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SOIL AND WATER CONSERVATION PLANNING: POLICY ISSUES AND RECOMMENDATIONS*

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I. Introduction

Soil and water are basic resources. Their exploitation or development is a matter of survival for many, an escape from poverty for most, and an opportunity to pursue additional power, wealth and selfish interest for some.

The overexploitation of these basic resources arises not from ignorance but mostly from an instinct for self-preservation. Forests are cut down, thin topsoils and fragile aquatic resources are depleted and marginal lands are overgrazed in order to meet short-term needs for food, energy, clothing and shelter. However, viewed in the wider and long-term context, the consequences of such actions are disastrous.

For the past fifteen years, forested areas have been decreasing annually by about 180,000 hectares so that presently, we have less than five million hectares of forest lands. The hydrology and productive capability of about a third of our total land area have been impaired by excessive soil erosion.

Excessive soil erosion, resulting from the manipulation of our watersheds, makes upland farmers more reliant on chemical fertilizers for sustained yield. In the extreme, hillside farmers constantly move from one area to another in their search for more fertile soils. Excessive soil erosion also pollutes streams and rivers. The sediment discharges of Philippine rivers whose catchments are subject to uncontrolled manipulations exceed 30 tons per hectare year (David, 1986). Reservoirs and ponds used for flood

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control, water supply and power generation are reduced in water qualities and storage capacities (e.g., Binga and Ambuklao reservoirs). Sedimentation threatens the stability of aquatic ecosystems such as lakes, mangroves and marshes.

The primary cause — and effect — of the more serious environmental problems is poverty. Poverty, environmental degradation, skewed distribution of wealth and power and selfish pursuit of sectoral interests are simply different aspects of the same set of problems associated with environmental degradation and resources development (Ramphal, 1987).

The general means for preserving Philippine landscapes and protecting their land and water resources are sound policies and programs towards the allocation and utilization of such resources are just enough to implement these policies. Such policies and programs should be of a nature whereby: (1) growth or development respects the limits to environmental resources; (2) the basic needs of the growing population for food, energy, clothing and shelter are met; and (3) economic mechanisms reward the good and penalize the bad users. Relief from population pressures partly implies the development and application of suitable technologies for increased and sustained agricultural production in uplands and hil / lands.

II. Soil Erosion Under Various Conditions in Selected Watersheds

Soil erosion is the product of many interactive subprocesses. In the Philippines as elsewhere in the humid tropics, water is the primary agent of soil erosion. The interactive processes causing soil erosion by water include detachment and transport by falling rain and flowing water. The various parameters influencing these subprocesses include: cover, soil physical and chemical properties, raindrop energy, flow velocities and hydraulic properties, cover management, slope, slope length and conservation practices.

Soil erosion is often classified based on descriptive parameters such as magnitude, source, location and shape (e.g. sheet, rill, gully, mass movement, construction and mining erosion). This section deals mainly with sheet and rill erosion which will be jointly referred to as sheet erosion in this paper. Thus soil erosion as defined here refers to the removal of the thin layer of top soil by raindrops, overland flow or by shallow, channelized rill flows.

1. *Soil Erosion Rates in Selected Sites*

There is a dearth of information on soil erosion in the Philippines, and research on soil erosion consists mostly of uncoordinated, isolated, empirical studies. In most of these studies, important parameters defining the conditions under which the results were obtained were not monitored. Furthermore, no standard conditions have been specified under which the various pieces of experimental evidence may be compared.

When synthesizing the available information on soil erosion rates in the Philippines, it becomes imperative — if such information is to be useful — to make quantitative or at least qualitative comparisons against certain standards. In an attempt to do this, we have taken the liberty of evaluating available information in the light of the mechanics or theory of the erosion process and of making assumptions regarding conditions under which some of the erosion studies were carried out. Furthermore, the results of studies conducted elsewhere but applicable to Philippine conditions are used to augment the meagre information available locally.

a. *Various Cover Conditions*

Undisturbed forests lands are the best soil conservers. In Mollucan Sau, Katoan Bangkal and Dipterocarp forest cover, Serrano *et al.* (undated) reported very low sediment yields of 0.10, 0.20 and 0.34 t/ha per year, respectively. Kellman (1968) reported an annual soil loss of 0.09 t/ha from primary forest at 20 percent slope on Mt. Apo in Mindanao. The comparative soil loss rate in 250 million hectares of contiguous forest in the United States was estimated at 0.4 t/ha per year. The above figures indicate that the average natural or geologic erosion in undisturbed catchments should be less than 1.0 t/ha/yr.

As the natural forest cover is disturbed by natural causes or human activities, erosion rates increase dramatically. Table 1 presents the ratios of soil loss rates for various cover to those for grasslands from small erosion plots on Mt. Apo in Mindanao and on Mt. Makiling in Laguna. The differences in the relative soil-loss ratios in the two studies reflect the differences in slope, soil, plot size and climatological conditions, as well as some known instrumentation errors in the hydroecology group study.

These studies point to several interesting observations. These include the following: (1) soil loss increases exponentially as vegetative cover decreases; (2) an undisturbed natural grass cover offers good soil protection; (3) soil erosion in some badly disturbed areas can be significantly reduced if these areas are left undisturbed for native grass species to quickly establish themselves; (4) the practice of large-scale clearing of grasses and shrubs to establish orchards and tree plantations may not be a sound idea as far as soil protection is concerned; and (5) cover manipulation offers a cheap and effective means of minimizing soil erosion.

Table 1 also shows the wide range of variability in soil erosion rates associated with cover and cover management practices. The Kellman study, for example, reported a 300 fold increase in soil erosion from primary forest to a 12-year old *kaingin*. Thus, only a small proportion of a watershed area needs to be mismanaged before a watershed's sediment yields drastically increase.

