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Addressing Land Degradation: Benefits, Costs, and Policy Directions

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ABSTRACT

Land degradation in the Philippines is a serious environmental problem with long-term implications for the sustainability of agricultural production. Protection of the resource base has thus become a policy priority, whether in terms of improving crop management in the lowlands or more urgently, arresting soil erosion in the uplands. This review aims to compile and evaluate estimates of the costs of land degradation; then analyze the costs, benefits, and equity implications of priority measures to protect soil resources; and lastly, draw implications for policy.

We find that the most important cause of land degradation in the Philippines is soil erosion. Despite wide variations in the figures, and considerable uncertainty about the degradation parameters, even the most conservative methods lead to large estimates of the cost of soil erosion, comparable at least to the annual investment in research and development of the public sector. Direct interventions such as promotion of soil-conserving farm technologies are worthwhile investments based on social benefit-cost analysis. Owing to liquidity and other constraints, however, farmers may forego these investments. Indirect interventions such as tenure reform have an ambiguous effect on soil erosion; however, removal of domestic protection of corn has a positive effect on soil conservation. Upland farmers, including the large population of subsistence corn growers, are among the poorest

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segments of the rural population. The review supports 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.

INTRODUCTION

The traditional strategy of agricultural development neglected protection and management of natural resources and instead focused on intensification. This involves the application of more inputs per unit of land to increase yield, based on modern technology such as genetically improved “Green Revolution” varieties. However, in the past few decades, the problems of the traditional strategy became increasingly evident. Cultivation of areas with a limited and fragile resource base wrought havoc on local ecosystems and land resources, benefiting little from modern technologies (World Bank 2008). Land degradation is now widely recognized as a serious threat to agricultural productivity worldwide (Eswaran et al. 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, causing accelerated soil erosion, siltation of irrigation systems, flooding, and water pollution (Briones 2005). The country’s research and agricultural development strategy is now being reoriented toward sustainable agriculture 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 toward a coherent review and assessment of status, trends, and impacts of human activity, environment and resource management interventions, and welfare impacts on poor households. Hence, this review aims to: i) compile and evaluate estimates of the costs of land degradation; ii) on this basis, analyze the costs and benefits, and equity implications of priority measures to protect soil resources; and iii) draw implications for policy.

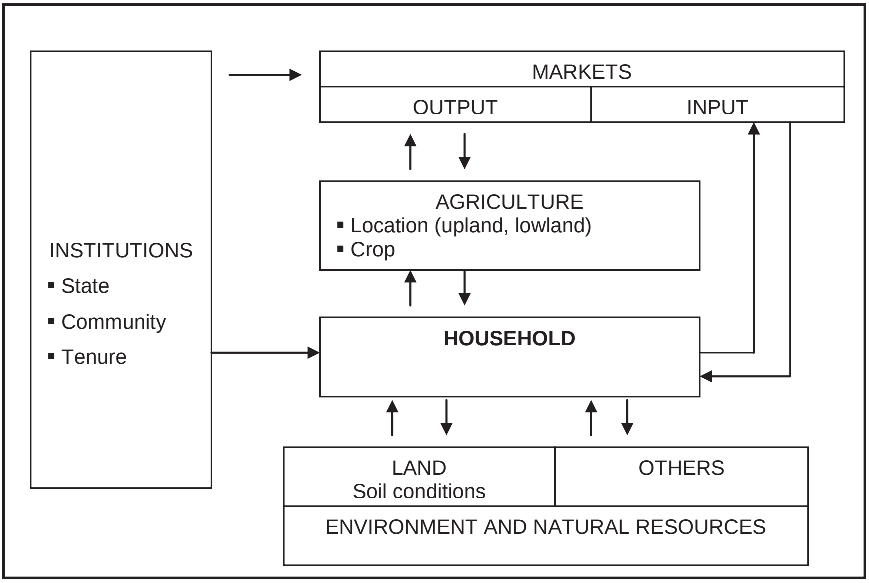
The rest of the paper is organized as follows: Section 2 reviews the background of land degradation within the context of Philippine agriculture. Section 3 deals with the impacts and costs of land degradation. Section 4 evaluates benefits and costs of priority interventions, while Section 5 covers the equity implications. Section 6 presents some conclusions.

CONTEXT

The agricultural system

In this study we focus on 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. Household behavior is modeled in terms of maximization of a pay-off function subject to constraints. Households produce goods and services by combining production factors, which are either purchased from the input market (e.g., fertilizer) or already in their endowment (e.g., land). Output is generally sold to the product market and returns income to households; households may also supplement income by selling their endowment (e.g., family labor) to the factor market. Agriculture is the main production activity and may be distinguished by location (upland, lowland) and crop grown. Farming also depreciates natural capital, i.e., through land degradation.

Figure 1. Conceptual framework



Source: Author's diagram

[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 ongoing degradation are appropriately linked to agriculture.

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 of ownership rights within a 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.

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; and 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 being equal, steeper land is more prone to erosion. 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.

Bojö (1996) lists the most common methods for computing the cost of land degradation. For onsite costs, there are: (i) macrolevel assessments using production functions to derive land degradation coefficients; (ii) microlevel assessments using plot-level data on land degradation impacts on yield that are scaled up; and (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 be 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 offsite impact calculations pertaining to lost capacity for irrigation and/or hydropower, dredging costs, etc. (e.g., Grohs 1994).

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

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 Soils and Water Management (BSWM). The country is an archipelago of about 30 million hectares (ha), formed out of 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 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) are classified as at least fairly suitable for cultivation. About 17 percent of total area are classified as very steep slopes (greater than 30% slope), and another 66 percent as steep slopes (between 8−30% slope), making them prone to erosion.[3]

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

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.

[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.

Box 1. Continued

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.

