestimate due to the severity of potassium degradation in the area.)

Alternatively, one may compute yield differences using an agronomic model. De Guzman (1997) used the EPIC (Erosion Productivity Impact Calculator) on IBSRAM experimental data over the period 1990 – 2002. Actual measured soil loss under farmer's practice ranges from 18 – 124 t/ha/yr; the EPIC simulations predicted 18 – 71 t/ha/yr, quite accurate for the majority of the sample. The EPIC also predicted nearly zero soil loss under conservation farming, consistent with actual measurement. However actual and predicted yields showed substantially larger discrepancies, which points to caution in the use of simulated data.[10] To project future yield loss, crop simulations (when done properly) would probably perform better than simply extrapolating forward from small-sample yield differences *ex post*.

Nelson (1996a, 1996b) applied agronomic modeling to compare open field maize farming and farming with soil conservation. Model parameterization used data from comparative field trials; economic data was collected from communities adjacent to the field trials. Cropping and tillage practices were kept identical across farming methods. For an erosion-prone site (located in Tranca, Laguna, Luzon), yields were projected using the APSIM (Agricultural Production Simulator) over a 50-year horizon, of which 36 years were based on past rainfall data, and the remainder obtained from a random re-sampling of the historical data. Predicted maize yields ranged from 1,000 to more than 3,000 kg/ha for conservation farming, with no clear time trend; however for open field cultivation, maize yield was initially highest at nearly 3,000 kg/ha, but deteriorated steadily over time, dipping below 500 kg/ha from year 30 onward. The differences in midpoint are about 1,250 kg/ha, which converts to about Php 13,318 in 2007 prices.

Meanwhile for a less erosion-prone site (Claveria, Mindanao), the SCUAF (Soil Changes Under Agroforestry) model was used over a 25-year horizon. The predicted yields under either open field or alley cropping was about 1,400 kg/ha, but would steadily decline; by year 25, yield under open field would fall below 400 kg/ha, while that of alley cropping would still reach nearly 800 kg/ha. The difference in midpoint are smaller, at only 200 kg/ha, which converts to just Php 892.

*On-site costs: evaluation and synthesis*

To summarize: the variations in per ha cost estimates is very large, rendering an extrapolation to a national scale problematic. The estimates vary according to plot and site characteristics, as well as valuation method. The fertilizer replacement approach is prone to exaggerating the cost of land degradation. On-site, soil loss from erosion does not entail a reduction in current plant nutrient uptake, only a decline in nutrient availability over the long term. Moreover even if the decline in nutrient uptake equals that lost from erosion, supplementation from inorganic fertilizer need not entail complete replacement of lost nutrients, as a profit-maximizing enterprise would limit fertilizer use to the point where the marginal benefits of fertilization equals the fertilizer price. Finally, there is little reliable information about the extent of soil transfer from farm to farm by way of erosion, further compounding the upward bias.

It turns out that applications of the yield difference approach, whether based on experiments or model simulation, also tend to produce high figures. For our national estimate, we take the lower bound from the replacement cost approach, i.e. from Francisco and de los Angeles (1998), and amend it further with more conservative erosion estimates (38 t/ha/yr) based on Presbitero et al (1995). We apply this to the estimated total upland area, which is about 7.5 million ha, based on the upland area estimates of Francisco and de los Angeles, though updated by a fixed share assumption to the current agricultural area (12.2 million ha).

The resulting figure is Php 6,428 million per year; this is equivalent to just 0.6% of gross value added in agriculture in 2007. In contrast, the research intensity ratio has ranged from 0.26 to 0.37% since 2001. Our estimate of the cost of soil erosion may be considered a conservative "lower bound", compared with estimates from other developing regions; for instance, Young (1994) reckoned the cost of land degradation at about 3.7% of agricultural value added in South Asia. Our national estimate is still however higher than other studies from the region; for example, Huang and Rozelle (1995) erosion and salinization reduced grain yields in China by only 0.4% per year in 1976-1989. Further work is needed to more accurately gauge the cost of land degradation on agriculture on a national scale.