Table 1
SOIL EROSION RATES ASSOCIATED WITH COVER AND COVER MANAGEMENT PRACTICES

Cover Condition	*Ratio of Soil Loss (Kellman, 1968)*[1]	*Rate to that of Grassland (UPLB Hydroecology Group, 1978)*[2]
Primary forest	0.50	
Softwood fallow	0.72	
Imperata grassland	1.00	1.0
Plantation forest		2.9
Secondary forest		10.9
New rice kaingin	2.11	27.3
New kaingin (mixed crops)		
12-year old rice kaingin	150.0	
Old mixed crops kaingin		77.7

[1]For 20% slope on Mount Apo, Mindanao.
[2]Average of 36, 50 and 70% slope on Mt. Makiling, Laguna.

A combination of high-intensity rainfall, steep slope, erodable soil and poor cover can lead to extremely high erosion rates. A study by Veracion and Lopez (1979) of old *kaingin* areas in Benguet, Mountain Province showed soil-loss rates of 308, 318, 360, 396 and 414 tons per hectare per year even with strip crops of pineapple, coffee, castor bean, tiger grass and banana, respectively. These excessive soil losses from old *kaingin* areas were reduced to an average of 251 t/ha/yr by leaving them untilled or undisturbed for a year.

In a plot study on the soil erosion rates in cashew plantations in Palawan, Madarcos (1985) reported that the selection of the appropriate type of cover and cover management is equally important in reducing soil loss during plantation establishment. The results of his study as summarized on Table 2 showed that (1) the practice of ring weeding (no intercrop) results in high soil-loss rates during the establishment stage of orchards; (2)

Table 2
SOIL LOSSES ON CASHEW-BASED CROPPING SYSTEMS FOR ONE FIELD CROP SEASON FROM SEPTEMBER TO DECEMBER, 1982 (Madarcos, 1985)

Cover: Cashew/Intercrop	*Soil Loss in T/Ha/Yr*	
	Slope=21.7%	*Slope=39.2%*
Three-year old cashew/No intercrop	27.01	54.72
Five-year old cashew/No intercrop	19.29	40.96
Five-year old cashew/corn	13.46	24.89
Five-year old cashew/soybean	11.70	22.69
Five-year old cashew/Guinea grass	9.96	19.10
Five-year old cashew/sweet potato	8.13	15.48

intercropping with cash crops such as corn and soybean may also result in high erosion rates; and (3) for a given slope, the soil-loss rate varies significantly with the type of cover.

A study on the effects of cover intercrops in citrus orchards on 35 percent slope in Taiwan by Chang and Cheng (1974) also showed that soybean intercropping resulted in high soil loss rates of 20 to 30 t/ha/yr. Their results also showed that Guinea grass, Bahia grass and rice straw mulch effectively controlled soil loss.

In a study of sheet erosion rates in the 412,000 ha Magat watershed using a modified universal soil loss equation (USLE), David and Collado (1987) estimated an average soil loss rate of about 50 t/ha/yr. The soil loss rates associated with the various slope ranges and types of land use are summarized in Table 3. For any given slope, the soil loss rates were highest in the open grasslands, river washings or deltas, built-up areas and cultivated uplands.

A similar study of the 83,000 has Pantabangan watershed by David (1987) showed higher erosion rates for the various land uses as a result of steeper slopes and more erosive rainfalls. As shown on Table 4, the average erosion rate for the entire watershed is 108 t/ha/yr.

A comprehensive review of published and unpublished data in the Philippines and elsewhere would indicate soil loss rates of varying orders of magnitude for different types of cover. Expressed in terms of cover coefficients (or multipliers compatible with those used in computing soil loss

Table 3
ESTIMATED PRESENT SHEET AND RILL EROSION LOSSES IN TONS PER HECTARE PER YEAR FOR THE VARIOUS LAND USES AND SLOPE RANGES OF THE MAGAT WATERSHED
(David and Collado, 1987)

Land use	*Slope Range, %*						*Area Weighted*
	0-3	*3-8*	*8-15*	*15-25*	*25-40*	*>40*	*Average for all Slope*
1. Primary forest	-	0.048	0.16	0.32	0.63	1.28	1.03
2. Secondary forest	0.064	0.34	0.96	2.05	3.73	8.79	5.73
3. Open grasslands	2.44	9.79	32.73	55.57	126.24	240.6	122.01
4. Irrigated paddy	0.21	0.67	1.52	3.74	10.43	10.92	1.03
5. Rainfed paddy	0.21	-	2.69	4.04	7.07	14.03	2.75
6. Terraced rice, irrigated	0.094	0.41	1.29	2.34	4.44	9.42	4.63
7. Terraced rice, rainfed	-	0.40	1.66	3.57	-	-	2.04
8. Diversified crops	4.13	9.00	-	68.97	144.46	-	10.95
9. Orchard	1.95	6.77	-	74.44	-	-	45.98
10. Built-up area	5.11	12.05	31.48	90.92	160.83	282.57	12.88
11. River washings	10.86	-	61.64	165.25	410.92	1125.22	93.81
AVERAGE FOR ALL LAND USES	2.07	4.99	25.58	31.24	57.21	72.23	49.99

Table 4
ESTIMATED PRESENT SHEET AND RILL EROSION LOSSES IN TONS PER HECTARE PER YEAR FOR THE VARIOUS LAND USES AND SLOPE RANGES OF THE PANTABANGAN WATERSHED
(David, 1987)

Land Use	*0-3*	*3-8*	*8-15*	*15-25*	*25-40*	*>40*	*Area Weighted Average For all Slope*
Primary forest				.86		2.25	2.22
Secondary forest		.41				7.03	6.95
Open grasslands		10.01	25.72	141.70	139.95	264.03	210.72
Irrigated paddy	.18				8.82		.45
Rainfed paddy	.22	.81		5.56		25.26	.64
Savannah					120.85	238.99	194.83
Kaingin				280.85	374.88	586.51	507.88
Diversified crops				177.77			177.77
Riverwash	10.17					985.97	418.39
Residential	3.68			169.30	161.17	333.48	103.26
AVERAGE FOR ALL LAND USE	.48	2.60	25.72	141.33	140.45	113.40	108.20

rates through the USLE), the soil loss rates for the more common cover conditions in the Philippines are estimated as shown in Table 5.