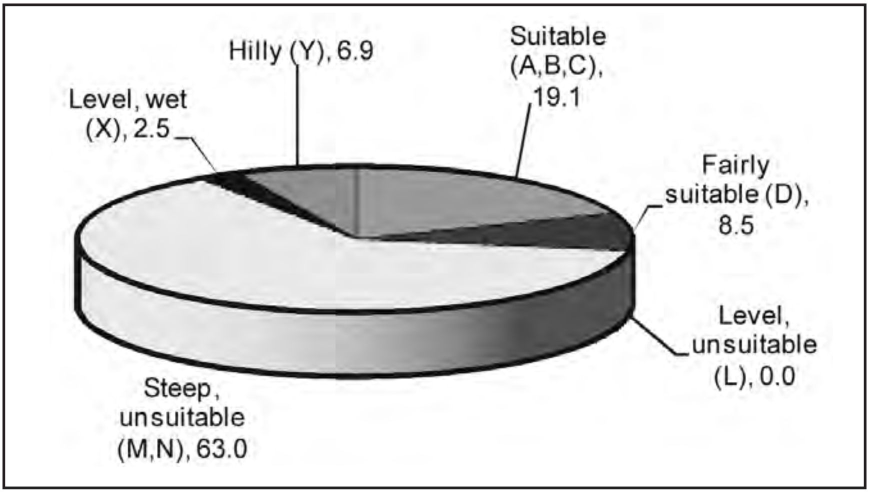
Class N (Very steep land): too shallow and rough or dry for cultivation and easily eroded. Can be used for grazing or forestry.

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.

Source: Bureau of Soils and Water Management (BSWM)

Figure 2. Shares in total land area by land capability category (in percent)



Source: BSWM

Patterns and trends in Philippine agriculture

Agricultural growth was respectable within the period 1965–1980, exceeding the average for developing monsoon Asia countries and comparing favorably with those of Thailand and Indonesia (Balisacan 1993a). In the 1970s, 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 this period, consistently staying above an annual rate of 2 percent. 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 had to be achieved by raising land productivity, i.e., through intensification together with the Green Revolution.

The growth slowdown in the 1980s was accompanied by stagnant productivity growth, both in terms of labor and total factor productivity. Growth in labor productivity, measured as value added in agriculture per agricultural worker, has in fact stagnated since the 1990s (Figure 3), growing only at an average annual rate of about 1.5 percent.

A number of studies have examined total factor productivity (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).

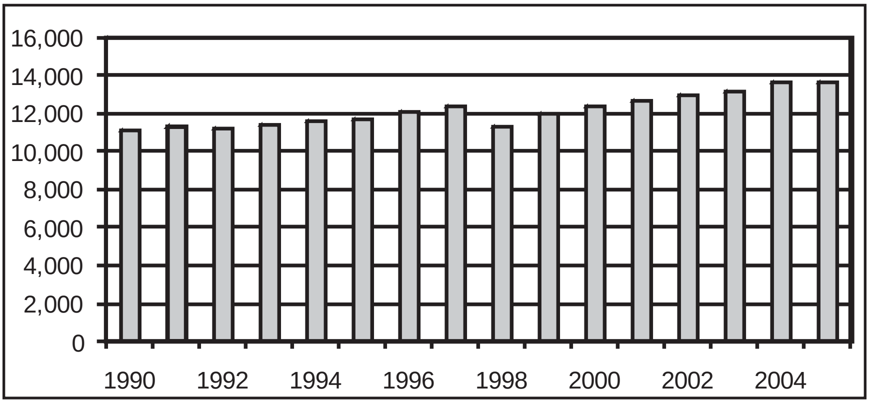
While land endowment, topography, and climate are limiting factors, human activity itself has undermined soil resources. This may have played a role in the

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.

Figure 3. Labor productivity in agriculture, in Philippine pesos per worker (in constant 1985 prices)



Sources: Bureau of Agricultural Statistics (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
Viet Nam	3.3	1.0		
China	4.8	3.6		

Note: Philippines, 1980−1998; Indonesia, 1981−1988; and Thailand, 1981−1995.

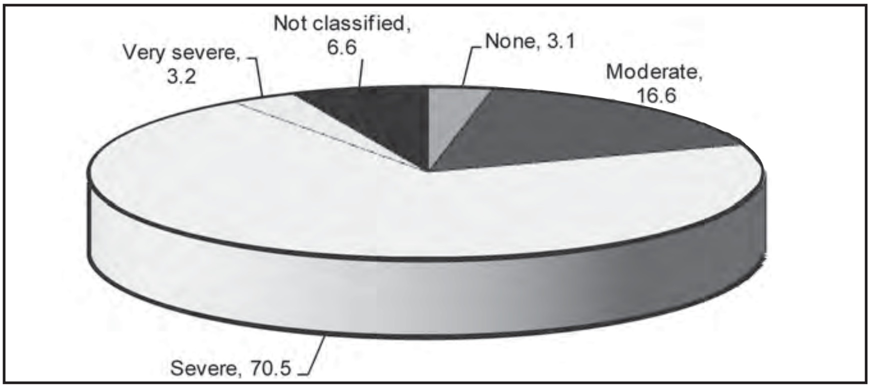
Sources: (1) Avila and Evenson (2010): 1981–2001; (2) FAO (2004): 1980−2000; (3) Cororaton and Caparas (1999); and (4) Mundlak et al. (2004).

slowdown of productivity growth in agriculture. Based on a classification by the Global Assessment of Soil Degradation (GLASOD), over 70 percent of the country's land area has been severely degraded due to soil erosion (Figure 4).[4]

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).

Boserup (1965) outlined economic development in the uplands as follows: before modern economic development, forest lands 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.

Figure 4. Degree of land degradation in the Philippines (percent of land area)



Source: Food and Agriculture Organization (FAO). http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp?country=PHL&search=Display+map+!National. Accessed October 2008.