*Off-site costs*

Thus far analysis has been restricted to on-site costs, studies on off-site costs are sparse. An early paper is Cruz, Francisco, and Conway (1988), a case study of two major irrigation and hydropower dams in Luzon (Magat and Pantabangan). In the watershed area, large areas of forest cover has been replaced by grassland and farmland. The measured sedimentation rate in the early 1980s is 73% higher than projected; higher sedimentation is attributed to the unanticipated land degradation in the watershed. This shortens dam lifespan, and reduces dam services by limiting storage capacity. Costs are largely accounted for by decreased irrigation services. The annual cost per ha of irrigation service area is estimated as high as Php 9,600 for Pantabangan and Php 6,000 for Magat.[11]

A fairly comprehensive, national-level assessment of off-site impacts and costs is done by Saastamoinen (1994), though the estimation is largely based on educated guesswork. Aside from irrigation systems, the other off-site impacts are itemized as follows:

- Rainfed agriculture – erosion reduces water supply and retention in rainfed areas, increases siltation in rivers and contributes to flooding.
- Fishery and aquaculture – silt reduces light penetration and primary productivity in the water column; flooding damages cages and ponds; siltation of rivers and lakes reduce productivity of inland fishing; sediment deposits damage coral reefs.
- Food and beverage manufacturing – reduced water quality increases manufacturing costs.
- Construction – flooding increases costs for the construction sector.
- Water supply – loss of natural cover and associated watershed degradation reduces available freshwater and affects water quality.
- Tourism – sedimentation reduces quality of beaches and coral reefs.

Estimates are then made about the magnitude of the effects, in terms of percentages of sector value-added or other related parameters. Where little is known about the impact of erosion, very low percentages are imputed (e.g. 0.5% for tourism). Where effects are clearer higher percentages are selected, e.g. 30% of reef fisheries. Replacement cost was used where this would lead to lower estimates, e.g. power loss from hydroelectric generation is set at 3% of total; this is then valued by the additional cost from replacing lost electricity through diesel – powered generation. Likewise, assumed domestic water supply loss of 5% was valued by the additional cost from replacing the water supply by other methods, e.g. deep well. The final figure is P6.8 billion for 1988 (Php 27 billion in 2007 prices), or about 0.8% of GDP at the time.

Water sampling in four sub-watersheds in upper Manupali River (Mindanao) over the period 1994 -2002 is one of very few time series data that can link water trends to deforestation. Suspended solids range from 5.5 to 5.9 mg/L for the two sub-watersheds where forest cover ranged from 31 – 44%, while agricultural land occupied only 36 – 45% of area. Suspended solids rose to 9.7 mg/L for a more degraded watershed (24% forest cover and 60% farm land). In the most degraded sub-watershed, (21% forest cover and 72% farm land), suspended solids in the upper rivers reached 29.4 mg/L, nearly a six-fold increase over the upper rivers in the more intact watersheds (Rola et al, 2004).

More recent studies have been reviewed in Rola et al (2008). Site-specific studies for the Manupali watershed indicate a 27% drop in lowland rice yield owing to deterioration of the irrigation system due to siltation. Serviceable area was also restricted to 24% of the irrigable area. In the case of the Malinao dam in the Visayas, siltation has shortened service life from 80 to 20 years. Upland agriculture was implicated, as over 60% of agricultural land in the watershed is sloped in excess of 18%, and traditional maize and cassava cultivation results in an eleven-fold increase in soil erosion over more conserving systems.

Rola et al (2008) however note that much of the sediments in irrigation systems may not actually come from soil erosion in upland farms, as there is considerable deposition in the hill slopes (NSCB statistics in fact assume just a 20% sedimentation rate from farm soil erosion.) Erosion in grasslands, bank deterioration, built-over structures (e.g. roads), footpaths, mining (where this is present) may also be implicated in siltation of lowland water systems. Hence, while sedimentation has seriously harmed lowland agriculture through its effect on water systems and irrigation service coverage, it is unclear that soil erosion from agriculture is a significant source of sediments.

## 5. Benefit-cost analysis of priority interventions

### 5.1. Background

*Governance and tenure in the uplands*

Based on our assessment of land degradation costs, we delimit the set of priority interventions to those aimed at upland soil conservation or land rehabilitation. At the national level, the agency with primary responsibility over natural resources, particularly forest land, is the DENR. Management of soil resources fall under the BSWM, which is a bureau of the Department of Agriculture (DA). Under the Local Government Code of 1991, local government units (LGUs) were assigned powers and functions previously exercised by national government; devolved functions include agricultural support services, health and social services, provision and maintenance of local roads, bridges, water supply, and other infrastructure, and management of local natural resources.

Land may be classified by legal status as *alienable and disposable*, or as *public forest land*. The former accounts for 47% of the country’s land total area. The majority of this area (64.8%) is privately owned and titled (Llanto and Ballesteros, 2003). The remainder consists of lands in the public domain which can be potentially converted into private lands. There is however an enormous difference between the legal classification, and actual use and possession. Forestland has been defined as areas with an 18-degree slope or higher; however a large portion of such areas are actually in use as settlement and agricultural land, although have yet to be reclassified. Of the 52% of the country's rural population, 22% reside in the forest zone (World Bank, 2004).