b. *Slope*

The bulk of the empirical evidence on the influence of slope on soil loss point to a power function, according to which the soil-loss factor or coefficient varies directly with the percent slope raised to a power greater than one. That is

$$S = a + b S^{m}$$

Table 5
ESTIMATED CROP COVER COEFFICIENT OR C VALUES FOR THE COMMON COVER CONDITIONS OF PHILIPPINE WATERSHEDS

Cover	C Value	Ratio Over That for Primary Forest
Bare soil	1.0	1000
Primary forest (with dense undergrowth)	0.001	1
Second growth forest with good undergrowth and high mulch cover	0.003	3
Second growth forest with patches of shrubs and plantation crops of 5 years or more	0.006	6
Industrial Tree Plantation (ITP)		
a) Benguet Pine with high mulch cover	0.007	7
b) Mahogany, Narra, 3-8 years with good cover crop	0.05-0.10	50-100
c) Mahogany, Narra, 8 years or more with good undergrowth	0.01-0.05	10-50
d) Yemane, 8 years or more	0.08	80
e) Mixed stand of ITP plant species, 8 years or more	0.07	70
Agro-forestry tree species		
a) Cashew, mango and jackfruit, less than 3 years, without intercrop and with ring weeding	0.25	250
b) Cashew, mango and jackfruit 3 to 5 years without intercrop, without ring weeding	0.15	150
c) Cashew, mango and jackfruit with intercrop or native grass undercover	0.08	80
d) Mixed stand of agroforestry species, 5 years or more with good cover	0.08	80
e) Coconut with tree intercrops	0.05-0.1	50-100
f) Coconuts, with annual crops as intercrop	0.1-0.30	100-300
g) Ipil-ipil, good stand, first year with native grass intercrop	0.2	200
h) Ipil-ipil, good stand, 2 years or more with high mulch cover	0.1	100
i) Ipil-ipil, newly cut for leaf meal or charcoal	0.3	300

TABLE 5 (Con't.)

Grasslands		
a) Imperata or themeda grasslands, well established and undisturbed, with shrub	0.007	7
b) Imperata or themeda grasslands, slightly grazed, with patches of shrub	0.15	150
c) Shrubs with patches of open, disturbed grasslands	0.15	150
d) Well-managed rangeland, slightly grazed cover of slow development, first year	0.3-0.8	300-800
e) Well-managed rangeland cover of fast development, first year, ungrazed	0.05-0.1	50-100
f) Well-managed rangelands, slightly grazed cover of slow development, 2 years or more	0.01-0.1	10-100
g) Well-managed rangeland, cover of fast development, ungrazed, 2 years or more	0.01-0.05	10-50
h) Grassland, moderately grazed, burned occasionally	0.2-0.4	200-400
i) Overgrazed grasslands, burned regularly	0.4-0.9	400-900
Annual cash crops		
a) corn, sorghum	0.3-0.6	300-600
b) rice	0.1-0.2	100-200
c) peanut, mungbean, soybean	0.3-0.5	300-500
d) cotton, tobacco	0.4-0.6	400-600
e) pineapple	0.2-0.5	200-500
f) bananas	0.1-0.3	100-300
g) diversified crops	0.2-0.4	200-400
h) new kaingin areas, diversified crops	0.30	300
i) old kaingin areas, diversified crops	0.80	800
Others		
a) built-up rural areas, with home gardens	0.20	200
b) riverwash	0.50	500

where S is the slope factor or coefficient, a and b are positive constants, S_L is the land slope in percent and m is greater than unity. The findings of Madarcos (1985) suggest an equation similar to that of Smith and Whitt (1947, 1948) where m is approximately 1.3. Table 6 presents the estimated values of the slope factor S for various slopes as estimated from the Smith and Whitt equation.

Table 6
ESTIMATED SLOPE FACTORS FOR VARIOUS SLOPES*

Slope in Percent	*Slope Factor, S*	*Slope in Percent*	*Slope Factor, S*
3	1.0	36	25.1
6	2.3	48	36.7
12	5.9	60	49.4
18	10.0	72	63.0
24	14.6	102	100.2
30	19.7	150	167.5

*Based on the equation $S = a + b\, S_L^{4/3}$ where a and b are approximately 0.1 and 0.21, respectively and S_L is the slope in percent.

c. *Soil Erodibility*

The soil properties influencing soil erodibility consist of those that affect the infiltration rate and permeability and those that resist dispersion, splashing, abrasion and transporting forces of rainfall and runoff. A comprehensive study on soil erodibility by Wischmeier and Mannering (1969) showed that soil erodibility is a complex interaction of many physical and chemical properties. Among others, these include particle size distribution, organic matter content, structure, pH, bulk density, pore space filled by air, slope shape and steepness, aggregation, and chemistry of parent materials. Many of these parameters are not, however, taken into account in standard soil sampling analyses.

Overall, particle size distribution and organic matter content rank first and second as indicators of soil erodibility. Soils that are high silt, low in clay and low in organic matter are the most erodible[1].

[1] An analysis of all known erodible soils in England, Canada, U.S. and India by Evans (1980) showed that over 95 per-cent of these soils have clay contents of less than 35 percent. There were no erodible soils in the sand class.

Using the simplified equation of Wischmeier and Mannering (1969) for estimating the soil erodibility index or factor on the basis of particle size distribution, organic matter content and pH, the soil erodibility indices of representative soil samples fromthe Magat and Pantabangan watersheds were estimated and the results shown in Table 7. The range of these values may be safely assumed as representative of that for most Philippine soils.