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[4] 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 nonreclaimable). The extent classes (per mapping unit) are: 0–5 percent; 5–10 percent; 10–25 percent; 25–50 percent; and 50–100 percent. The classification "severe" denotes light degradation for over 50 percent; moderate degradation for 10–50 percent; strong degradation for 5–25 percent; and extreme degradation for 5–10 percent.

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).

Profile of the major crops

Land use in Philippine agriculture has been dominated by a few traditional crops. Despite apparent market incentives toward diversification, resources have shifted very slowly away from existing cropping patterns. Based on area planted/harvested (Table 3), the major crops in the Philippines are palay (paddy rice), corn, coconut, and sugarcane, which are the traditional export crops; and banana, which is a high-value export crop. These crops have been the mainstays of Philippine agriculture accounting for 90 percent of total agricultural area in 2007. In fact, the top three (palay, corn, and coconut) already account for 85 percent 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 both the share and absolute area of corn has been shrinking until the 2000s.

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 (Table 4). In 1960, annual palay yield was only 1.1 tons per hectare (t/ha) (de Leon 2005). This doubled within 20 years, and the yield continued to climb to its current level of about 3.7 t/ha. Even more impressive is the growth in corn yield in recent decades, although this was largely due to the spread of yellow corn varieties for feed production. Yield in the traditional export sector has stagnated and even declined in the case of sugarcane. On the other hand, spectacular yield growth was achieved by the new cash crops.

The consistent climb of yield growth is partly due to intensification. Irrigated area rose from just 0.83 million ha in 1970 to 1.43 million ha by 2007. Growth of irrigated area was due largely to the expansion in privately irrigated rice-growing areas (Inocencio and Barker 2006). Rice production has benefited enormously

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

Table 4. 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

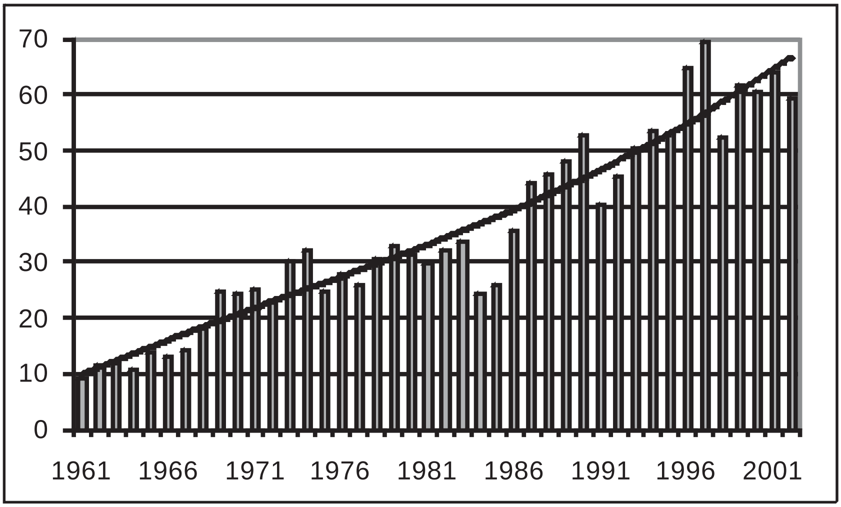
from production support given by the government. Agricultural mechanization proceeded very rapidly, as the number of tractors increased nearly fifteen-fold.[5] Figure 5 shows fertilizer application rates since the 1960s, to which we have added a trendline.[6] Clearly, fertilizer application has generally been on an upward trend, particularly with the onset of the Green Revolution in the late 1960s and 1970s.

Unfortunately, intensification may have been 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 that adjusts for input application, has generally been on a slowdown since the 1980s. However, there is limited analysis of TFP at the crop level. In the case of rice, only

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

[6] Polynomial trendline of order 3.

Figure 5. Fertilizer application rates in kg/ha, Philippines, 1961−2002



Source: FAOStat

one study covering the 1971–1990 period is available (Umetsu et al. 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.

COST OF LAND DEGRADATION

Physical effects of land degradation

Degradation in the lowlands

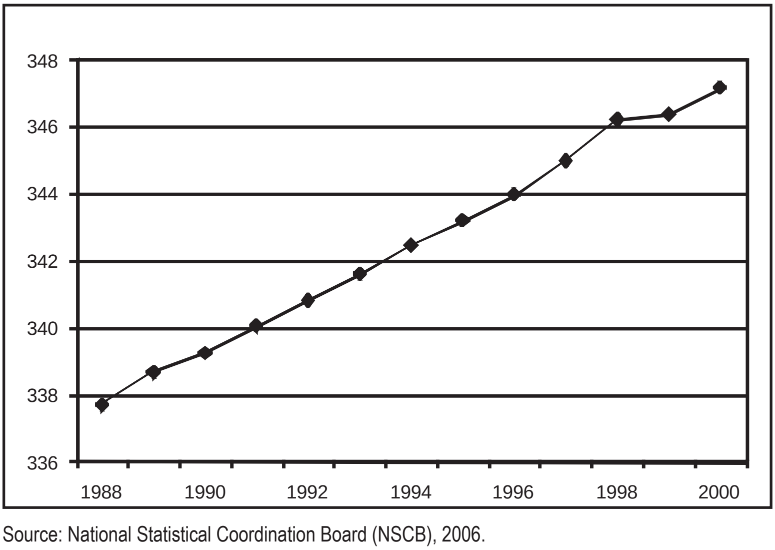
In lowland agriculture, intensive cultivation and high yield accelerate removal of nutrients and alteration of physical and chemical properties of soil. It is possible that continuous cropping, extensive submergence, and high chemical usage may lead to soil degradation. These are indicated by: declining organic matter content and nutrient-supplying capacity; nutrient imbalance; water logging; soil salinity and alkalinity; and forming of hardpans at shallow depths (Reichardt et al. 1998, in Badayos and Calalo 2007). Micronutrient deficiencies were observed in intensively cropped Asian soils, particularly with regard to zinc, boron, iron, manganese, and sulphur (Singh et al. 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, 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. 1991, in Rola 2004).