Following the 1986 Constitution, public forest lands can, with the approval of the State, be exploited by individuals or associations through co-production, joint venture, or production-sharing agreements (subject to nationality requirements). Table 12 lists the tenure instruments for forest lands. Of these, the most important by far is the CBFMA, which subsumes various earlier instruments, such as the Forest Land Management Agreement (FLMA), the Community Forestry Management Agreement (CFMA), and the Certificate of Stewardship Contract (CSC). As of 2005, the targeted coverage of the CBFMA is 9 million ha or 57% of forest land. Of this target, about two-thirds has been covered by CBFM, involving nearly 700,000 households in over 5,500 sites. The CBFMA represents a marked departure from the earlier system in which private sector enterprises held TLAs to most of the forest lands. Under a CBFMA, a community represented by a PO (People's Organization) is given the right to occupy, possess, utilize, and develop a CBFM area by the DENR. Community activities are to be guided by a CBFM Framework and 5-year Work Plan. The Agreement also formalizes the distribution of benefits, both between PO and government (often a 70-30 sharing in favor of the former), and among the members of the PO (Pulhin, Amaro, and Bacalla, 2005). Meanwhile traditional community tenure arrangements among indigenous groups may be given formal support through a CADC (Philippine Environmental Governance Program, 2004).

**Table 12: Typology of formal tenure instruments in forest lands**

| Type of forest | Party | Instrument |
|---|---|---|
| Production | Community | CBFMA, CADT/CALC |
| | Private sector | IFMA, SIFMA, FLGMA, FLA, SPLUMA/SLUP, TLA |
| | LGUs | Communal forest |
| | | Community watershed |
| | | Co-management |
| Protected | Community | PACBMRA |

Notes: CBFMA – Community Based Forest Management Agreement; CADT – Certificate of Ancestral Domain Title; CALC – Certificate of Ancestral Land Title; IFMA – Integrated Forest Management Agreement; SIFMA – Socialized Industrial Forest Management Agreement; FLGMA - Forest Land Grazing Management Agreement; FLA – Foreshore Lease Agreement; SPLUMA/SLUP – Special Land Use Management Agreement/Special Land Use Permit; TLA – Timber License Agreement.

Source: Philippine Environmental Governance Program (2004).

*Types of interventions*

Instruments to address land degradation are either **direct** or **indirect**. Direct instruments involve the promotion of: i) soil conserving technologies; ii) more sustainable land uses, such as tree and permanent crops. Of these instruments, benefit-cost analysis has been most frequently applied to soil conservation technologies. These technologies, as described in Garcia et al (2000), include physical barriers, vegetative barriers (e.g. contour hedgerows), supplementary physical structures (e.g. drainage canals), and farm practices (e.g. crop rotation, multiple cropping, etc.) The more important types promoted in the Philippines include:

- Hedgerow intercropping –establishment of hedgerows (often in double rows) of leguminous shrubs or grasses on contour, while farming annual and perennial crops on the alleys. This technology reduces run-off, traps sediments, and forms terraces.
- Bench terracing – construction of terraces using the cut-and-fill method, to reduce run-off and erosion by leveling the slope.
- Contour rock walls – construction of rock walls (0.5 to 1.0 m thick) on contour, with walls stabilized by shrubs or trees, to reduce runoff and trap sediments at the wall base.
- Contour bunds – construction of embankments and canals on the contour, often with hedgerows on the embankments, to trap sediment, increase infiltration, and drain excess runoff.

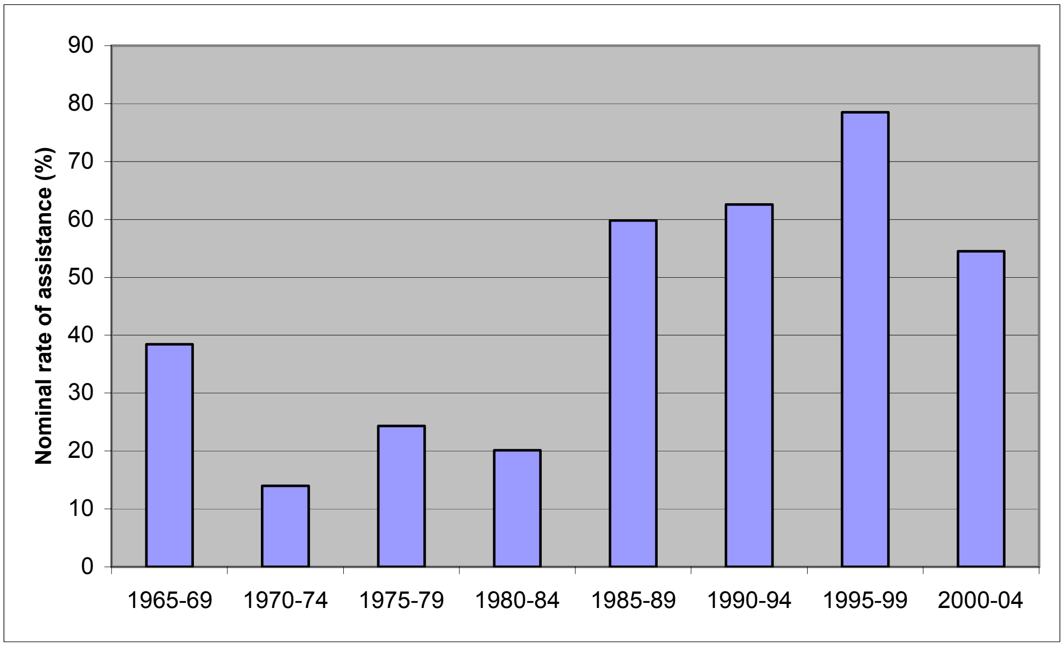
Among these, sloping agricultural land technology (SALT) based on alley cropping has been the focus of various government and nongovernment efforts (Esquejo, 2004). The SALT in the Philippines was pioneered by nongovernment organizations. Government programs also subscribe to these technologies, often within agroforestry projects of the DENR in the CBFM and ISF areas. Similarly numerous research projects in natural resource management (NRM) have been pursued in state universities and colleges, Department of Agriculture - Bureau of Agricultural Research, and PCARRD.