Table 7
REPRESENTATIVE VALUES OF SOIL ERODIBILITY FOR VARIOUS PHILIPPINE SOILS

Soil Texture	*pH*	*O.M.* %	*Sand* %	*Silt* %	*Clay* %	*K value*[1]
Loamy fine sand	5.5	2.4	75	6	19	0.07
Sandy loam	5.6	4.8	65	26	9	0.23
Sandy loam	5.7	2.4	55	31	14	0.30
Loam	6.3	5.2	34	29	37	0.19
Loam	5.6	4.6	50	34	16	0.27
Loam	5.8	2.1	44	42	14	0.38
Loam	7.4	0.9	42	47	11	0.63
Silt loam	5.8	6.0	30	50	20	0.30
Silt loam	5.7	3.0	25	55	20	0.36
Silt loam	5.8	1.1	24	59	17	0.60
Clay loam	5.3	4.7	33	35	32	0.22
Clay loam	5.4	3.0	38	32	30	0.24
Clay loam	5.6	1.8	35	35	30	0.30
Silty clay loam	5.8	4.0	8	60	32	0.28
Silty clay loam	5.4	1.9	2	61	37	0.35
Silty clay	5.5	5.3	6	49	45	0.19
Silty clay	5.6	2.1	6	46	48	0.27
Sandy clay	6.3	0.9	54	14	32	0.20
Sandy clay	6.1	3.5	57	10	33	0.09
Clay	5.4	4.9	17	27	56	0.13
Clay	5.2	3.0	15	29	56	0.16
Clay	5.6	1.2	16	30	54	0.26

[1] K values were computed using the equation

$$K = [(0.043)(pH) + 0.62/OM + 0.0082S - 0.0062C]\,Si$$

where OM = organic matter content in percent,
S = percent sand
C = clay ratio = % clay/(% sand + % silt)
Si = % silt/100

d. *Rainfall*

There is very little information on the erosive power of rainfall patterns in the Philippines. The generally accepted equation for estimating rainfall erosivity indices developed for the USLE requires more detailed rainfall information (recording rain gage data) than is currently available. Following the suggestion of Mihara (1951) and Hudson (1971), David and Collado (1987) adopted the equation

$$Rj = A \sum_{1}^{n} Pi^m$$

where Rj is the erosion index for any year j and Pi is the precipitation total for day i when this exceeds the threshold of 25 mm.

Using A and m values of 0.002 and 2.0, respectively, the average annual R values for selected stations in Northern and Central Luzon were estimated and the results are shown in Table 8. (The use of an A value of 0.002 renders the R estimates compatible with those of the USLE.)

Table 8
SAMPLE RANGE OF VALUES OF RAINFALL ERODIBILITY (R)*

	Location	Annual Rainfall, mm	R value
1.	Bontoc, Mt. Province	2280	174
2.	Lagawe, Ifugao	2645	158
3.	Hapid, Lamut, Ifugao	1838	107
4.	Baretbet, Bagabag, Nueva Vizcaya	1770	112
5.	Diadi, Nueva Vizcaya	1937	168
6.	Ambuklao, Benguet	2391	165
7.	Carranglan, Nueva Ecija	3122	130
8.	Carrili, Nueva Ecija, Pantabangan	2665	329
9.	Marikit, Pantabangan, N.E.	2247	197
10.	Tanauan, Nueva Ecija	2136	138

*Based on the equation

$$R = A \cdot \sum_{1}^{n} Pi^m$$

where R = daily rainfall > 25.0 mm and i = counter for the days of the year, A and m are 0.002 and 2, respectively.

e. *Influence of Conservation and Management Practices on Soil Erosion*

Table 9 summarizes the values of the commonly accepted conservation practice or management factors. As is the case with the other factors or indices, these are used as multipliers or correction factors for the estimated soil loss rates under conditions of no conservation practices.

Soil erosion rates may be considerably reduced with the adoption of one or more conservation practices. For example, contour farming and mulch tillage in areas with 21 to 25 percent slope will give an overall multiplier of 0.23 (0.90 x 0.26), a fourfold reduction in the soil-loss rate.

2. *Estimates of Soil Loss Rates under Various Combinations of Factors*

In the absence of any applicable method for estimating soil erosion rates in tropical Asia, David (1976), David and Collado (1977) modified the universal soil loss equation (USLE) to suit locally available information and prevailing environmental conditions. This modified USLE stipulates that

$$E = R \cdot K \cdot LS \cdot C \cdot P$$

where E = soil loss rate in tons/ha/yr
R = rainfall erosivity index value (see Table 8)
LS = length-slope factor which may be approximated on the basis of percent slope (see Table 6)
C = cover factor value as shown in Table 5
K = soil erodibility value as shown in Table 7
P = is the product of the conservation or management factors being practiced (Table 9)

Hence, it is possible to obtain "guesstimates" of the soil loss rates associated with any set of conditions by estimating the values of the various parameters in the modified universal soil loss equation.

The above considerations have some far-reaching implications on erosion control, land-use planning and allocation, and development of farming schemes for sustained production. Consider the following:

(1) There exist effective and technically sound methods to control soil erosion. These may include proper selection of cover, cover management, conservation practices, tillage practices, soil amelioration and control structures such as terraces, diversion channels and check dams.

(2) The erosion rates of cropped areas with steep slopes (greater

Table 9
APPROXIMATE CONSERVATION PRACTICE OR MANAGEMENT FACTORS

a) Tillage, terracing, contouring and strip cropping

Land Slope %	*Terracing*		*Contouring*	*Contour Strip Cropping*
	Bench	*Broad-based*		
1-2	0.10	0.12	0.60	0.30
3-8	0.10	0.10	0.50	0.15
9-12	0.10	0.12	0.60	0.30
13-16	0.10	0.14	0.70	0.35
17-20	0.12	0.16	0.80	0.40
21-25	0.12	0.18	0.90	0.45
>25	0.14	0.20	0.95	0.50

