Journal of Philippine Development
Number Twenty-Six, Volume XV, No. 1,1988

THE ON-SITE AND DOWNSTREAM COSTS OF SOIL EROSION IN THE MAGAT AND PANTABANGAN WATERSHEDS

Wilfrido Cruz, Herminia A. Francisco, and Zenaida T. Conway

I. Introduction

Objectives and Overview

The conversion of forest land to agricultural use or to open grassland has led to accelerated soil erosion and sedimentation problems in uplands throughout the Philippines. While estimates of the extent of both deforestation and soil erosion vary, the situation is serious enough to warrant these problems being referrred to as the most critical environmental problems in the country (NEPC, I982).

Much research remains to be done in quantifying the extent of soil erosion as well as in developing predictive models that may be used to identify erosion-prone areas (see David, this volume). However, together with such a research effort, there is a need to consider the economic aspects of the soil erosion problem if the relative benefits and costs of alternative conservation projects are to be determined. Towards this end, the first task must be to estimate the economic costs (both private and social) that arise from indiscriminate exploitation of the uplands. This paper offers a practical methodology for asssessing the economic impact of soil erosion and illustrates the methodology with results from two key watersheds — Magat and Pantabangan in the Philippines.

Dr. Cruz is Assistant Professor, Economics Department, College of Economics and Management (CEM), University of the Philippines at Los Baños (UPLB); Dr. Francisco is Associate Professor, Department of Agricultural Economics, Benguet State University; and Ms. Conway is Instructor, Economics Department, CEM, UPLB. This article is a condensed version of *The On-site and Downstream Costs of Soil Erosion,* Technical Report No. 87-04 of the Upland Resource Policy Program, funded by the Philippine Institute for Development Studies and the International Development Research Centre. The authors are grateful to Drs. William Hyde, Thomas Weins, and Emmanuel de Dios for their helpful comments on the various findings of this study.

Apart from contributing to benefit-cost analyses, however, valuation methods for soil erosion are important for assessing the government's general policy options with respect to erosion abatement. Among these options, reforms in the system of resource pricing, which includes charges for timber-cutting and possible subsidies for conservation practices, will have the most relevance. The importance of resource-pricing is perhaps rivalled only by project-oriented watershed management efforts in terms of making an immediate and widespread impact on the reduction of soil erosion.

In Part II we assess the on-site economic cost of soil erosion in the Magat and Pantabangan watersheds, and in Part III we evaluate off-site (or downstream) effects. Part IV presents the implications of the results obtained in the previous sections for (a) forest and soil conservation policy and (b) approaches to watershed assessment and management.

II. The On-site Environmental Cost of Soil Erosion

The on-site productivity effects of erosion arise from the loss of topsoil, leading to (a) loss of organic matter and nutrients and (b) a reduction of water-holding capacity and degradation of soils for plant roots. Owing to data limitations, only the first effect of topsoil loss will be considered in this study.

At least two methodologies exist for evaluating on-site productivity losses (Crosson and Stout, 1983; Hufschmidt et al., 1983; Easter et al., 1986). Ideally one could directly assess the decline in crop production associated with soil degradation, but this would require data that are presently unavailable and extremely difficult to generate. For this reason, the second methodology, referred to as the "replacement cost method", is utilized in this valuation exercise. This approach estimates the value of erosion losses in terms of how much it would cost to replace the natural soil nutrients carried away by erosion with the use of inorganic fertilizers. Figure 1 summarizes how this study applies the replacement cost method for assessing on-site losses from erosion.

A. *On-Site Effects of Erosion at the Magat Watershed*

Land use data for two periods, 1980 and 1983, are provided in Table 1. This indicates a substantial change occurring in the Magat watershed in a fairly short period, seen in the rise of open grasslands. The disturbing consequence of the increase in open grassland areas is the accelerated erosion associated with this form of land use. The Magat watershed management program in fact recognizes the need to convert portions of

Figure 1
BASIC APPLICATION OF THE REPLACEMENT COST METHOD TO ASSESSMENT OF ON-SITE EFFECTS OF EROSION

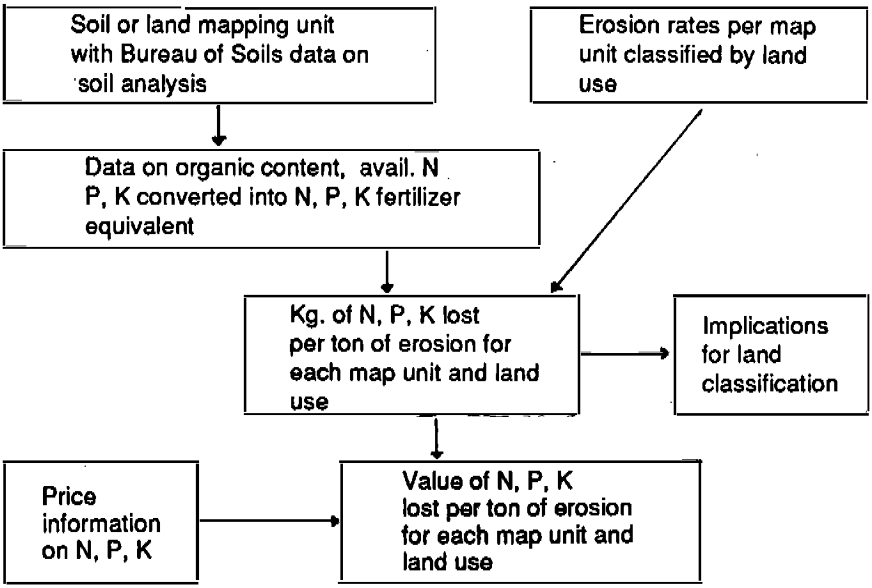

Table 1
LAND USE CHANGES IN THE MAGAT WATERSHED

	1980		*1983*	
Land Use	*Hectares*	*%*	*Hectares*	*%*
Primary forest	123,780	30.7	102,212	24.8
Secondary forest	123,479	30.7	91,109	22.1
Open grassland	102,265	25.4	159,517	38.7
Agricultural land				
irrigated rice	25,470	6.3	34,145	8.3
non-irrigated rice	4,191	1.0	986	0.2
bench-terraced rice	14,620	3.6	15,087	3.7
diversified crops	2,260	0.6	2,142	0.5
orchards	25	0.0	272	0.1
Residential land	2,647	0.7	2,270	0.6
Riverwash	4,090	1.0	4,570	1.1
Total	402,827	100.0	412,303	100.0
Reservoir	4,900			

Source: Madecor (1985).

these grasslands into sustainable agro-forestry systems. Excessive erosion in these lands therefore will reduce their potential productivity under the proposed agro-forestry management program.