Meanwhile indirect instruments work by altering incentives for the direct instruments, i.e. encourage the adoption of conserving technologies, penalize erosive land use, and so forth. These include trade policies, taxation, finance policies, as well as institutional changes such as tenure reform, devolution of field extension services, etc. In particular, domestic protection for annual crops grown in the uplands point to market distortions that inadvertently promote upland degradation. Domestic corn producers have in particular enjoyed high nominal rates of protection, peaking in the late 1990s (Figure 9). Hence, trade liberalization could in principle reduce soil erosion, though the magnitude of the impact requires further study.

### 5.2. Evaluation of direct interventions

Soil conservation technologies do prevent soil erosion, hence providing on-site benefits to farmers. However the benefits from avoided soil loss should be balanced against the costs of intervention. In general, adoption of soil conservation technologies may involve an investment decision, with large outlays up front, and pay-offs in later periods. Hence the streams of net benefit would need to be discounted to its present value, a calculation that is highly dependent on the choice of discount rate. The social discount rate adopted by NEDA is 15%, a figure that probably incorporates a margin of safety to ensure selection of the most socially beneficial projects.[12] Medalla et al (1990) estimate the marginal productivity of capital at about 10%, which we adopt as an approximation of the social discount rate.

**Figure 9: Nominal rate of assistance to corn (%)**



Source: David, Intal, and Balisacan (2007).

Decena (1999) estimates roughly that contour hedgerow technology incurs investment costs, opportunity costs, and maintenance cost. The first takes the form of labor and planting materials to establish contour hedgerows. The next two are recurring costs: the opportunity cost is the loss in farm production owing to the diversion of farm land into hedgerows; the last is the cost in terms of labor and planting materials to keep the hedgerows intact. Establishment cost is estimated at Php 28,360/ha/yr (2007 prices); opportunity cost can be estimated from the fact that, on average, 16% of farm area is occupied by the hedgerows; finally, maintenance costs is only Php 2,127/ha/yr.

These figures are perhaps based on extension agent recommendations. Farm level data from key informants (farmers) obtain somewhat different estimates (Table 13). These estimates compare open-field (conventional farming) with hedgerow intercropping (conservation technology), in two sites, namely one with relatively erodible soil, and one with less erodible soil. In both sites, the establishment phase involves higher labor cost owing to the added labor requirement. However during the regular farming phase, additional maintenance cost of the conservation technology is offset by lower variable costs from operating a smaller farm land for annual crops (Nelson, Cramb, and Mamicpic, 1996).

**Table 13: Cost comparison, open field and hedgerow intercropping**

| | Open field | Establishment phase | | Regular farming | |
|---|---|---|---|---|---|
| | | Hedgerow | Difference | Hedgerow | Difference |
| Erosion-prone site | | | | | |
| Labor | 31,395 | 51,357 | 19,961 | 35,271 | 3,876 |
| Others | 36,357 | 34,583 | -1,773 | 30,320 | -6,037 |
| Total | 67,752 | 85,940 | 18,188 | 65,591 | -2,161 |
| Less erosion-prone site | | | | | |
| Labor | 12,016 | 22,093 | 10,078 | 13,372 | 1,357 |
| Others | 16,473 | 16,279 | -194 | 15,891 | -581 |
| Total | 28,488 | 38,372 | 9,884 | 29,264 | 775 |

Source: Nelson, Cramb, and Mamicpic (1996). Values converted to 2007 prices using the official CPI.