b) Mulching and cover management

Surface Cover	*Percent Cover*	*Percentage Cover of Mulch or Vegetation at Ground Surface*					
		0	*20*	*40*	*60*	*80*	*100*
a) None	0	1.0	0.53	0.33	0.20	0.10	0.02
b) Tall weeds or short bush, 0.5m effective height	25	1.0	0.56	0.36	0.23	0.11	0.03
	75	1.0	0.71	0.53	0.40	0.22	0.06
c) Bush or brushes 2 m effective height	25	1.0	0.55	0.35	0.22	0.11	0.03
	75	1.0	0.61	0.43	0.27	0.14	0.04
d) Trees, 4 m effective height	25	1.0	0.55	0.33	0.21	0.10	0.03
	75	1.0	0.56	0.36	0.23	0.11	0.03

c) Tillage and residue management

Tillage Practice	*P Value*
a) Conventional tillage	1.0
b) Zoned tillage	0.25
c) Mulch tillage	0.26
d) Minimum tillage	0.52

than 18 percent) can be reduced to acceptable levels of, say, 8 tons/ha/yr with sound erosion control practices. Hence, the government's policy of classifying lands with slopes of 18 percent or more as forest lands or non-arable lands does not have a sound technical basis. This observation has far-reaching implications, specially in the implementation of the Comprehensive Agrarian Reform Program.

(3) Natural cover such as forest and native grasses are good soil protectors even in areas with erodible soils, steep slopes and erosive rainfall. If undisturbed, grasslands will naturally evolve into second growth forests and eventually into primary forests. Thus there are very cheap methods for arresting soil erosion in areas that are unfit for farming.

(4) A soil-loss threshold level for sustained yield must be inferred from, among others, soil-inherent fertility and fertility regenerative capability, existing or intended land uses, slope-rainfall-soil erodibility conditions, economic cost of conservation measures and off-site effects of eroding soil particles.

In support of some of the above observations, in Table 10 are shown sample calculations of soil erosion rates under various conditions. It is quite clear that with proper cover selection and management, areas on slopes greater than 18 percent could be used for ecologically sustainable agricultural development. As shown in Table 10, a combination of broad-based terraces, mulching, zoned tillage and contouring could keep the erosion rate below 5.5 t/ha/yr even in areas with moderately erodible soils, erosive rainfall and 18-48 percent slope.

Table 10

SAMPLE CALCULATIONS OF THE SOIL LOSS RATES UNDER VARIOUS CLIMATIC, SLOPE, LAND USE AND COVER MANAGEMENT CONDITIONS.

	Rainfall Erosivity Value (R)					
	120			*250*		
I. Soil erodibility, K (silty clay)	0.20			0.20		
II. Slope (a) percent	18	30	48	18	30	48
(b) LS value	10.0	19.7	36.7	10.0	19.7	36.7
III. (R) (K) (LS) value	240.0	472.8	880.8	500.0	987.0	1835.0
IV. Erosion rate, t/ha/yr or (R) (K) (LS) (C) without any conservation practice whatsoever						

Table 10, continued

	Rainfall Erosivity Value (R) 120			250		
a) Primary forest (C=0.001)	0.24	0.47	0.88	0.50	0.99	1.84
b) Well established, undisturbed grassland (C=0.007)	1.68	3.31	6.10	3.50	6.91	12.84
c) Cashew orchard, 5 yrs or more (C=0.08)	19.2	37.82	70.46	40.00	78.96	146.8
d) Corn crop (C=0.4)	96.0	189.12	352.32	200.00	394.8	734.00
e) Old kaingin (C=0.8)	192.0	378.2	704.64	400.00	789.6	1468.0
V. Erosion rate, t/ha/yr, with the following conservation practice(s)						
a) Cashew orchard						
(1) Establish grass intercrop, such as centrosema, 80% surface cover (P=0.11)	2.11	4.16	7.75	4.40	8.69	16.15
(2) Grass intercrop, 60% surface cover (P=0.23)	4.42	8.70	16.21	9.2	18.16	33.76
(3) Broad-based terraces (P=0.20) with cover inter-crop at 80% cover (P=0.23)	0.88	1.74	3.24	1.84	3.62	6.75
b) Corn						
(1) Contour strip cropping (P=0.40-0.50)	38.4	94.56	176.16	80.00	197.40	367.00
(2) Zoned tillage (P=0.25) with contouring (P=0.90-0.95)	21.6	44.91	83.67	45.00	93.77	174.32

Table 10, continued

	Rainfall Erosivity Value (R)					
	120			250		
(3) Zoned tillage, contour farming and mulching at 40% cover (P=0.40)	8.64	17.96	33.47	18.00	37.51	69.73
(4) Broad-based terraces (P=0.18-0.20), contouring and mulching at 40% cover)	6.22	14.37	26.77	12.96	30.00	55.78
(5) Broad-based terraces, with mulch tillage (P=0.26) contour farming	4.04	9.34	17.40	8.42	19.50	36.26
(6) Broad-based terraces, mulching at 80% cover (P=0.15), zoned tillage (P=0.25) and contouring	0.58	1.35	2.51	1.21	2.81	5.23
c) Old kaingin						
(1) Contour strip cropping, mulching at 60% cover (P=0.30), zoned tillage contour farming	5.83	12.12	22.59	12.15	25.31	47.07
(2) Left undisturbed for natural grasses to establish themselves, 2 to 4 yrs after (C=0.01)	2.4	4.72	8.81	5.0	9.87	18.35
(3) Left undisturbed for 10 years for second growth forest establishment (C=0.003)	0.72	1.41	2.64	1.50	2.96	5.50

III. Sediment Yields

Not all eroded soil particles will be delivered to the waterways of a watershed. Some will be deposited for good or temporarily at various locations within the watershed. Thus at a watershed the sediment yield or outflow at any point across a stream and for a given period of time may differ significantly from the total soil loss due to erosion. Sediment yield as defined here refers to the total annual sediment discharge at a reference point across a stream system. This reference point defines the watershed boundary and the basin area.