The annual erosion rate per hectare for open grasslands is 88 tons, as against 28 tons for all other land uses at the watershed. Since sheet erosion is only about 40 percent of the gross erosion rate (Madecor, 1985), gross annual erosion per hectare is about 219 tons for the open grasslands as against 71 tons for other land uses. Of 31 Land Mapping Units (LMUs) with open grassland areas, 19 were selected on the basis of availability of information on the thickness of the first two soil layers and the organic carbon, phosphorus, and potassium content of the soil.

Erosion rates per hectare for each of the 19 LMUs were then used to derive annual soil loss per hectare and the associated nutrient loss. Appendix 1 provides the step-by-step procedure for converting soil-analysis data into equivalent quantities of inorganic fertilizers (i.e., nitrogen (N), phosphorus (P), and potassium (K)) lost per ton of soil erosion.

The results of the replacement-cost method of estimating soil erosion are presented in Table 2. The first column of the table lists the weighted averages of nutrients (N, P, K) lost through erosion which are converted into their equivalents in kilograms of urea, solophos (P_2O_5), and muriate of potash (K_2O). The second column lists the value of these fertilizer equivalents using nominal fertilizer prices (i.e., those prices actually paid by purchasers in the area). Finally, the third column gives the values of fertilizer lost using shadow prices, or those prices that account for the social cost of providing such fertilizers.

Therefore, for the Magat watershed, each ton of erosion annually carried away an equivalent of 3.08 kg. of urea, 0.79 kg. of solophos, and 0.57 kg. of muriate of potash, with a combined value of about ₱15 per ton, in nominal current prices. On a per hectare basis, the combined loss is about ₱1,068.00. Using the annual gross-erosion estimate of 219 tons per hectare, the loss is about ₱3,392 per hectare.

This estimate of on-site cost must be interpreted cautiously. From a technical aspect, there is an underestimation bias because of the simplifying assumption adopted which identifies the on-site impact of erosion only with the loss of soil nutrients and which does not include the effects of deterioration in soil structure and water-holding capacity that is linked with erosion. However, from an economic viewpoint, the bias is toward overestimation. The reason is that in their current use, the open grasslands are not intensively planted to agricultural crops such as rice and corn. Thus, nutrient losses from such lands would not have the same opportunity cost as losses from lands which are continuously cultivated. However, since the valuation figures assume grasslands to be potential areas for agricultural production, the estimates may be regarded as an upper bound of the economic costs associated with a ton of soil erosion.

Table 2
FERTILIZER LOSSES DUE TO SOIL EROSION IN THE MAGAT WATERSHED

Fertilizer Cost	*Quantity (kg)*	*Valuation with Use of Nominal Price (₱)*	*Valuation with Use of Shadow Price (₱)*
1. Urea			
– price		3.60/kg	9.86/kg
– amount lost/ton of soil eroded	3.08	11.09	30.37
– amount lost/ha. of affected land	118.13	677.23	1854.96
2. Solophos (P_2O_5)			
– price		2.50/kg	6.20/kg
– amount lost/ton of soil eroded	0.79	1.98	4.90
– amount lost/ha. of affected land*	70.65	176.63	438.03
3. Muriate of potash (K_20)			
– price		4.20/kg	8.28/kg
– amount lost/ton of sort eroded	0.57	2.39	4.72
– amount lost/ha. of affected land*	51.07	214.49	422.86
4. All fertilizers			
– amount lost/ton of soil eroded		15.46	39.99
– amount lost/ha. of affected land*		1,068.35	2,715.85

*Computed with the procedure outlined in Appendix 1. Note that although the average sheet erosion rate for Magat watershed is about 88 tons/ha., for the various land mapping units where the soil analyses were available, erosion rates in tons/ha. differed.

2. *The On-site Effects of Erosion in the Pantabangan Watershed*

The Pantabangan watershed is the second site included in the Watershed Management and Erosion Control project of the NIA. Table 3

Table 3
LAND USES IN PANTABANGAN AND CANILI-DIAYO WATERSHED
(1977)

Land Use	*Mapped Area* (hectares)*	*Percent of Total Area*
Forest[1]		
Primary Forest	36,008	39.3
Secondary Forest	915	1.0
Sub-Total	36,923	40.3
Grassland[2]		
Open Grassland	33,487	36.5
Savannah	2,175	2.4
Sub-Total	35,662	38.9
Cropland		
Kaingin Area	2,325	2.5
Diversified Crops	617	0.7
Rainfed Riceland	2,608	2.8
Irrigated Riceland	3,992	4.4
Sub-Total	9,542	10.4
Other Uses		
Residential	600	0.7
Reservoir	7,998	8.7
Riverwash, gravelly or stony	175	0.2
Sub-Total	8,773	9.6
Unevaluated Area	750	0.8
TOTAL	91,650	100.0

*Based on Bureau of Soils Mapping.

[1]As measured from the UPRP Multiple Use Management map of BFD, primary forest is only 23,747 hectares and secondary forest is 13,176 hectares.

[2]Effective area of forest plantings by NIA, BFD, and others from 1974 to 1977 is around 4,000 hectares. These are counted as grassland areas since the forest crops are still in seedling stage.

Source of basic data: ECI-NIA, 1978.

shows the land uses in Pantabangan as well as at the Canili-Diayo watershed. The latter is included because it augments the water inflow into the Pantabangan reservoir.

Detailed erosion estimates for the Pantabangan watershed based on rainfall polygons, slope categories, soil types, and land uses are provided in a separate report (David, 1987). In addition, a soil map with chemical and physical information for 5-50 cm. soil layers is used for the nutrient loss estimates.

The results of the computations for various average erosion rates is presented in Table 4 for each type of land use together with slope information. The erosion rates for ricelands are low not because of soil cover but because these lands are either flat or terraced. Thus in this case, it is the slope and not the soil cover that leads to minimal erosion. However, it is worth noting that the erosion rates show the protective role of forests.