Based on these figures, along with predicted yield trends (Section 4.2), Nelson et al (1996, 1998) conduct a benefit-cost analysis (Table 14). The analysis covers another option, namely open-field, with-fallow, which involves a corn monocrop alternating with a fallow period (two seasons each). For the erosion-prone site, under a market discount rate of about 25%, the NPV (net present value) of open-field and open-field, with-fallow exceed that of hedgerow intercropping up to a 5-year horizon. For longer horizons, NPV of hedgerow intercropping exceeds that of open-field, but not of open-field, with-fallow. Similarly for the site that is less erosion-prone, open-field cultivation outperforms open-field with fallow, which in turn does better than hedgerow intercropping, whether under the short or long horizon, though at the market rate of discount. This is obviously due to the lower amounts of soil erosion prevented in the first place. However at the social discount rate, in the erosion-prone site, hedgerow is still inferior to open-field in the short horizon, but outperforms the other cropping systems in long horizon. The results conform to the intuition that farmers would have an incentive to invest in soil conservation technologies only if: they have low time preference; they are able to borrow at the social rate of interest; and have longer planning horizon.

**Table 14: Approximate net present value for alternative farming methods (2007 prices)**

| | 5-year horizon | | | 25-year horizon | | |
|---|---|---|---|---|---|---|
| | Open-field | With-fallow | Hedgerow | Open-field | With-fallow | Hedgerow |
| Erosion-prone site | | | | | | |
| 25% discount | 19,380 | 32,946 | > 19,380 | 15,504 | 31,008 | < 31,008 |
| 10% discount | 23,256 | 42,636 | 29,070 | -3,876 | 38,760 | 77,519 |
| Less erosion-prone site | | | | | | |
| 25% discount | 22,287 | 17,442 | 13,566 | 19,380 | 15,504 | 13,566 |

Sources: Nelson (1996, 1998).

These findings are based on crop model simulations. Pattanayak and Mercer (1998) value soil conservation benefits and costs using survey data of upland farmers from Leyte (Visayas), over the period 1993-94. Their indicator is farm profit per household; the effects of variables of interest are isolated from other explanatory variables through econometric analysis. The variables of interest are *soil conservation*, i.e. improvement in soil quality, and *adoption of technology* (hedgerow intercrop). They find that on average, soil conservation yields a benefit of Php 2,749/yr (in 2007 prices), around 10% of average farm income. However the technology itself reduces profit due to maintenance cost and opportunity cost; netting out the two yields a net loss of about Php 5,000/yr. Hence farmers would have no incentive to adopt soil conservation technology. The authors speculate that there “there may be good reason for society to implement an incentive system, through subsidies or extension services, for the farmers to practice agroforestry that would conserve the soil (p. 45)”, in order to realize on-site and downstream benefits not captured by farm profit.

Benefit-cost analysis incorporating land degradation can be applied, not just to soil conservation technologies, but also for outright changes in land uses, i.e. annual versus tree and other permanent crops. One such analysis (Predo and Francisco, 2008) compares several land use options: pasture (*Imperata* grass), annual maize cropping, timber pasture, maize alley cropping with timber hedgerows, alley cropping with bigger timber area (social agroforestry), and timber plantation. Yields were projected using SCUAF. The evaluation horizon is 20 years. Results are shown in Table 16; values are adjusted to 2007 prices. NPVs and rankings are identical, whether a market rate or a social rate of discount is used. Pasture grazing results in the lowest NPV, followed by annual maize cropping. Timber plantation has the highest NPV; at lower (social) discount rates the advantage of timber plantation becomes even sharper. The next most valuable use obtained from social forestry, followed by maize alley cropping. Clearly tree crops (or its variants) offer the highest value; however farmers may still not make the switch owing to their inability to absorb negative income from farming during the long gestation phase of the plantation.

**Table 15: Net present values of various land use systems at alternative discount rates (2007 prices)**

| Land Use System | Net present value (Php/ha) at alternative discount rates | |
|---|---|---|
| | 25% | 10% |
| Pasture | 619 | 1,137 |
| Annual maize cropping | 48,313 | 70,578 |
| Timber with pasture | 79,979 | 341,231 |
| Maize alley cropping with timber hedgerows | 128,023 | 424,114 |
| Social forestry | 224,021 | 870,927 |
| Timber plantation | 550,616 | 2,326,954 |

Source: Predo and Francisco (2008).

### 5.3. Evaluation of indirect interventions

*Tenure reforms*

One set of indirect instruments relate to property rights: in the Philippines, as we have seen, this is implemented through the formalization of tenure in the uplands. Secure tenure may be seen as a means to encourage farmers to make long term investments in land quality, such as soil conservation or shifting to permanent crops. A series of studies on the Philippine uplands in the 1990s (reported in Cramb et al, 2000) find that tenure is not a significant factor in the adoption of soil conservation technologies. One reason may be that farmers already feel reasonably secure about their informal tenure even without a formal instrument, whether individual or collective.