As mentioned before, the sediment yields from watersheds with primary forests are low, averaging less than 0.5 t/ha/yr. This is because the forest cover and the cover litter cushion the soil against raindrops energy, intercept a certain amount of rainfall, improve soil structure, aggregation and infiltration, and increase the soil-surface resistance to overland flow channelization. Obviously, erosion rates and sediment yields from forested watersheds or watersheds with good cover do not fluctuate too much and are influenced primarily by channelized or stream flows.

As the watershed cover is disturbed and reduced, sediment yields increase and fluctuate considerably. This is because the effects of other parameters (e.g., climate, slope, soil erodibility, cover management and conservation practices) and their interactions become more pronounced.

Table 11 presents the sediment yields at selected watersheds in the island of Mindoro. The large variation in their sediment discharges may be traced to variation in rainfall patterns, land use, productive capabilities, and cover management. The watersheds in Mindoro Oriental experience uniformly distributed and less intense rainfall, while those in Occidental Mindoro undergo distinct wet and dry seasons.

Table 12 shows the specific flows and land uses of a representative watershed in each of the two provinces on the island. Bucayao watershed in Oriental Mindoro has more forest cover and a smaller proportion of open lands. It has more cropped area owing to good climate and more productive soils. A higher level of productivity not only encourages soil protection and good farming systems but also reduces population pressures to overexploit hinterlands. Oriental Mindoro also has better roads and port facilities and, hence, better access to the markets in the Metro Manila and Southern Tagalog regions.

Over half of the catchment of the Bugsuanga watershed consists of pastures or open areas. Used mostly as range lands, these open areas are overgrazed. The long dry spell aggravates the cover conditions in these areas. It is also worth noting the fact that the specific dependable flows of this watershed are just about a tenth of those in Oriental Mindoro.

A preliminary study by David (1982) projected a sediment discharge

Table 11
SEDIMENT YIELDS OF SELECTED RIVER BASINS IN THE ISLAND OF MINDORO
(David, 1984)

River Basin	*Catchment Area km2*	*Mean Annual Sediment Discharges, t/ha*
A. Mindoro Oriental		
1. Pula	161	4.6
2. Bongabon	369	6.7
3. Bucayao	300	4.0
B. Mindoro Occidental		
1. Mamburao	144	348.0
2. Pagbahan	337	171.0
3. Bugsuanga	415	233.3

Table 12
SPECIFIC FLOWS AND LAND USES IN TWO MINDORO WATERSHEDS
(David, 1984)

	WATERSHED	
	Bucayao	*Bugsuanga*
Catchment area, km^2	384	438
Specific dependable flows in $m^3/sec/km^2$, catchment		
80% dependability level	0.052	0.0064
90% dependability level	0.037	0.0041
Major land use Categories in %		
Forest	45	16
Cultivated area	33	18
Grasslands (good stand)	4	45
Savannah (cogon and talahib grasses with shrubs and brushes)	18	18

The difference in catchment areas of the two watersheds in Tables 11 and 12 is due to different sets of reference or monitoring points on their stream system.

in the order of 30 to 40 t/ha/yr into the Magat Dam reservoir. Actual reservoir sedimentation measurements during the period from 1983 through 1985 showed sedimentation rates of about 38.8 t/ha/yr. For the Pantabangan Dam watershed, David and Collado (1987b) projected a sediment yield of 77 t/ha/yr during the period 1980 to 1982. Preliminary results of actual measurements by the NIA for the past several years ending in 1982 show a sediment yield in the order of 80 to 90 t/ha/yr (personal communication with the NIA watershed management staff in December, 1987).

Both the Pantabangan and Magat reservoirs are foreign-assisted (IBRD) multipurpose water-resources development projects. Each was designed to irrigate over 100,000 has. The estimated sediment inflows into these reservoirs are two to three times higher than those assumed in their feasibility and design studies. Although various governmental agencies have been directing massive protection and reforestation efforts to these watersheds for the past ten years, these efforts have very little to show for themselves (David and Collado, 1987 and David, 1987). This is because: (1) considerable sediments are already in transit and are near the reservoir areas, (2) some of the current efforts are not properly focused, or are designed to generate income for the agencies concerned rather than arrest soil erosion and (3) the agencies concerned lack rational policies as well as management and regulating capabilities.

Even given an optimistic scenario of no further increase in erosion and sediment discharges, the Magat and Pantabangan sediment storages are likely to fill up in about 30 and 40 years, respectively (as against the designed lives of 95 and 75 years, respectively). Unless measures are taken to refocus, coordinate and expand the government's watershed protection efforts, the sediment pools of these reservoirs will get filled up 20 years from now.

Pollisco (1975) reported annual suspended sediment discharges of 74 and 13 t/ha for the Agno and Pampanga river basins, respectively. Various NIA documents on river basin development projects during the past 10 years estimate sediment yields ranging from 6.8 to 44.8 t/ha/year. Considering the ongoing massive land-use transformations at these watersheds, their sediment yields could be higher by several orders of magnitude at present.

A study by Mahbub (1978) of 28 major rivers in Indonesia reported sediment yields in equivalent depth of soil eroded ranging from 0.03 to 23.0 mm/yr. The major rivers of Central Java had an average equivalent load of 4.0 mm/yr. At an assumed soil bulk density of 1.2 gm/cc, a sediment discharge of 1.0 mm/yr is equivalent to 12 t/ha/yr. Thus a range of 0.03 to 23.0/mm/yr is roughly equivalent to a sediment discharge of 0.4 to 276 t/ha/yr.

Lin (1981) reported an average sediment production of 8.04 mm/yr from nineteen watersheds in Taiwan. These watersheds range in catchment size from 175 to 3,257 sq km, and in sediment yield from 1.5 to 20.1 mm/yr. His study also revealed that extreme flow events produce most of the total annual sediment loads of rivers.

IV. Land Use and Conservation Planning

1. *Land Use Policies*

The Philippine Constitution mandates the proper utilization and conservation of natural resources. The revised Forestry Code of the Philippines (P.D. 705) stipulates government ownership, control, regulation and management of some 419 large watersheds whose combined area roughly equals 70 percent of the total land area of the country. With the exception of areas earmarked for geothermal explorations, the administration, control and management of these areas are entrusted to the Department of Environment and Natural Resources (DENR).