Table 4
LAND USE AND EROSION RATES BY SLOPE CLASSES IN THE PANTABANGAN WATERSHED

Slope Class/ Erosion Rate	Slope Range (%)	*LAND USE TYPE* Kaingin/Diversified Croplands (has.)	(%)	Grasslands/ Savannahs (has.)	(%)	Primary/Secondary Forest (has.)	(%)	Irrigated/Rainfed Ricelands (has.)	(%)
S1	0.0 to 3.0	-	-	-	-	3469.74	12.66	3510.08	89.63
S2	3.0 to 8.0	-	-	-	-	-	-	406.04	10.37
S3	8.0 to 15.0	-	-	356.36	1.53	-	-	-	-
S4	15.0 to 25.0	1119.96	49.50	1300.92	5.58	74.09	0.27	-	-
S5	25.0 to 40.0	36.04	1.59	6732.27	28.89	-	-	-	-
S6	> 40.0	1106.58	48.91	14914.94	64.00	23854.02	87.07	-	-
TOTAL[1]		2262.58	100.0	23304.49	100.00	27397.85	100.00	3916.12	100.00
Average Erosion[2] Rate (t/ha/yr)		428.59		197.80		2.15		0.28	

Notes:

[1] Based on total areas of sample SMUs for each land use.

[2] Does not include riverwash, reservoir, and residential lands.

Minimal erosion rates are associated with forest lands, independently of slope.

Table 5 summarizes the results on the amounts of N, P, and K in terms of urea, solophos, and muriate of potash that are lost with erosion, for each 5-cm. layer of soil. Additionally, the losses estimated for Pantabangan are available for each major land use category. Table 5 also indicates that the losses are most pronounced at the top layers of the soil. Since the associated erosion is presumed constant throughout the soil profile, the declining nutrient loss supports the view that soil fertility (and therefore potential for nutrient loss) is greatest in the upper soil layers.

From an *ex post* project perspective, the economic (shadow) prices that may be used for valuing the fertilizer equivalents of nutrients lost are from l977, the time when the project feasibility was studied. These prices were ₱2.05, ₱0.98, and ₱1.47 per kilogram of urea, solophos, and muriate of potash, respectively. For the entire Pantabangan and Canili-Diayo watersheds, with the first 5-cm. layer of soil, ₱2,541 and ₱1,411 per hectare are the replacement costs of nutrients from *kaingin* and grassland areas, respectively. Given that the total areas under these two land uses are 2,942 and 35,662 hectares, respectively, the total value of nutrients lost (if erosion is taking place from the first 5-cm. layer of the top soil) is approximately ₱57.8 million per year (2942 has. x ₱2,541/ha. + 35,662 has. x ₱1,411/ha.).

The measurement and valuation biases discussed for the case of Magat watershed also apply here, except in the case of on-site losses for *kaingin*, or shifting cultivation lands. In this case, there is no economic

Table 5
REPLACEMENT COST OF LOST NUTRIENTS PER TON OF ERODED SOIL FROM PANTABANGAN *KAINGIN* AND GRASSLAND AREAS.

Soil Depth	*Kaingin/Diversified Cropland*				*Grassland/Savannah*			
	Urea	*Solophos*	*Muriate of Potash*	*Total*	*Urea*	*Solophos*	*Muriate of Potash*	*Total*
0-5	4.98	0.24	1.78	7.00	5.45	0.13	1.54	7.12
5-10	4.92	0.24	1.78	6.94	5.37	0.12	1.54	7.03
10-15	4.84	0.21	1.78	6.83	5.00	0.10	1.23	6.33
15-20	4.63	0.21	1.47	6.31	4.72	0.06	1.07	5.85
20-25	2.66	0.07	1.03	3.76	3.59	0.06	0.87	4.52
25-30	2.62	0.07	0.96	3.65	3.53	0.06	0.82	4.41
30-35	2.54	0.07	0.96	3.57	3.36	0.06	0.82	4.24
35-40	2.54	0.07	0.96	3.57	3.36	0.06	0.82	4.24
40-45	2.54	0.07	0.96	3.57	3.32	0.06	0.82	4.24
45-50	2.54	0.07	0.66	3.57	3.32	0.06	0.82	4.24

overestimation bias, since these lands are actually being cultivated. However, the technical underestimation bias remains.

III. The Downstream Cost of Soil Erosion

For off-site effects, sedimentation (as distinct from soil erosion itself) is the more relevant process. Where the watershed drains into a major dam and reservoir system — which provides irrigation, hydroelectricity, and flood control services — much of the impact of sedimentation is captured by looking at reservoir sedimentation and its effects on the multiple services provided by the dam project.

The off-site economic impact of erosion centers on its role in the sedimentation of the Pantabangan and Magat reservoirs. From an *ex post* project perspective, sedimentation reduces potential benefits by (a) shortening reservoir and dam service life and (b) by reducing the reservoir's useful storage capacity. (Please refer to Appendix 2 for a formal definition of these losses).

There is, however, a third category of sedimentation loss which is relevant only from an *ex ante* project perspective. If a watershed project were still in the planning stage, one potential cost of sedimentation that should be considered would be the opportunity cost of providing for excessive sediment storage capacity in the reservoir because of large upstream erosion. In other words, the existence and acceptance of heavy erosion would make the dam project cost more than it otherwise would. The resulting increase in *ex ante* project cost is a measure of the loss from erosion. In what follows, we present estimates for the first and third categories of losses from sedimentation in the case of Magat and estimates for all three categories in the case of Pantabangan.

1. *Off-site Economic Effects of Erosion in the Magat Watershed*

a. *Reduction in Project Life*

The sediment pool capacity for Magat was designed for an annual rate of 20 tons/ha. of sedimentation. However, a follow up study (Madecor, 1982) determined that a higher sedimentation rate of 34.5 tons/ha./yr. was occurring. At the sedimentation rate of 20 tons/ha./yr., for which it was designed, the reservoir was expected to remain operational for 95 years (after which the sediments would block the outlet works of the dam). If the new erosion rate continues, however, the operational life of the reservoir will only be 55 years.

Table 6 shows that using a discount rate of 15 percent, a 40-year reduction of reservoir life reduces the present value of the net irrigation and hydropower benefits by ₱262,623, with an annualized value (for 50 years) of about ₱39,430. This foregone value is directly caused by the additional l4.5 tons/ha./yr. contributed by the 406,960 hectare watershed area. On a per hectare basis, the cost of this added sedimentation is about ₱0.10 per year, or ₱0.01 per year per ton of new sediment input.