However other studies undertake to explain econometrically the adoption decision and find that ownership is a positive and significant factor, e.g. Lapar and Pandey (1999).

The most comprehensive tenure reform in the uplands is the establishment of CBFM areas. While tenure reform offers great promise as an effective intervention against upland degradation, operational and programmatic problems stand in the way of its fulfillment. This is confirmed in a a recent audit report (Commission on Audit, 2005) whose findings include the following:

- ***Community organizing*** – due to inadequate training, the community organization was not transformed into a viable institution for sustained forest protection.
- ***Livelihood activities –*** majority of the livelihood projects were suspended and terminated; these suffered from inadequate training of participants, and inadequate feasibility studies.
- ***Membership*** – nearly half of the household population within the CBFM area were not members, complicating the task of managing the entire area.
- ***Forest protection*** – forest protection measures were not enforced; in particular forest fire prevention was not implemented, leading to the outbreak of several serious forest fires in the areas.
- ***Forest rehabilitation*** – survival rates of replanted trees were low, ranging from 36 to 68%, owing to poor site selection for tree planting.
- ***Land use planning*** – there was considerable deviation of actual land use from the land use plan; violations of existing policies were observed, e.g. the operation of a mining concession within the area.

### *Economywide price policies*

Another set of indirect instruments are economywide policies (not specifically targeted to land degradation). The effect of policy reform packages on land degradation has been explored using local and economywide (general equilibrium) models. An example of a local level analysis is given in Nelson (1998), who apply the APSIM model described earlier to simulate the effect of a removal of trade protection in corn. This policy is expected to reduce domestic prices by 76% (the nominal protection rate). All types of land use involving corn planting (open-field, with fallow, and hedgerow intercrop) register negative NPV under any horizon; this should induce farmers to move to other land uses, perhaps to less erosive crops.

Another study models the Manupali watershed using an explicit behavioral model (Coxhead and Zelek, 2002; Shively and Coxhead, 2004). In each period, farm households maximize expected returns from farming across various crop types; each crop type generates a mean return for the household. Households face market prices, which can be raised (lowered) by a tax. Crops are produced with inputs along with soil stock; the soil stock can decrease due to erosion, which in turn depends on crop mix, slope, soil type, and rainfall. Erosion also affects downstream sedimentation with some delay. Households solve a one-period problem, which updates the soil stock. There are four types of households, all of which grow white corn: i) households in the forest-buffer area, also growing coffee, ii) households in the same zone, also growing vegetables; iii) households in the mid-watershed area, also growing coffee; iv) households in the same zone, also growing yellow corn. Crop choices reflect resource constraints, i.e. unconstrained households are able to diversify to vegetables and yellow corn. The model is solved for ten periods.

Four policy experiments are examined: i) a 10% subsidy on white corn; ii) a 10% input subsidy for vegetable producers; iii) a 10% tax on vegetables; iii) a 10% reduction in price variance for all crops. Policies are imposed throughout the simulation horizon. Impacts are stated in comparison with a base run. The results of their analysis are as follows:

- Corn subsidy raises erosion by 1.16% , while increasing household welfare by 8%.
- Vegetable subsidy raises erosion by 5%; surprisingly, it reduces welfare by 1%, owing to the long term effects of soil loss. This is because vegetable growing is a highly erosive activity, more so than corn farming.
- Vegetable tax reduces erosion by 9%, and increases household welfare by 6%.
- Market stabilization to reduce price variance increases erosion slightly, by 0.56%. Household welfare improves by 1%.

The most comprehensive modeling approach would be that of computable general equilibrium (CGE). A series of studies beginning from the mid-1990s investigate the environmental effects of trade liberalization via the erosion channel (e.g. Coxhead and Jayasuriya, 1995; 2003a; Coxhead, 2000). An illustrative simulation is Coxhead and Jayasuriya (2003b), which uses the APEX (Agricultural Policy Experiments), a 50-sector whose major structural parameters are econometrically estimated. Side equations based on soil erosion functions permit calculation of land degradation outcomes upon obtaining the CGE solution. In one scenario, cereal imports are exogenously fixed while government purchases of excess supplies to maintain a fixed output price ("NFA closure"). The experiment involves a 10% increase in this support price. Results are as follows: Erosion rises by 1.44%, an additional 6.8 million tons of soil loss. As a share of GDP or even value added, the additional cost is minimal (respectively, 0.014 and 0.06%). However the effect sizable compared to the annual environmental component of government spending on agriculture (7%). This analysis shows that food security-type support policies have significant environmental costs, over and above the usual deadweight burden.