There is no evidence, however, 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 that have contributed most to agricultural growth. In Karnal, India, soil analysis over the past 15 years shows 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 microlevel assessments and extrapolated nationwide. This method is adopted by official statistics on soil erosion (Figure 6). Over time, estimated soil loss due to erosion has been rising slowly but inexorably, from about 340 million tons per year (t/yr) in the late 1980s to nearly 350 million t/yr by the 2000s.

Figure 6. Amount of soil eroded from agricultural soils, million t/yr, 1988−2000



Source: National Statistical Coordination Board (NSCB), 2006.

The Knowledge Networking for Rural Development in Asia/Pacific Region (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 5. 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 tons per hectare per year (t/ha/yr). Total loss from agriculture is under a third that of grasslands, and its rate of erosion per hectare is 74 percent lower. The average figure reported for agriculture (63 t/ha/yr) is close to the figures obtained by plot experiments of Poudel et al. (1999). There is of course a large variation across studies depending on experimental site: Paningbatan et al. (1995) report figures in the high range, e.g., 140 t/ha/yr for moderately sloped lands in Laguna Province, planted to corn and mungbean; Rose (2001) 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 5. Gross and average erosion rates by land use, 1993

Region		Gross Erosion Rate (million t/yr)				Average
		Agriculture	**Grassland**	Woodland	Total	**(t/ha/yr)**
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 delos Angeles (1998).

Table 6. Soil depletion horizon by region, 1993

	Soil Depth (cm)	Density (gm/cc)	Years to Deplete 1 cm	Years to Deplete 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	1.40	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	1.90	177
XII	120	0.91	0.96	115
Philippines	97	1.18	1.43	135

Source: Francisco and delos Angeles (1998).

Erosion by crop is quantified in several Sustainable Agriculture and Natural Resource Management (SANREM) studies (Table 7). The three major crop categories are rice, corn, and other agriculture crops (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).

Erosion coefficients have so far been measured for direct farming activities in the uplands. Indirect effects through interindustry linkages can also be gauged using input-output analysis. This obtains soil depletion multipliers shown in Table 8 (ENRAP Phase III 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 7. Area and erosion rates of selected upland crops (various sources)

Land Use	Slope Grade (%)		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 (2002)

Table 8. Soil depletion multipliers, in t/yr per PHP 1,000 change in demand (in constant 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)

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 delos Angeles (1998) convert Francisco's (1994) soil loss estimates into monetary values based on replacement cost as of 1993 (Table 9). 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.

Losses per ton of soil can be converted into losses per hectare 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 per ha. Table 9 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

Table 9. Nutrient loss due to erosion per ha, quantity in kg, and value (in constant 2007 prices)

	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 delos Angeles (1998) for national estimates; and Josue and Mendoza (2001) for Bondoc estimates. Values converted to 2007 prices using the official CPI.

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 delos Angeles (1998), 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 percent above that of the second. At the last level, the value of loss virtually matches the net farm income per hectare─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 Philippine Council for Agriculture and Natural Resources Research and Development (PCARRD) and International Board for Soil Research and Management (IBSRAM) study. 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 Erosion Productivity Impact Calculator (EPIC) on IBSRAM experimental data over the period 1990–2002. Actual measured soil loss under farmer's practice ranges from 18 to 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, suggesting caution be taken in using simulated data.[7] 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 et al. (1996a, 1996b) applied agronomic modeling to compare open-field maize farming and farming with soil conservation. Model parameterization uses data from comparative field trials; economic data was collected from communities adjacent to the field trials. Cropping and tillage practices are kept identical across farming methods. For an erosion-prone site (located in Tranca,

[7] 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, is merely indicative of some correlation, as statistical inference is impossible with nonstochastic data.

Laguna, Luzon), yields were projected using the Agricultural Production Simulator (APSIM) over a 50-year horizon, of which 36 years are based on past rainfall data, and the remainder obtained from a random resampling of the historical data. Predicted maize yields range 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 Soil Changes Under Agroforestry (SCUAF) model was used over a 25-year horizon. The predicted yields under either open field or alley cropping were 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 is smaller at only 200 kg/ha, which converts to just PHP 892.

On-site costs: evaluation and synthesis

To summarize: the variations in per hectare cost estimates are 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 equal 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 delos 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 delos 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 percent of gross value added in agriculture in 2007. In contrast, the research intensity ratio has ranged from 0.26 to 0.37 percent 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 percent of agricultural value added in South Asia. However, our national estimate is still higher than other studies from the region. For example, Huang and Rozelle (1995) noted that erosion and salinization reduced grain yields in China by only 0.4 percent 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, the analysis has been restricted to on-site costs. Studies on off-site costs are sparse. An early paper is by Cruz et al. (1988), which is a case study of two major irrigation and hydropower dams in Luzon (Magat and Pantabangan). In the watershed area, large areas of forest cover have been replaced by grassland and farmland. The measured sedimentation rate in the early 1980s is 73 percent 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 to be as high as PHP 9,600 for Pantabangan and PHP 6,000 for Magat.[8]

A fairly comprehensive, national-level assessment of off-site impacts and costs is done by Saastamoinen (1994), although 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 reduces 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 the associated watershed degradation reduce available freshwater and affect water quality.
- Tourism – sedimentation reduces quality of beaches and coral reefs.

[8] 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 percent.