Table 6
PRESENT VALUE OF FOREGONE BENEFITS ASSOCIATED WITH A REDUCTION IN THE MAGAT RESERVOIR'S SERVICE LIFE
(In ₱1,000)

Year	*Total Cost*	*Total Benefit*	*Net Benefit*
64-65	10,256	275,903	265,647
66	26,042	275,903	249,861
67-85	10,256	275,903	265,647
86	29,356	275,903	246,647
87-103	10,256	275,903	256,647

Net Present Value (at 15% interest) = 262,623

Notes:

l. The undiscounted irrigation and power benefits remain the same for the years before Year 64.
2. There is no change in the operating and maintenance expenses.
3. The second replacement for pumps, transformers, and electrical equipment will take place in Year 66, and that of turbines and generators will take place in Year 86.

b. *Losses due to Opportunity Cost of Sediment Pool from an "Ex-Ante" Project Perspective*

In the Magat River Project Feasibility Report (l973), the reservoir is expected to provide water to 95,100 hectares of irrigable land amounting to an average annual volume of 2060 million cubic meters of water. With some allowance for conveyance losses, this means the amount of water that would have been provided for a hectare of farmland is about 21,66l cubic meters per year. The average irrigation requirement of the different land classes in the Magat service area by cropping season, for rice lands, was estimated at 16,299 cubic meters per hectare per year (with 6,933 cubic meters per hectare for the wet season and 9,366 cubic meters per hectare for the dry season).

The sediment storage capacity of the Magat reservoir is about 500 million cubic meters. Since the annual per hectare water release from the reservoir is 21,661 cubic meters, the number of potential irrigated hectares that have been supplanted by the sediment pool is about 23,086 (or 500 million cubic meters/21,661 cubic meters per hectare). The loss of this potential irrigable hectarage due to the requirement of setting aside 500 million cubic meters of storage capacity for the sediment pool is a social cost, since additional hectarage could otherwise have been added to the command area.

The crop yield differences between irrigated and non-irrigated rice lands are valued at about ₱1,740 per hectare during the wet season and about ₱4,691 per hectare during the dry season. The total difference is therefore about ₱6,431 (or ₱1,740 + ₱4,691) per hectare annually. Since the irrigated hectarage foregone is about 23,086, the loss in yield due to the sediment pool is therefore about ₱148,787,000 (or ₱6,431 X 23,086) per year.

Since the estimated sediment input rate was 20 tons/ha. annually, for the 406,960 hectares at the watershed, the total sediment input per year is 8,139,200 tons. The loss associated with sedimentation is therefore about ₱365.61 per hectare or ₱18 per ton per year [₱148,787,000 / (20 X 406,960)]. Note that not all of this represents true opportunity cost, since some amount of the 20 tons/ha./yr. of sedimentation will be due to upstream erosion that represents a natural minimum.

2. *Economic Costs of Sedimentation in the Pantabangan Reservoir*

a. *Reduction in Service Life of the Pantabangan Dam and Reservoir*

The Pantabangan reservoir was designed for a service life of about 100 years. As in the Magat reservoir, a sedimentation rate of 20 tons/ha./yr. was estimated for Pantabangan (ECI-NIA, 1978). To absorb this, a sediment pool with 130 million cubic meters (MCM) capacity was incorporated into the project. In addition, 95 MCM of inactive storage was included so that the total dead storage was 225 MCM.

According to David (1987), the annual average sheet and rill erosion in the watershed is about 108 tons/ha. This indicates that gross erosion is about 270 tons per hectare per year (assuming sheet and rill erosion is only about 40 percent of gross erosion). Assuming further a sediment delivery ratio of 30 percent, the sediment inflow into the reservoir will be about 81 tons/ha. With a trap efficiency of 95 percent, annual sediment deposition will be about 77 tons per hectare or 6.4 million tons for the entire watershed. In volume terms, this will equal 4.9 MCM per year [(77 tons/ha./yr. X 82894 ha. in the watershed)/a bulk density of 1.3]. With the practical assumption that only 75 percent of sediment deposition actually settles in the dead storage, with 25 percent being deposited along the active storage of the reservoir, the operational life of the reservoir will be reduced by 39 years. (Refer to Table 7.)

Table 7
FOREGONE BENEFITS ASSOCIATED WITH REDUCTION IN THE PANTABANGAN RESERVOIR'S SERVICE LIFE

	75% of sediments into dead storage
Assumed service life of Pantabangan dam with 20 t/ha/yr sediment yield	100 years
Computed service life of the dam with 81 t/ha/yr sediment yield	61 years
Nominal values of annual project net benefit for year 62 to 100	₱406.82 million
Present value of net benefits	₱0.616 million (39 years)
Annualized value of foregone benefit	₱0.092 million
Annual value of foregone benefit	
per hectare	₱1.11
per ton of sediment	₱0.02

Source: W. Cruz et al., 1987

The net present value of the benefits foregone from shorter irrigation and hydro-power service life with this reduction, at 15 percent interest rate, is ₱0.616 million, with an annualized value of ₱0.092 million. This net present loss is equal to ₱1.11 per hectare per year or ₱0.02 per ton of sediment per year.

b. *Reduction in Active Storage Capacity*

i. *Implications for Irrigation Losses*

The assumption that 25 percent of sediment deposition occurs in the active storage of the reservoir implies that this will be displacing water that could have been used for irrigation. The average annual water release from the reservoir for irrigation is 17,595 cubic meters/ha. (13,029 cubic meters/ ha. in the dry season plus 4,566 cubic meters /ha. for the wet season).

If 25 percent of the 4.9 MCM of sediment encroaches on the live storage, this will displace water that could have irrigated about 70 hectares per year [(0.25 X 4.9 MCM)/17595 CM per hectare]. To derive the foregone benefit, we need a measure of the loss per hectare if irrigation is not available. This is provided by the original project feasibility study which shows the per hectare farm income under with- and without-project conditions. Since we wish to make our assessment conservative, we adopt the project's low irrigation benefit estimate of ₱3,558. The yearly loss due to foregone irrigation with the sedimentation of active storage is thus ₱240,060 (70 ha. X ₱3558 per ha.). This annual foregone benefit amounts to ₱2.90 per hectare (₱240,060/82,894 has.) or ₱0.05 per ton of additional sedimentation (₱240,060/4.7 million tons per year).

The loss would be minor if the effect were to stop at this point. However, because each year an additional 70 hectares is affected, while all lands already affected continue to be less productive, the effect accumulates over time: 70 hectares in year one, 140 hectares in year two, 210 in year three, etc., for the life of the project. The loss therefore becomes cumulative over 61 years so that we take the present value of this stream of losses at 15 percent interest rate and then annualize the present worth to get an annual value associated with the annual loss of soil. This annualized value of foregone irrigation benefit is ₱1,906,690 — which amounts to ₱12.99 per hectare or ₱1.19 per ton.

c. *Reduction in Power Generation*

Although the original target for the hydropower generation of Pantabangan was about 263 million KWH, the power plant has generally been unable to meet this target. About 6.6 cubic meters is needed for each KWH of power. With 25 percent of sediments encroaching on the live storage of the reservoir, about 185,606 KWH would be displaced annually. Since the cost of electricity in the late 1970s was about ₱0.17 per KWH, the loss in power is about ₱31,553 per year. (This is very conservative since the price of electricity has since increased tremendously, and it is now in excess of ₱1.00.) This annual loss equals ₱0.38 per hectare (₱31,553/82,894 has.) or less than ₱0.01 per ton (₱31,553/4.7 million tons per year).