### 5.4. Who benefits and who loses from land degradation interventions?

So far we have examined the benefits and costs without considering its distribution. However social policy may be biased towards improving the well-being of the poor or the worse off. Benefit-cost exercises seldom address equity, hence we examine existing socio-economic profiles of upland farmers in the Philippines to gain insight into the incidence of benefits of land degradation interventions.

It is widely believed that upland farmers are among the "poorest of the poor." A World Bank (1998) report attempts to break down rural poverty into upland and lowland areas, using the 1994 Family Income and Expenditure Survey (which is the source of official statistics on poverty). The breakdown is based on a simple classification of villages as either upland or lowland. Results are shown in Table 16. Upland poverty is indeed higher than in the lowlands, but the difference is trivial in Visayas, though somewhat more important in Luzon and Mindanao. These figures should however be taken with caution as the original survey was not designed to accommodate these categories, and a village-wide classification of "upland" and "lowland" is too aggregative given the actual heterogeneity of the rural landscape.

**Table 16: Poverty incidence in percent, by upland-lowland categories, 1994**

| | Upland | Lowland | Total |
|---|---|---|---|
| Luzon | 58.0 | 45.5 | 50.7 |
| Visayas | 52.4 | 52.0 | 51.7 |
| Mindanao | 67.6 | 57.0 | 60.8 |
| Philippines | 60.6 | 50.3 | 53.8 |

Source: World Bank (1998)

Using an earlier round of the FIES (for 1985), Balisacan (1993b) finds that poverty incidence among corn farmers is 83.5%, compared to 72.9% for all agricultural families, making it the poorest among the sub-sectors of farm households. Turning now to village level studies, for corn there is a rapid field appraisal reported by Gerpacio et al (2004) covers 24 villages from eight provinces. The rapid appraisal covers villages in rainfed lowlands, upland plains, and rolling hills, covering a spectrum of poor to affluent farmers. Owner-operation is the most common tenure, followed by share tenancy. Self-help groups (farmer associations, cooperatives, NGOs, etc.) are present in the corn villages; however, such groups appear to be devoted to enterprise assistance such as for livestock, handiwork business, retail trade, etc., rather than to collective action on the management of common pool resources (such as the watershed). Interestingly, in only two provinces (Cebu and Leyte, both in Visayas) are the corn farmers poorer than average (based on the headcount ratio), in contrast to earlier findings; this points to heterogeneity within this subset of the population. In general the lower income corn farmers have smaller farm sizes, and obtain a smaller share of income from corn farming compared to better-off farmers. A possible source of heterogeneity is in the type of corn crop: white corn farmers grow their crop at least in part for subsistence, and may be asset-poor compared to yellow corn farmers, who are more specialized for commercial growing.

Rice farmers in Palawan, Luzon (Shively, 2001) were surveyed in both upland and lowland environments. Lowland irrigated rice farmers had the biggest average farm size (4.2 ha), compared to upland farmers; the former also obtained bigger yields (over 3 tons/ha/yr in either rainfed or irrigated systems), compared to 1.7 t/ha/yr for upland farmers. Annual farm income per ha is bigger for lowland farmers (from Php 37,000 to Php 61,000 per ha), compared to upland farmers who earned about Php 9,000 – 10,000 per ha. Not surprisingly, per capita income of upland farmers ranges from Php 4,500 to 6,500 per ha, which is way below the national poverty threshold of Php 16,455 per capita. Compare this with lowland farmers, whose household per capita incomes are about Php 32,000 per year.

The last group of farmers we consider are vegetable growers in Lantapan, surveyed under the SANREM project (Nguyen et al, 2007). The village, which hosts 513 households, has about 109 vegetable farmers, of whom the majority (55%) farmed less than 1.5 ha. The village is located in the uplands: 86% of its area is sloped at least 18%. A sample of 50 farmers were surveyed. Despite steep slopes, only three-fourths regard soil erosion as either not a problem, or only a moderately serious problem.

While farming was the major occupation of 70% of the respondents, it turns out agriculture accounts for just 40% of household income on average; 50% came from nonfarm sources, and the remainder from off-farm. These upland farmers were overwhelmingly poor: per capita household income was only Php 2,200 per year, compared to the relevant poverty threshold of Php 14,800; poverty headcount was 80%. Food insecurity was widespread: 37% reported experiencing insufficient food availability throughout the year.