Estimates of the magnitude of the effects are then made 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. For instance, power loss from hydroelectric generation is set at 3 percent of total, which is then valued by the additional cost from replacing lost electricity through diesel-powered generation. Likewise, assumed domestic water supply loss of 5 percent was valued by the additional cost from replacing the water supply by other methods, e.g., deep well. The final figure is PHP 6.8 billion for 1988 (PHP 27 billion in 2007 prices), or about 0.8 percent of GDP at the time.

Water sampling in four subwatersheds in upper Manupali River (Mindanao) over the period 1994–2002 is one of the very few time-series data that can link water trends to deforestation. Suspended solids range from 5.5 to 5.9 microgram per liter (mg/L) for the two subwatersheds where forest cover ranged from 31–44 percent, while agricultural land occupied only 36–45 percent 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 subwatershed (21% forest cover and 72% farm land), suspended solids in the upper rivers reached 29.4 mg/L or 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 percent drop in lowland rice yield owing to deterioration of the irrigation system due to siltation. Serviceable area was also restricted to 24 percent 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 percent of agricultural land in the watershed is sloped in excess of 18 percent, 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.[9] Erosion in grasslands, bank deterioration, built-over structures (e.g., roads), footpaths, and 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.

[9] NSCB statistics in fact assume just a 20 percent sedimentation rate from farm soil erosion.

BENEFIT-COST ANALYSIS OF PRIORITY MEASURES

Background

Governance and tenure in the uplands

Based on our assessment of land degradation costs, we delimit the set of priority measures 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 percent 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. Forest land 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 they have yet to be reclassified. Of the 52 percent of the country's rural population, 22 percent 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 coproduction, joint venture, or production-sharing agreements (subject to nationality requirements). Table 10 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 percent of forest land. Of this target, about two-thirds have 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 Timber License Agreements (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

Table 10. 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
		Communal forest
	LGUs	Community watershed
		Comanagement
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).

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).

Types of interventions

Instruments to address land degradation are either *direct* or *indirect*. Direct instruments involve the promotion of: i) soil-conserving technologies; and 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 (0.5−1.0 m thick) on contour, with walls stabilized by shrubs or trees, to reduce run-off 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 run-off.

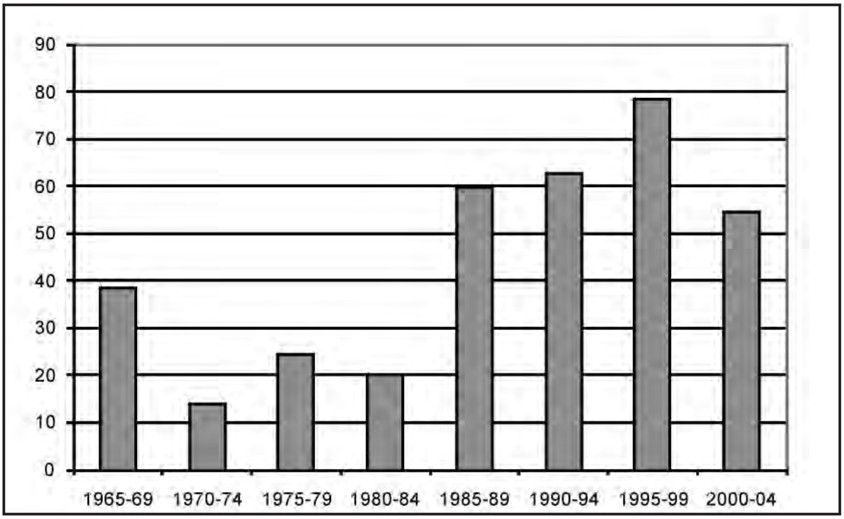
Among these, sloping agricultural land technology (SALT) based on alley cropping has been the focus of various government and nongovernment efforts (Esquejo 2004). The SALT in the Philippines was pioneered by nongovernment organizations. Government programs also subscribe to these technologies, often 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 7). Hence, trade liberalization could in principle reduce soil erosion, though the magnitude of the impact requires further study.

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

Figure 7. Nominal rate of assistance to corn (%)



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

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 the National Economic and Development Authority (NEDA) is 15 percent, a figure that probably incorporates a margin of safety to ensure selection of the most socially beneficial projects.[10] Medalla et al. (1990) estimate the marginal productivity of capital at about 10 percent, which we adopt as an approximation of the social discount rate.

Decena (1999) roughly estimates 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 percent 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 11). 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 et al. 1996a).

Based on these figures, along with predicted yield trends (Section 4.2), Nelson et al. (1996b, 1998) conduct a benefit-cost analysis (Table 12). 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 percent, the net present value (NPV) 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

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

Table 11. 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 et al. (1996a). Values converted to 2007 prices using the official CPI.

Table 12. 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 percent discount	19,380	32,946	> 19,380	15,504	31,008	< 31,008
10 percent discount	23,256	42,636	29,070	-3,876	38,760	77,519
Less erosion-prone site						
25 percent discount	22,287	17,442	13,566	19,380	15,504	13,566

Sources: Nelson et al. (1996b, 1998)

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.

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 percent 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 argue that "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 to 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 13, 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 is 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 13. 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 percent	10 percent
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)

Evaluation of indirect interventions

Tenure reforms

One set of indirect instruments relates 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) finds 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 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 percent, 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.

Economy-wide price policies

Another set of indirect instruments are economy-wide policies (not specifically targeted to land degradation). The effect of policy reform packages on land degradation has been explored using local and economy-wide (general equilibrium) models. An example of a local level analysis is given in Nelson et al. (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 percent (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 (Shively and Zelek 2002; Coxhead and Shively 2006). 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; and 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 percent subsidy on white corn; ii) a 10 percent input subsidy for vegetable producers; iii) a 10 percent tax on vegetables; and iv) a 10 percent 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 percent, while increasing household welfare by 8 percent.
- Vegetable subsidy raises erosion by 5 percent; surprisingly, it reduces welfare by 1 percent 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 percent and increases household welfare by 6 percent.
- Market stabilization to reduce price variance increases erosion slightly by 0.56 percent. Household welfare improves by 1 percent.