As in the case of irrigation losses, we need to cumulate this yearly effect for the 61 years of the life of the project. We then compute the present value of this stream of losses at 15 percent interest, and annualize the amount to arrive at ₱241,477 per year. This is equal to ₱2.91 per hectare or ₱.15 per ton of sediment.

d. *Opportunity Cost of Sediment Pool from an "Ex-Ante" Project Perspective*

As computed earlier, the dead storage of the Pantabangan reservoir is about 225 MCM, and if this excessively large sediment pool had not been constructed, more water could be stored and utilized for irrigation. An average of 13,029 CM of water is required per hectare in the dry season. This means that the 225 MCM in the sediment pool could have irrigated an additional 17,269 hectares in the dry season. The Pantabangan system already irrigates 75,716 hectares, on the average, in the dry season. Therefore, with the additional water from the dead storage, the reasonable service area for the system (if no sediment pool is constructed) would be about 92,985 hectares (17,269 hectares plus 75,716). Since the irrigation benefit during the dry season is ₱1,876 per hectare, the benefit foregone due to the sediment pool is ₱32.40 million.

In the wet season, with the smaller water requirement for irrigation, the opportunity cost of the inactive storage will be based on the reasonable target service area (92,985) less the average area that is already serviced (83,882) or 9,103 hectares. With the wet season irrigation benefit of ₱1,682 per hectare, the total foregone benefit is ₱15.31 million. Together with the dry season amount, the annual foregone benefit equals ₱575.55 per hectare or ₱28.78 per ton of sediment (₱575.55/20 tons of sedimentation per hectare).

The dead storage could probably also be used to generate additional electricity. However, the data needed to evaluate this is limited.

Table 8 summarizes the estimates of off-site costs associated with sedimentation of the Magat and Pantabangan reservoirs. It is important to keep in mind that these still underestimate the true value of foregone benefits arising from sedimentation. Only lost irrigation and power benefits were considered, though the dam and reservoir serve other functions such

Table 8
SUMMARY OF ESTIMATED COSTS OF SEDIMENTATION IN THE PANTABANGAN AND MAGAT RESERVOIRS

Source	*Annual Sedimentation Cost (₱)*** *per hectare*		*per ton*	
	Panta-bangan	*Magat*	*Panta-bangan*	*Magat*
Reduction in service life*	1.11	0.10	0.02	0.01
Reduction in active storage*				
(a) for irrigation	12.99	n.a.	1.19	n.a.
(b) for hydropower	2.91	n.a.	0.15	n.a.
Opportunity cost of dead storage for irrigation	575.55	365.61	28.78	18.00
Total	592.56	365.71	30.14	18.01

*The Pantabangan estimates are based on the assumption that 75% of sediments settle in dead storage and 25% in active storage. For Magat, the assumption is that all sediments go to dead storage.

**The prices used for Pantabangan are late 1970s prices; for Magat early 1980s prices are used.

as flood control, fisheries, and providing domestic water supply. Measurement and valuation of the impacts of watershed erosion on these other services require much more information than is currently available.

IV. Implications for Forest Conservation Policy and Contributions to Practical Watershed Assessment and Land Classification

In this concluding part, we focus on two general implications of the foregoing valuation results, namely (a) their significance for policy regarding commercial and social forestry,and (b) their contributions to the economic assessment of watershed projects and to land classification approaches.

1. *Implications for Forest Conservation Policy*

One of the most important results of the assessment of the cost of conservation has been the quantification, using the modified universal soil loss equation, of the proposition that forest cover is a major protective factor in soil conservation. Erosion is minimized with forest cover, fairly independent of slope. With such minimum soil erosion rates, actual soil regeneration through the decomposition of tree litter and related processes will effectively sustain soil nutrient levels indefinitely.

a. *Implications for Commercial Forestry*

Since forest drain is occurring at substantial rates, the conservation-oriented components of current forest policy is clearly inadequate. Indeed,traditional approaches to conservation in Philippine forestry are highly dependent on the viability of the selective logging system (SLS) — a management system designed to lead to sustained yield use of forests. The system essentially requires loggers to leave behind a residual stand in the logging operation to allow a second cut after a period of time. When the system fails, the standard government response is limited to undertaking planting, replanting, and more replanting (which does not necessarily lead to effective reforestation).

To be effective, the policy or management system governing the exploitation of forest resources should incorporate realistic conservation components. However, the absence of broad assessments regarding the true social cost of the effects of the exploitation of forest resources has meant that one of the most critical inputs into the policy choice process — namely the economic benefits that may accrue to conservation-oriented policy could not have been realistically taken into consideration. With no estimated value of their benefits,conservation programs (given their significant and *monetized* costs) would predictably pale in comparison with logging, and other resource exploitation activities. The latter's substantial net present values and attractive rates-of-return are always bound to impress policymakers constrained by tight budgets and concerned with the bottom line.

The valuation approaches we have illustrated, however, now demonstrate that soil erosion leads to environmental damage, and that therefore its abatement generates true economic benefits. Measures of this environmental cost — and its mirror image, conservation benefit — should be important inputs into policy reform for the key forestry sectors. For commercial forestry, for example, the most important policy issue is the pricing of timber for logging. Part of the government's inability to take a strong position to increase the price of logging (and probably the source of moral certitude among loggers that this price should be low) is traceable to the notion that the forest has always existed and that the government did not pay to produce the resource. The degradation or removal of this resource, however, has been shown to generate substantial environmental cost. While the net social benefit from logging will probably still be positive for the Philippines, the environmental cost — being a true economic cost and not a mere transfer payment such as the BFD forest charge — cannot be waived.

Ultimately somebody winds up paying the cost and if not the logger, then the rest of society may end up with the bill. Together with the assumption that the area of forest lands has already declined below environmentally acceptable levels, this may justify the argument of some foresters that the minimum charge for cutting trees should be the cost of *replanting and maintaining* a healthy stand to replace them.