Lands not needed for forestry or conservation practices are designated as alienable and disposable (A and D) by the DENR and are thus open for private ownership. To date, DENR retains control of over 50 percent of the country's total land area, a monumental task. There are indications, however, that DENR's regulatory and management capabilities are inadequate for this task. The DENR, for example, controls about 80 percent of the total land area of the 412,000 ha Magat watershed. In spite of the reforestation efforts by the DENR and the BFD, the badly disturbed open areas continue to increase at the expense of forested areas on steep slopes at a rate of about 11,000 ha each year (David and Collado, 1987). In 1984, the watershed grassland area was estimated at about 155,000 ha, about 90,000 ha of which have slopes exceeding 25 percent.

With legislation on agrarian reform, more government lands will be declared A and D lands. This will require the development and implementation of a sound land-classification and land-use allocation scheme which considers short and long-term land use objectives. The need to evolve such a scheme becomes more urgent considering its inherent requirements for massive baseline information and strengthening of the linkages among various institutions.

Other major government land-use and watershed management policies include the sustained multiple-use forest management approach, environmental quality management, and active participation of and partnership with the people in managing natural resources. The selective logging system is an example of the sustained multiple-use management policy. The policies for sound environmental quality management are embodied in the provisions of the Environmental Policy Acts of the Philippines. The policies mandating active people's participation are implemented through the various upland livelihood programs such as the Integrated Social Forestry (ISF) Program of the DENR, the Dendrothermal Program of the National Electrification Administration, and the People's Forest program of the former Ministry of Human Settlements.

The general land use policies of the country are premised on fundamental concern for conservation, development, control by nationals, and social justice. The concern for conservation, for example, determines the public lands that may be classified as alienable and disposable. Section 13 of P.D. 705, for example, stipulates that only public lands with 0-18 percent slope may be alienated and disposed. While general policy for conservation is beyond debate, the specific regulation designed to implement it is technically unsound and, hence, highly controversial. The specific regulations restricting the alienation of lands with 0-18 percent slope (e.g. head stream areas, critical watersheds, coastal areas, river banks 20 m from normal high water line, water bodies of at least 5 m in width, reforested areas, parks and wildlife sanctuaries, historical sites, shrines and forest reserves) are generally less controversial but leave room for fine tuning and improvement.

The policy of control by nationals limits the disposition, development, and utilization of public lands to Filipino citizens and corporations with at least 60 percent ownership by Filipinos. The policy of development pursues a goal of sustainable development, while the policy of social justice aims to insure the dignity, welfare and security of all citizens.

There are countless laws, regulations, and programs concerning forest land use in the Philippines. The more important ones and those that are relevant to the objective of sustainable development include LOIs 1258, 1260 and 1262 (all dated 1982). LOI 1258 provides for a rational evaluation and re-examination of all government reservations and parks in order to provide for a scientific reallocation scheme of forest resources for the benefit of the majority of Filipinos. LOI 1260 provides a program to help uplift the plight of upland farmers by stabilizing the tenures of the lands they till and providing governmental assistance in the development of these lands.

LOI 1262 aims to provide a rationale and scientific basis for the allocation of forest lands into more specific uses such as agro-forestry, protection forest, pastures, production forests and parks or recreational areas. It calls for the implementation of a system of land classification that will promote optimum, and equitable utilization of forest resources and other public lands in order to meet the increasing needs of our growing population.

Most land use policies are focused on the management of public lands and the disposition into broad land use categories of A and D lands. There are few specific policies aimed at stipulating the land use and management of public lands declared as alienable and disposable. The few existing specific land use policies are commodity oriented and aimed primarily at promoting the production of food crops.

2. *Issues on Land Allocation and Use*

Case studies involving the Magat and Pantabangan watersheds (David, 1987 and David and Collado, 1987) revealed many interrrelated issues and problems on land use planning and management and watershed management. Below are some of them.

a. *Policies and Conditions Affecting Policy*

Unrealistic Policies and Regulations. As shown in Table 10, Section 13 of P.D. 705 which, in effect, has restricted the utilization of vast tracts of lands for agricultural purposes for which they are suited, is an unrealistic regulation.

The lack of specific policies aimed at regulating the use and management of public lands to be declared alienable and disposable is cause for alarm in the light of government policy of distributing over a million hectares of public lands under the proposed Comprehensive Agrarian Reform Program. Specific land-use policies aimed at sustainable development of such lands are needed, since most of these lands are only marginally productive. It is unlikely, however, that sound specific land use policies can be formulated in the near future unless greater efforts are directed immediately at generating information which will allow a classification of land according to crop-suitability. As pointed out by Revilla (1984a), existing public-forest policies are too diffuse, subject to various shades of interpretation, sometimes contradictory in nature, and in many cases unrealistic. The causes of these may be traced to lack of data base; too many implementing agencies whose functions are stipulated by a maze of decrees, directives, LOI's, and administrative orders; and failure to fully consider the interdependence and interactions of the social and biophysical aspects of forest ecosystems. The constant changing of the guard at the DENR makes it difficult to reconcile, modify and fine-tune these policies and regulations.

Rural Poverty. There is no denying the fact that for any watershed management scheme to be effective, it must be premised on satisfying the basic needs of people dwelling in and around the watershed. At the Magat watershed, where the average upland farm family income is about a third of the food-threshold income, there is bound to be continuing population pressures to exploit more hilly lands. The government should channel a critical minimum of natural, financial and technical resources to satisfy these basic needs if it is to relieve population pressures just enough to effectively implement long term watershed management plans and programs. It should again be pointed out that the disturbed open areas in the Magat watershed are increasing at a rate of about 10,612 hectares per year in spite of the combined reforestation efforts of the BFD and the NIA.