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 maintain a fixed output price ("NFA closure"). The experiment involves a 10 percent increase in this support price. Results are as follows: erosion rises by 1.44 percent, 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 is 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.

Land degradation and equity

We have examined so far the benefits and costs without considering its distribution. However, social policy may opt for a bias toward the well-being of the poor. Benefit-cost exercises seldom address equity hence we examine existing socioeconomic 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 (FIES), 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 14. 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.

Using an earlier round of the FIES (for 1985), Balisacan (1993b) finds that poverty incidence among corn farmers is 83.5 percent, compared to 72.9 percent for all agricultural families, making it the poorest among the subsectors of farm households. Turning now to village-level studies, for corn there is a rapid field appraisal reported by Gerpacio et al. (2004) covering 24 villages from eight

Table 14. 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)

provinces. The rapid appraisal covers villages in rain-fed 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 livestock production, 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 t/ha/yr in either rain-fed or irrigated systems) compared to 1.7 t/ha/yr for upland farmers. Annual farm income per hectare is bigger for lowland farmers (from PHP 37,000 to PHP 61,000/ha) compared to upland farmers who earned about PHP 9,000–10,000 per hectare. Not surprisingly, per capita income of upland farmers ranges from PHP 4,500 to 6,500 per hectare, 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 percent of its area is sloped at least 18 percent. A sample of 50 farmers was 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 percent of the respondents, it turns out agriculture accounts for just 40 percent of household income on average; 50 percent 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 percent. Food insecurity was widespread: 37 percent reported experiencing insufficient food availability throughout the year.

In short, upland farmers, particularly subsistence 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 be resource poor is a major reason behind this slow uptake as segmented credit markets and liquidity constraints restrict adoption of sustainable technologies and the shift 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).

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 of 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.

REFERENCES

Avila, A. and R. Evenson. 2010. Total factor productivity growth in agriculture: the role of technological capital. In R. Evenson and P. Pingali (eds.), *Handbook of Agricultural Economics* 4:3769–3822. Amsterdam: North Holland.

Badayos, R. and F. Calalo. 2007. Farm sustainability and organic farming. In A. M. Balisacan, L. S. Sebastian, and Associates (eds.), *Securing rice, reducing poverty: challenges and policy directions.* Laguna: Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Balisacan, A. 1993a. Agricultural growth and rural performance: a Philippine perspective. *Journal of Philippine Development* 20(2):289–317.

———. 1993b. Agricultural growth, landlessness, off-farm employment, and rural poverty. *Economic Development and Cultural Change* 41(3):533–562.

Bojö, J. 1996. The costs of soil degradation in sub-Saharan Africa. *Ecological Economics* 16:161–171.

Boserup, E. 1965. *The conditions of agricultural growth: the economics of agrarian change under population pressure.* Chicago: Aldine.

Briones, N. 2007. Environmental sustainability issues in Philippine agriculture. *Asian Journal of Agriculture and Development* 2(1/2):67–78.

Cassman, K. and P. Pingali. 1995. Extrapolating trends from long-term experiments to farmers' fields: the case of irrigated rice systems in Asia. In V. Barnette, R. Payne, and R. Steiner (eds.) *Agricultural sustainability: economic, environmental and statistical considerations*. New York: John Wiley and Sons Ltd.

Commission on Audit. 2005. Community-based Forest Management Program: Department of Environment and Natural Resources. Sectoral Performance Audit Overall Report. Commission on Audit, Quezon City, Philippines.

Concepcion, R. 2004. Philippines Country Report: gateway to land-water information [online]. www.fao.org/agl/swlwpnr/reports/y_ta/z_ph/ph.htm#physio [Accessed 25 August 2008.] Rome: Food and Agriculture Organization.

Cororaton, C. and M. Caparas. 1999. Total factor productivity: estimates for the Philippine economy. PIDS Discussion Paper No. 99-06. Makati City: Philippine Institute for Development Studies.

Coxhead, I. 2000. Consequences of a food security strategy for economic welfare, income distribution, and land degradation: the Philippine case. *World Development* 28(1):111−128.

———. 2002. Development and the upland resource base: economic and policy context, and lessons from a Philippine watershed. *Philippine Journal of Development* 29(1): 1−32.

——— and S. Jayasuriya. 1995. Trade and tax reforms and the environment: the economics of soil erosion in developing countries. *American Journal of Agricultural Economics* 77:631– 44.

——— and S. Jayasuriya. 2003a. *The open economy and the environment, development, trade and resources in Asia.* Cheltenham: Edward Elgar.

——— and S. Jayasuriya. 2003b. Environment and natural resources. In A. Balisacan and H. Hill (eds.), *The Philippine economy: development, policies, and challenges.* Quezon City: Ateneo de Manila University Press.

——— and G. Shively. 2006. Economic incentives and agricultural outcomes in upland settings. In I. Coxhead and G. Shively (eds.), *Land use changes in tropical watersheds*. I. Wallingford: CABI Publishing.

Cramb, R. 2000. Agricultural land degradation in the Philippine uplands: an overview. In R.A. Cramb (ed.), *Soil conservation technologies for smallholder farming systems in the Philippine uplands: a socioeconomic evaluation.* ACIAR Monograph No. 78. Canberra: ???

———, J. Garcia, R. Gerrits, and G. Saguiguit. 2000. Adoption of soil conservation technologies in the case study sites. In R.A. Cramb (ed.), *Soil conservation technologies for smallholder farming systems in the Philippine uplands: a socioeconomic evaluation.* ACIAR Monograph No. 78. Canberra: Australian Center for International Agricultural Research.