With respect to the pricing of environmental services of forest conservation, it was already indicated that under the SLS, the private returns to conservation (through what is called the timber stand improvement phase) are uneconomical. This is due primarily to the long gestation period required before the residual stand reaches commercial size (Cruz and Tolentino, 1987). Since forests provide benefits by controlling soil erosion and its unwanted downstream effects, there is an economic argument for the conservation effort to be directly subsidized by government.

It might be argued that the underpricing of timber under the SLS essentially makes up for the lack of support to the concessionaire for the conservation phase. This is precisely where the problem lies, however, since the incentive structure then becomes biased for the logging activity versus conservation. Because there are two distinct economic objectives required in forest management, policy reform calls for adjustments in both the pricing of standing timber (toward substantially higher prices) and the conservation services of sustaining a forest cover (toward subsidizing reforestation or penalizing excessive cutting), in the Koopmans tradition that there must be at least as many instruments as targets. Indeed there is no compelling reason why these two activities and pricing systems should be integrated or expected of the same firm. Each activity may be contracted out to separate bidders — the first according to the highest offer for the wood value in a site, the second according to the expected cost of replanting and maintaining trees in the area.

b. *Implications for Social Forestry*

For social forestry, the most critical policy issues revolve around the problem of land tenure for forest dwellers and the need for government support for adoption of conservation practices. The prospects for encouraging conservation in the social forestry framework are constrained by the extremely limited approach taken in allocating land to individual upland cultivators. The results of our discussions of on-site effects of erosion bring out two questions of relevance to the need to review the land disposition strategy prospects for soil conservation:

(a) Should the loss of soil nutrients due to erosion (nominally worth about ₱1,000 per hectare in the Magat case), not provide enough incentive for upland cultivators to practice soil conservation methods?

(b) If the social cost of nutrient loss is about 2.5 times its nominal or private cost, should government not directly subsidize conservation activities by upland cultivators?

In regard to the private incentives for conservation, it must be recognized that soil erosion does not necessarily impose current costs on the private land user, as long as the topsoil layers are not completely depleted. Only with the removal of topsoil does the nutrient loss have a direct impact on the current productivity of the land. However, since the upland farmer typically has no property rights in the land and therefore no stake in ensuring its long-term productivity, the potential gain by reducing the ₱1 068/ha./yr. of lost soil nutrients cannot be captured by the farmers. It is therefore not surprising that upland farmers exploit the land until its productivity declines and then move on to a new plot.

A necessary condition therefore for the adoption of conservation practices in upland farming is the allocation of secure claims over the land. *The sufficient condition is that the private cost of conservation should not be so large as to eliminate the potential gain from reducing soil loss.*

At this point the social cost of on-site erosion becomes relevant. The difference between the nominal and social cost of soil erosion indicates the level of subsidy that society should be willing to provide to help reduce soil erosion. It would, of course, be unrealistic to attempt the complete elimination of erosion. If the target is to reduce erosion to one-half, from about 88 tons/ha. to 44 tons/ha., in sites similar to Magat, the potential private gain is about ₱534 per hectare (assuming only a one-year planning period).

Contour-plowing techniques, as well as the construction of hillside ditches, could probably accomplish this 50 percent reduction in erosion, but the associated cost of 30-35 man-days plus 7 man-animal days for these techniques may greatly reduce the potential private gains. In this case, it should be socially beneficial to subsidize the conservation effort by up to ₱824/ha. (for the 50 percent erosion reduction), since the potential net social gain is ₱1,358/ha.less the private user's gain of ₱534/ha. These are clearly conservative estimates, considering that the environmental cost being measured includes only sheet erosion and excludes the downstream losses.

To underscore the point, the above discussion shows that substantial on-site benefits in terms of sustainable soil productivity will in fact result from the adoption of conservation-oriented farming and forestry practices. Upland cultivators, however, will adopt these practices (which are not costless) only if they can capture the long-term benefits that will accrue. This indicates that a necessary condition to conservation is for cultivators to acquire a long-term stake in the land. At the same time, social benefits at the site as well as downstream indicate that it would pay government to actively subsidize conservation efforts as a sufficient condition for abatement. In this light, the existing social forestry program should be regarded as only a beginning, and government must seriously look beyond this toward a massive land reform program in the uplands supported by conservation-oriented subsidies.

2. *Contributions to Watershed Assessment and Land Classification*

a. *Implications for Benefit-Cost Analysis*

For benefit-cost analysis, the potential contribution quantifying environmental costs includes not only the determination of proper shadow prices for projects with significant environmental effects. More importantly, the effort of identifying the effects of soil erosion and defining the boundaries of the required management effort should help define a more realistic *project assessment stance* that will recognize the important relationship among activities in the uplands and in downstream water development projects.

i. *On Expanding the Project Assessment Stance*

The valuation perspective assesses particular activities or processes as they occur within the watershed as a physical system. While there are various activities occurring in different bio-physical components of the watershed, their common environmental effects register in the erosion and sedimentation processes. Through erosion and sedimentation, these upstream activities generate downstream externalities, for example by reducing irrigable hectarage and silting water conveyance structures. The adoption of a watershed management/irrigation development assessment stance represents an integration of the standard watershed erosion control project and the irrigation project approaches.[1] This expanded approach is

[1]See, for example, Dixon and Easter (1986), who point out that evaluating irrigation development projects separately from watershed activities upstream of the

broad enough to properly assess key upstream and downstream interrelations while still manageable enough to allow systematic evaluation. For example, as has been pointed out in this paper, downstream irrigation losses due to accelerated erosion may be so substantial that otherwise unprofitable soil conservation projects may be socially justifiable if viewed in a broader context of water management and irrigation development.

ii. *On the Opportunity Cost of Sedimentation*

The need to explicitly incorporate the environmental effects of erosion in the economic assessment of reservoir projects does not mean that standard economic appraisal approaches to such projects completely fail to include environmental effects. In fact, some of these effects are implicitly incorporated in the cost and benefit streams that are regularly estimated. Consider, for example, the added reservoir or dam construction cost associated with the need for a sediment pool beyond the capacity required for "natural" or "baseline" sedimentation such as that associated with the figure of 3-12 tons/ha./yr. from forest lands. This effect is implicitly incorporated in the standard appraisal because the additional construction cost associated with the sediment pool is automatically included in total construction cost and is therefore also included in the evaluation of the social profitability of the project.

However, when the erosion rate assumed at the time of project design is subsequently exceeded by actual erosion, the environmental effects lead to *incremental* reductions in benefits from the system which the appraisal, of course, will have failed to incorporate. This failure stems not from the methodology of appraisal itself but from the inaccuracy of erosion data.