In short, upland farmers, particularly corn growers, are poorer than the average rural household. Hence upland soil conservation and incentives for permanent crop growing do tend to benefit the poor. However farmer adoption has been limited despite aggressive research and extension programs (Lapar and Pandey, 1999). The very fact that upland farmers tend to bee resource-poor is a major reason behind this slow uptake. As mentioned previously, segmented credit markets, credit rationing, and liquidity constraints do restrict adoption of sustainable technologies and shifting to permanent crops. For an upland area in Mindanao, Shively (1997) finds an additional factor, that of consumption risk brought about by the opportunity cost of adopting contour hedgerows. In general, higher farm size, greater tenure security, and higher labor availability are all positively correlated with the likelihood of adoption.

Conversely, measures that reduce profitability of erosive farming in the uplands, such as trade liberalization of corn imports, may harm the poor. Granted that such liberalization measures may need to be pursued for its environmental and allocative benefits, the dislocated upland corn farmers may need special protection measures to facilitate their transition to other activities (World Bank, 1998).

## 6. Conclusion

Land degradation is a complex phenomenon fraught with site-specific processes and relationships. In the Philippines, the spread of settled agriculture into large swathes of erstwhile forested uplands signaled the onset of large-scale soil erosion, the most prominent form land degradation in the country. While land degradation may have as yet location-specific effects, it is likely to become (if not already is) a significant factor in the slowdown and collapse of productivity growth, whether measured in terms of yield or more generally with TFP. The more important cost element of soil erosion is diminution in the stock of available soil nutrients; off-site costs on a national scale are too uncertain to make a viable estimate. Despite the uncertainty associated with valuing soil erosion loss, the evidence suggests a serious enough problem, comparable in importance to the entire public sector investment in research and development.

The benefit of soil conservation technologies, or shifting away from erosive land use, is the avoidance of this soil loss in the long term. Direct interventions typically involve investments as well as immediate maintenance costs to realize these benefits; meanwhile indirect interventions alter the incentive structure of technology adoption or land use. From a social benefit-cost perspective, some studies indicate that direct interventions are worthwhile. However when the credit market is segmented, farmers set short planning horizons (say under insecure tenure), and face liquidity constraints, then farmers would forego these investments. Meanwhile among the indirect interventions, tenure reform has an ambiguous effect, while removal of domestic protection of corn has a positive effect on soil conservation. As upland farmers, including the large population of subsistence corn growers, are among the poorest segments of the rural population, the analysis suggests increasing and widening incentives for adoption of soil conservation and permanent tree crops, while ensuring that trade adjustment measures be accompanied by adequate social protection.

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[1] While agriculture may not have been the primary motivation for the initial clearing of trees and vegetation (as would be mentioned later), farming is a dominant and enduring feature in land use, hence causes and effects of on-going degradation are appropriately linked to agriculture.

[2] Note that yield difference is an incomplete indicator when input application differs between land use or farming systems, and should be supplanted by *net revenue difference* where cost and returns data is available.

[3] Terrastat database: http://www.fao.org/ag/agl/agll/terrastat/wsrout.asp?wsreport=3&region=1&search=Display+statistics+%21. Accessed 26 August 2008.

[4] World Development Indicators (WDI), 2007.

[5] Figures from FAOStat – Agriculture, and BAS Countrystat.

[6] Estimates are based on the GLASOD database (FAO, 2005). The classification involves two dimensions: first is *degree* of degradation, the other is *extent.* The degrees are: light (somewhat reduced agricultural suitability); moderate (greatly reduced agricultural productivity); strong (biotic functions largely destroyed); and extreme (biotic functions destroyed and land is non-reclaimable). The extent classes (per mapping unit) are: 0 – 5%; 5 – 10%; 10 – 25%; 25 – 50%; and 50 – 100%. The classification "severe" denotes light degradation for over 50%; moderate degradation for 10 – 50%; strong degradation for 5 – 25%; and extreme degradation for 5 – 10%.

[7] Throughout the discussion, values reported in the literature are converted to 2007 prices using the Consumer Price Index of the National Statistics Office. In 2007 the average exchange rate was Php 46.15/$US 1.00.

[8] Returns are also highly variable over time. The reason is that annual figures are given based on maintaining a fixed input-output relation but valued using contemporaneous prices.

[9] Polynomial trendline of order 3.

[10] The author also ran a regression relating corn yield to soil loss using estimates generated by EPIC itself, over the period 1990 – 2002. The coefficient of soil loss is 12.5, i.e. every ton of soil loss would supposedly reduce corn yield by 12.5 kg. This result however merely indicative of some correlation, as statistical inference is impossible with non-stochastic data.

[11] Cruz et al's (1988) method assumes that the dam's "dead storage" capacity is an allowance for sedimentation; in the absence of sedimentation, this amount would be available for irrigation. Such an assumption may be problematic. Removal of this item would essentially eliminate the cost of sedimentation in the case of Magat, and reduce the cost estimate for Pantabangan by 97%.

[12] http://www.neda.gov.ph/ads/press_releases/pr.asp?ID=461. Accessed 12 November 2008.