Cruz, W., H. Francisco, and Z. Conway. 1988. The on-site and downstream costs of soil erosion in the Magat and Pantabangan watersheds. *Journal of Philippine Development* 15(1):85−111.

Cummings, D. 1999. What is soil degradation? *Landcare Notes*. December LC0063. Department of Primary Industries, State of Victoria, Australia.

David, C., P. Intal, and A. Balisacan. 2009. The Philippines. In K. Anderson and W. Martin, (eds.), *Distortions to agricultural incentives in Asia*. Washington, D.C.: The World Bank.

De Guzman, M. 1997. Evaluating the impacts of area development plans and soil conservation practices on soil productivity: a simulation approach. Unpublished M.S. Thesis, University of the Philippines Los Baños.

De Leon, J. 2005. Rice that Filipinos grow and eat. PIDS Discussion Paper Series No. 2005-11. Makati City: Philippine Institute for Development Studies.

Decena, F. 1999. Economic values of erosion in upland farms in Rizal and Batangas, Philippines, 1989–1994. Unpublished M.S. Thesis, University of the Philippines Los Baños.

Department of Environment and Natural Resources (DENR). 2005. *The Philippines green environment: some facts and figures*. Quezon City: DENR.

Doberman, A. and D. Dawe. 2008. Can organic agriculture feed Asia? *Rice Today*. October–December Issue. Los Baños, Laguna: International Rice Research Center.

ENRAP Phase III. 1996. *Main Report*. DENR-USAID, Manila, Philippines.

Esquejo, E. 2004. Philippines. In T. Partap (ed.) *Sustainable farming systems in upland areas: Report of the APO study meeting, New Delhi, India, 15–19 January 2001.* Tokyo: Asian Productivity Organization.

Eswaran, H., R. Lal, and P. Reich. 2001. Land degradation: an overview. In E. Bridges, I. Hannam, L. Oldeman, F. Pening de Vries, S. Scherr, and S. Sompatpanit (eds.), *Responses to land degradation*. Proceedings of the 2nd International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. New Delhi: Oxford Press.

Food and Agriculture Organization (FAO). 2004. *State of agricultural commodity markets 2004.* Rome: FAO.

———. 2005. TerraStat: Global land resources GIS models and databases for poverty and food insecurity mapping. FAO Land and Water Digital Media Series CD-ROM No. 20. Rome: FAO.

Francisco, H. 1994. Upland soil resources of the Philippines: resource assessment and accounting for soil depreciation. ENRAP Phase II Technical Report No. 6.

——— and M. delos Angeles. 1998. *Soil resources depreciation and deforestation: Philippine case study in resource accounting.* Rome: Food and Agriculture Organization.

Garcia, J., R. Gerrits, R. Cramb, and G. Saguiguit. 2000. In R. Cramb (ed.), *Soil conservation technologies for smallholder farming systems in the*

Philippine uplands: a socioeconomic evaluation. ACIAR Monograph No. 78. Canberra: Australian Center for International Agricultural Research.

Gerpacio, R., J. Labios, R. Labios, and E. Diangkinay. 2004. *Maize in the Philippines: production systems, constraints, and research priorities*. Mexico, D.F.: International Maize and Wheat Improvement Center.

Grohs, F. 1994. *Economics of soil degradation, erosion, and conservation: a case study of Zimbabwe*. Kiel: Wissenshaftsverlag Vauk Kiel KG.

Huang, J. and S. Rozelle. 1995. Environmental stress and grain yields in China. *American Journal of Agricultural Economics* 77:853–864.

Inocencio, A. and R. Barker. 2006. Water resources and irrigation. In A. Balisacan, R. Sebastian, and Associates (eds.), *Securing rice, reducing poverty: challenges and policy directions*. Los Baños: Southeast Asian Regional Centre for Graduate Study and Research in Agriculture.

Josue, D. and T. Mendoza. 2001. Valuation of nutrient losses due to soil erosion in a tropical upland agroecosystem. *The Philippine Agricultural Scientist* 84(1):90–98.

Kaosa-ard, M. and B. Rerkasem. 2000. *The growth and sustainability of agriculture in Asia.* Oxford: Oxford University Press.

Lapar, M. and S. Pandey. 1999. Adoption of soil conservation: the case of the Philippine uplands. *Agricultural Economics* 21:241–256.

Llanto, G. and M. Ballesteros. 2003. Land issues in poverty reduction strategies and the development agenda: Philippines. PIDS Discussion Paper Series No. 2003-03. Makati City: Philippine Institute for Development Studies.

Medallla, E., V. Pineda, E. Tan, R. Querubin, and C. del Rosario. 1990. Reestimation of shadow prices for the Philippines. PIDS Discussion Paper Series No. 90-16. Makati City: Philippine Institute for Development Studies.

Mundlak, Y., D. Larson and R. Butzer. 2004. Determinants of agricultural growth in Thailand, Indonesia, and the Philippines. In T. Akiyama and D. Larson (eds.), *Rural development and agricultural growth*. Canberra: Asia Pacific Press.

National Statistical Coordination Board (NSCB). 2006. *Compendium of Philippine Environment Statistics*. Manila: NSCB.

Nelson, R., R. Cramb, and M. Mamicpic. 1996a. Costs and returns of hedgerow intercropping and open-field maize farming in the Philippine uplands. SEARCA-UQ Uplands Research Project Working Paper No. 11. College, Laguna: SEARCA and UQ.

Nelson, R., P. Grist, K. Menz, R. Cramb, E. Paningbatan, and M. Mamicpic. 1996b. A cost-benefit analysis of hedgerow intercropping in the Philippine uplands using the SCUAF model. *Agroforestry Systems* 35(2): 203–220.

Nelson, R., J. Dimesa, E. Paningbatan, and D. Siburna. 1998. Erosion/ productivity modeling of maize farming in the Philippine uplands part I: parameterising the Agricultural Production Systems Simulator. *Agricultural Systems* 58(2): 129–146.