There is one major effect, however, which is not at all encompassed in the standard assessment procedure: the loss of potential irrigation and hydro-power capacity due to the requirements of allowing for a substantial sediment storage. There are, actual social costs from losing potential active storage capacity because options for reducing the rate of erosion (and therefore the required sediment pool or inactive storage) are available if watershed management and erosion control components are explicitly included at the inception of the reservoir project.

While the preceding measure of cost in terms of reduction in project life is an incremental one (due to additional erosion), the opportunity cost of the reservoir's sediment pool is a fundamental cost and must be incorporated even without any additional erosion and sedimentation. Sediment buildup reduces the reservoir's storage capacity, which in turn decreases

---

irrigation dam may lead to unrealistic assessment of expected irrigation project benefits and costs.

the quantity of hydro-power, irrigation water, and flood damage protection provided by the reservoir. Because of this, an allowance for siltation is always included as a component of reservoir design, especially if this is meant to store water from run-off over many years (as in the case of the Magat and Pantabangan reservoir).

b. *Contributions to Assessment Methodology*

i. *On Land Suitability Classification*

Together with the modified Universal Soil Loss model, the methodology for assessing the susceptibility of various land uses to productivity decline can be packaged as a practical approach to land classification. The persistence of the old criterion of classifying lands as alienable and disposable (A&D) vs. forest land (non-A&D) according to the simple rule of whether or not they are less than or greater than 18 percent in slope does not necessarily imply that policymakers are satisfied with the system. Indeed the impression gained is that there is a fair amount of dissatisfaction concerning the extreme restrictiveness of this criterion (and the classification system associated with it) with respect to the disposition of public lands.

One problem is that no serious practical alternative has been suggested to the 18 percent rule. Our recommendation that a new system be adopted represents such a feasible alternative. In fact, it may be viewed as a complementary system to be used in areas already designated as forest lands but still within the practical limits of sedentary agriculture (i.e., those with moderate slope of 18 -35 percent). Once land classification in an area is completed, disposition would be based not only on the slope but also on the true potential for erosion. In addition, zoning restrictions on what may be cultivated (e.g., annual crops vs. trees) plus the technology and the subsidy package may then all be generated by the same comprehensive assessment methodology.

ii. *On Identifying Critical Watersheds*

The economic assessment methodology developed here should also make a contribution to the operational definition of what constitutes a "critical" watershed. The identification of such watersheds is useful for basic governmental planning for resource management. To be of practical value, such a listing of watersheds, with all their bio-physical and socio-economic dissimilarities, cannot be based on a one-dimensional classification. At least three criteria are important: (a) the economic value of massive downstream capital investments (usually irrigation infrastructure) and of upstream environmental costs, (b) the presence of accelerated soil erosion, and (c) the demographic pressure on resources. The assessment methodology presented in this paper can provide the data for the set of economic criteria. Meanwhile, other methodologies — namely, a generally applicable soil erosion model and a means of assessing upland population and migration patterns — have likewise been developed by researchers associated with the Upland Resource Policy program. [Please refer to David (1987) and to C.J. Cruz *et al.* (1986) respectively].

c. *Suggestions for Training and Action Programs*

Two action programs may also benefit potentially from the combined methodologies mentioned above. The first could involve the organization and training of regional level teams from the Department of Environment and Natural Resources and associated agencies to do a quick environmental, economic, and community assessment of selected watersheds, with a specialized team to make inter-watershed analyses and identify potential conservation projects. The second program may respond to the immediate need to classify lands according to their suitable uses and in this manner quickly identify public lands that may be included in the national land reform effort.

The latter could be a crucial contribution. Although the classification approach to identifying areas for land reform will not be inexpensive, most of the basic information is already available. Also, in practice the cost of detailed surveys and land reclassification may be well below the monetary and political cost of transferring lands in Programs A, B, and C of the land reform plan.

The extent of lands in the public domain potentially suited to agriculture (which dwarfs the land reform targets in the other programs of the agrarian reform plan), requires serious study of the potential for government, as enlightened landowner, to allocate these lands. Indeed, a large proportion of the population (numbering more than 14 million) already resides in these uplands, and population growth, as well as the pattern of upland migration, suggests that the demand for these lands will continue to increase.

Appendix 1
ANALYSIS OF THE NUTRIENT CONTENT OF SOIL CARRIED BY EROSION

I. To estimate the amount of N and the equivalent Urea carried by soil loss on a per ton basis:

a) convert Organic Carbon (OC) to % Total Organic Matter (OM), using the relationship

$$\% \text{ total OM} = \frac{\% \text{O.C.}}{0.6}$$

b) compute % total N as a proportion of % total OM
% total N = 3.0 of % total OM
[Based on Caramancion (1971).]

c) estimate kg. of N/ha. = % total N x Soil loss (in kg./ha.)

d) convert kg. of N/ha. to kg. of Urea/ha. by the formula:

$$\frac{\text{kg.N/ha.}}{0.45} = \frac{\text{kg. of urea}}{\text{ha.}}$$

e) calculate the weighted average kg. of Urea/ha.:

$$= \frac{\text{(Urea/ha.) (nos. of has./LMU)}}{\text{Total No. of hectares for all sample LMU's}}$$

f) compute the weighted kg. Urea/ton of soil:

$$= \frac{\text{(kg. Urea/LMU)}}{\text{[(Soil Loss/LMU)(No. of ha./LMU)]}}$$

2. To estimate kg. of P and kg. P_2O_5

a) Determine % total P in the soil using the relationship: Available P (%) = (1.28) (% total P)*

b) Compute kg. P/ha. = % total P x Soil Loss (kg./ha.)

c) Compute Kg.P_2O_5 loss/ha. $= \text{kg.P/ha.} \times \frac{P_2O_5}{2P}$

d) Estimate the weighted average kg. P_2O_5/ha.

$$= \frac{\text{(kg. } P_2O_5\text{/ha.) (No. of has./LMU)}}{\text{Total Number of Has. of all sample LMU}}$$

e) Calculate the weighted average kg. P_2O_5/ton =

$$\frac{\text{kg. } P_2O_5/\text{LMU}}{[(\text{Soil Loss/LMU})(\text{No. of ha./LMU})]}$$

3. To estimate the weighted kg. K and kg. K_2O per ton given exchangeable K (meq./100g.)

   a) Convert exchangeable K in meq.K/100 gm. to exchangeable gm. k./gm. soil loss using the conversion factor of 1 meq. K = 0.039 gm. K [Based on Oagmat, R.D. (1980)]

   b) compute gm K total/gmm soil = $\frac{\text{gm.K exch/100 gm. soil}}{0.10}$
   [Exchangeable K = 10% total K; Available K (%) = 1% total K (Bonoan, 1984).]

   c) calculate kg. K/ha. = gm. K total/Kg./ha. x Total soil loss in gm. soil

   d) estimate Kg. K_2O lost/ha. = (Kg. K/ha.) x K_2O/2K

   e) compute for the weighted average Kg. K_2O lost/ha.

   f) compute for the weighted average Kg.K_2O/ton of soil loss = $\frac{\text{Kg.}K_2O/\text{LMU}}{(\text{Soil Loss/LMU})(\text{No. of ha./LMU})}$

Source: Francisco, 1986

(Note: A detailed presentation of how this is applied for the case of Pantabangan is presented in Cruz *et al.*,1987, and for Magat, see Fransisco, 1986.)

Appendix 2
EROSION LOSSES IN BENEFIT-COST ANALYSIS (BCA) FRAMEWORK

The measures of losses from sedimentation may be interpreted within the framework of the standard net present value (NPV) equation in BCA. The original project was justified in terms of an acceptable NPV, given projected erosion rate (e_0):

$$NPV(e_0) = \sum_{t=1}^{n(e_0)} B(t,e_0) - C(e_0)$$

In the equation, the flow of benefits, B, over time is affected by the erosion rate while the costs, $C(e_0)$, refers to construction cost at the start of the project. The life of the project is dependent on the erosion rate since the latter determines how long before the sediment storage capacity is filled up. Note that we are abstracting from operating costs to simplify the presentation.

Because accelerated erosion from watershed degradation has led to actual erosion, e_1, exceeding e_0, the actual stream of benefits leads to a lower NPV from the project:

$$NPV(e_1) = \sum_{t=1}^{n(e_1)} B(t, e_1) - C(e_0)$$

with $n(e_1) < n(e_0)$.

The difference between $NPV(e_0)$ and $NPV(e_1)$ is the loss from accelerated erosion. Thus

$$\begin{aligned}
\text{Loss} &= NPV(e_0) - NPV(e_1) \\
&= [\sum_{t=1}^{n(e_0)} B(t, e_0) - C(e_0)] - [\sum_{t=1}^{n(e_1)} B(t, e_1) - C(e_0)] \\
&= \sum_{t=1}^{n(e_0)} B(t, e_0) - \sum_{t=1}^{n(e_1)} B(t, e_1) \\
&= \sum_{t=1}^{n(e_1)} B(t, e_0) + \sum_{t=n(e_1)+1}^{n(e_0)} B(t, e_0) - \sum_{t=1}^{n(e_1)} B(t, e_1) \\
&= \sum_{t=1}^{n(e1)} [B(t, e_0) - B(t, e_1)] + \sum_{t=n(e_1)+1}^{n(e_0)} B(t, e_0)
\end{aligned}$$

Now the first term (in brackets) refer to loss component (b) in the text and the second term is loss component (a).

The third category of cost cannot be included in the above analysis because it does not refer to actual losses as the project is implemented. The reason is that it concerns "sunk" cost since the potential net gain from irrigating additional hectarage (by reducing erosion to below e_0) can no longer be attained once construction of the reservoir is finished. It can thus be interpreted only from an *ex ante* perspective, i.e., as a component of one project among various other projects.

REFERENCES

Bonoan, Roberto R. *Potassium Availability and Its Relations to the Growth and Yield of Flue-Cured Tobacco.* Unpublished Masteral Thesis,University of the Philippines at Los Baños, 1984.

Bureau of Forestry Development. *Philippine Forestry Statistics.* Manila: Department of Environment and Natural Resources, 1985.

Caramacion, N.V. *Distribution of the Forms of Nitrogen in Some Philippine Soils.* Unpublished MS Thesis, University of the Philippines at Los Baños, 1971.

Crosson, Pierre, and A. T. Stout. *Productivity Effects of Cropland Erosion in the United States.* Washington, D. C.: Resources for the Future , 1983.

Cruz,Cerenilla, and VirginiaTolentino. *Assessment of Costs and Benefits in Commercial Forest Management,* Technical Report No. 87-06 of the Upland Resource Policy Program, funded by the Philippine Institute for Development Studies and the International Development Research Centre, 1987.

Cruz, Ma. Concepcion, *et al. Philippine Upland Population and Migration.* Philippine Institute for Development Studies, Working Paper No. 86-02, 1986.

Cruz, Wilfrido, *et al. Upland Resource Policy Program: Technical Report No. 87-04,* Philippine Institute for Development Studies, 1987.

David, W. P. *Upland Resource Policy Program: Technical Report No. 87-03,* Philippine Institute for Development Studies, 1987.

Easter, K. William, *et al. Watershed Resources Management.* Boulder, Colorado: Westview Press, 1986.

ECI/NIA (Engineering Consultants, Inc., and National Irrigation Administration). *Feasibility Report, Pantabangan Watershed Management Project.* Manila, Philippines, 1978.

Francisco, Herminia A. *Economics of Soil Erosion and Conservation: The Case of the Magat Watershed,* Ph.D. Dissertation, University of the Philippines at Los Baños, 1986.

Hufschmidt et. al. *Environment Natural Systems and Development: An Economic Valuation Guide,* Baltimore: Johns Hopkins University Press, 1983.

MADECOR. *Pre-Feasibility Report, Magat Watershed Erosion Control Project.* Los Baños: MADECOR ,1982.

NEPC. *The Philippine Environment.* Manila: National Environmental Protection Council, 1982.

National Irrigation Administration. *Magat River Multi-Purpose Project: Volumes I, III, and V,* Manila: National Irrigation Administration), 1973.

Magat River Multi-Purpose Project: Stage II— Irrigation: Progress Report No. 2, Manila: National Irrigation Administration , 1980.

Magat Watershed Erosion Control Project Feasibility Report. Los Baños: MADECOR , 1985.

Oagmat, R. B. *Evaluation of Nitrogen and Phosphorus Soil Test for Upland Soils of Bukidnon.* Unpublished Masteral Thesis, University of the Philippines at Los Baños, 1980.

Omengan, E. *Nitrogen and Phosphorus Cycles in a Bontoc Rice Paddy System.* Unpublished Masteral Thesis, University of the Philippines at Los Baños, 1981.

Sabio, E.A. *Some Physical, Chemical, and Mineralogical Characteristics of the Soils in the Pantabangan and Canili-Diayo Watersheds.* Unpublished Masteral Thesis. University of the Philippines at Los Baños, 1981.