Nguyen, M., J. de Mesa, and A. Rola. 2007. Vegetable agroforestry system: baseline survey results in Songco, Lantapan, Bukidnon, Philippines, 2006. Working Paper No. 05-07. Virginia: SANREM-CRSP, Virginia Tech.

Pampolino, M., E. Laureles, H. Gines, and R. Buresh. 2008. Soil carbon and nitrogen changes in long-term continuous lowland rice cropping. *Soil Science Society of America Journal* 72:798−807.

Paningbatan, E., C. Ciesiolka, K. Coughlan, and C. Rose. 1995. Alley cropping for managing soil erosion of hilly lands in the Philippines. *Soil Technology* 8:193–204.

Pattanayak, D. and E. Mercer. 1998. Valuing soil conservation benefits of agroforestry: contour hedgerows in the Eastern Visayas, Philippines. *Agricultural Economics* 18(1):31−46.

Philippine Environmental Governance Project. 2004. *Allocation and tenure instruments on forest lands: a source book.* Quezon City: Department of Environment and Natural Resources.

Poudel, D., D. Midmore, and L. West. 1999. Erosion and productivity of vegetable systems on sloping volcanic ash-derived Philippine soils. *Soil Science Society of America Journal* 63:1366–1376.

Predo, C. and H. Francisco. 2008. Improving productivity, profitability, and sustainability of degraded grasslands through tree-based land use systems in the Philippines. In D. Snelder and R. Lasco (eds.), *Smallholder tree growing for rural development and environmental services.* Advances in Agroforestry Vol. 5. Dordrecht: Springer Science.

Presbitero, A., M. Escalante, C. Rose, K. Coughlan, and C. Ciesiolka. 1995. Erodibility evaluation and the effects of land management practices on soil erosion from steep slopes in Leyte, the Philippines. *Soil Technology* 8:205–213.

Pulhin, J., M. Amaro, and D. Bacalla. 2005. Philippines community-based forest management 2005. Country report presented during the Community Forest Forum, Regional Community Forestry Training Center, Bangkok, 24−26 August.

Reichardt, W., A. Doberman, and T. George. 1998. Intensification of rice production systems: opportunities and limits. In G. Dowling, S. Greenfield, and K. Fisher (eds.), *Sustainability of rice in global food systems*. Los Baños: Pacific Basin Study Center and International Rice Research Institute.

Rola, A. 2004. Research program planning for agricultural resource management: a background analysis. In E. Ponce (ed.), *Special issues in agriculture*. Makati City: Philippine Institute for Development Studies.

———, W. Deutsch, J. Orprecio, and A. Sumbalan. 2004. Water resources management in a Bukidnon subwatershed: what can community-generated data offer? In A. Rola, H. Francisco, and J. Liguton (eds.), *Winning the water war: watersheds, water policies, and water institutions*. Makati City: Philippine Institute for Development Studies.

——— and I. Coxhead. 2005. Economic development and environmental management in the uplands of Southeast Asia: challenges for policy and institutional development. *Agricultural Economics* 32(1): 243–256.

———, A. Sajise, D. Harder, and J. Alpuerto. 2008. Can soil conservation practices improve upland corn productivity? Paper presented at the 6th Asian Agricultural Economics Society Meeting, AIM Conference Center, Makati City, Philippines, 28−30 August.

Rose, C. 2001. Soil erosion models and implications for conservation of sloping tropical lands. In *Sustaining the global farm: selected papers from the 10th International Soil Conservation Organization Meeting, 24−29 May 1999*. Winnipeg: International Institute for Sustainable Development.

Saastamoinen, O. 1994. Off-site costs of soil erosion and watershed degradation in the Philippines: sectoral impacts and tentative results. PIDS Discussion Paper Series No. 94-18. Makati City: Philippine Institute for Development Studies.

Sadasa, D., M. Baratang, L. Siase, H. Aplinares, and M. Recel. 1991. Nutrient management for sustaining crop production. Soil Resources Development Center, Bureau of Soils and Water Management.

Schmitt, L. 2009. Developing and applying a soil erosion model in a data-poor context to an island in the rural Philippines. *Environment, Development, and Sustainability* 11(1):19−42.

Shively, G. 1997. Consumption risk, farm characteristics, and soil conservation adoption among low-income farmers in the Philippines. *Agricultural Economics* 17:165–177.

———. 2001. Agricultural change, rural labor markets, and forest clearing: an illustrative case from the Philippines. *Land Economics* 77(2):268–284.

———. and C. Zelek. 2002. Linking economic policy and environmental outcomes at a watershed scale. *Philippine Journal of Development* 29(1):101−126.

Singh, R., T. Woodhead, and M. Papademetriou. 2002. Strategies to sustain and enhance Asia-Pacific rice production. In Dat Van Tran (ed.), *Sustainable rice production for food security: Proceedings of the 20th Session of the International Rice Commission*, Bangkok, 23–26 July. Rome: Food and Agriculture Organization.

Umetsu, C., T. Lekprichakul, and U. Chakravarty. 2003. Efficiency and technical change in the Philippine rice sector: a Malmquist total factor productivity analysis. *American Journal of Agricultural Economics* 85(4):943–963.

World Bank. 1998. *Philippines: promoting equitable rural growth.* Rural Development and Natural Resources Sector Unit, East Asia and Pacific Region, World Bank, Washington, D.C.

———. 2008. *Agriculture for development: World Development Report 2008*. Washington D.C.: World Bank.

World Bank Country Office-Philippines. 2004. *Philippine Environment Monitor 2004: Assessing Progress.* Washington D.C.: World Bank.

Young, A. 1994. *Land degradation in South Asia: its severity, causes, and effects upon the people.* World Soil Resources Reports. Rome: Food and Agriculture Organization.