Ineffective Land Use Planning and Allocation. The country does not have a comprehensive system of land-use planning and allocation. This need is more acute in the case of forest lands. The primary criteria at present for classifying lands into either forest or alienable and disposable lands are slope and existing land use. Ideally, however, lands should be allocated on the basis of capability and suitability for alternative uses and utilization demands or objectives. Thus land-use allocation must be validated from land physical properties such as climate, slope, elevation and soil fertility; suitability for sustainable uses such as productivity, erosion rates and biological stability under alternative land uses as well as socio-economic goals, objectives and constraints. Comprehensive land classification and allocation are constrained mainly by the lack of proper appreciation of the interdependence and extent of interactions of the various components of watershed ecosystems by agencies or parties concerned. This has resulted in critical gaps in the manpower and skills needed for proper land classification and allocation. For example, neither the DENR nor DA today has the capability to quantify erosion rates and the effects of watershed modifications on soil loss rates and runoff. Yet protection from soil erosion and its adverse environmental effects is supposedly one of the main considerations in declaring some forest lands unalienable.

Lack of Active Support for Forest Resources Conservation and Management by the People. This problem is related to many other problems such as those mentioned above. Rural poverty, insensitivity of the government to the needs and aspirations of the upland poor, among others, contribute to the uplanders' indifference to government forest resources conservation and management programs.

b. *Implementation Problems*

Ineffective Planning and Implementation of Action Programs. As Revilla (1985) points out, the various upland livelihood programs suffer from serious problems which include: (1) too much focus on marginal lands; (2) inadequate and faulty planning; (3) low capability to provide socio-economic upliftment of uplanders; and (4) inadequate manpower to effectively implement upland development programs. The basic flaw of many of these programs is the assumption that upland development programs must be financially viable in an out-of-pocket sense. In reality, they are not likely to be so and must be viewed as rehabilitation activities whose benefits are not privately appropriable rather than as usual business activities. On the other hand, the off-site externalities are ignored and, hence, the social value of encouraging such activities is underestimated. Demanding that such programs function as viable business ventures is tantamount to asking the poorest of the poor to shoulder the cost of forest rehabilitation.

The case studies of the Magat and Pantabangan watersheds by David and Collado (1987) and David (1986) also point to ineffective planning and implementation of watershed management programs. Projected yields and benefits were unrealistic. In the case of the Pantabangan watershed and erosion control project, the cost of reforestation was too high and the accomplishments so far have fallen too short of the targets.

The proposed Magat watershed management project, even if effectively implemented, will not significantly reduce the sediment inflow into the Magat reservoir. It is premised primarily on having the project pay for itself through increased production. It focuses only on a small portion of the watershed. It projects unrealistically high yields and a very short full development period. Both projects do not provide for mechanisms for monitoring environmental impact. They do not fully consider the erosion and sediment transport processes involved.

Bonita (1981) cited the Forest Ecosystem Management Program (PROFEM) as a classic example of ineffective and unrealistic reforestation program. After five years of implementation which started in 1976, it had yet to translate its plans and programs into action. The failure of the program was traced to lack of planning, lack of coordination and failure to consider the needs and aspirations of forest land occupants.

Lack of Effective Coordination Among Agencies Concerned. Many of the problems in watershed management are institutional in nature. More than 50 percent of all our land resources are still classified as forest lands. The DENR has been entrusted with the primary responsibility for the management of our non-urban watersheds. As already pointed out in many reports, the DENR as an institution is rather weak and unable to perform its tasks of protecting, regulating and managing our forest land resources. This has resulted in the creation and/or involvement of many other agencies in the regulation, management and development of our forest land resources. Among others, these agencies include the National Irrigation Administration (NIA), the Department of Agriculture (DA), the National Electrification Administration (NEA), National Power Corporation (NPC), Department of Trade and Industry (DTI), NEDA, National Dendro Development Corporation (NDDC), Presidential Committee for Wood Industries Development (PCWID) and the Manila Seedling Bank Foundation.

Coordination between two ministries alone is already difficult. For example, the coordination between the DA and DENR in the upland livelihood programs is almost non-existent in the Magat watershed area. It is quite obvious that the task of integrating and coordinating the Magat watershed management activities is almost insurmountable given the many participating agencies with overlapping functions.

Poor Delivery of Social and Agricultural Support Services. Both the NIA and Bureau of Soils surveys in the Magal watershed revealed very low average income for the upland dwellers. The 1982 and 1984 surveys conducted by NIA also showed poor delivery of social services and inadequate agricultural support services. There are very little agricultural support services in the form of marketing, extension, farm inputs distribution and farm credits in the uplands as these services are concentrated in the lowlands. Although a number of government-initiated rural organizations exist, membership in these is, however, low. The watershed occupants are, in general, skeptical of externally initiated organizations.

Highly Centralized System of Governance. Unlike many other countries (e.g., Indonesia), the planning and implementation of watershed management programs are highly centralized. The inherent difficulties with such a system include: the lack of accountability for failure, even at field staff level and the lack of participation of, and control by local institutions (e.g., local governments) in reforestation. In this respect, perhaps, it is worth considering the Indonesian experience, where the greening or agroforestation of certain areas was relegated to districts and provincial governments.

The above issues and problems are, in fact, restatements of the requirements for sound policies and programs which take into consideration the concept of sustainable development, livelihood security for the poor, and equitable and economic use of basic resources, as well as the institutional and technical constraints in putting developmental plans into action. The literature is replete with suggestions and recommendations for achieving sustainable growth. (See, e.g. Swaminathan, 1987).[2]

V. Conservation Planning

In the context of the government's recent decentralization policy, past experience in conservation work, and the realities of the Philippine countryside, conservation planning should have a clearer focus on the competencies assigned to its various levels. This means that coherent plans and staement of objectives must be expected from the national level, while plans and designs of greater resolution must come from the regional or local levels.

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[2]Swaminathan proposes a seven-point action plan for achieving sustainable nutrition security in developing countries, namely: a) local level codes for the sustainable and equitable use of environmental systems; b) sustained livelihood security for the poor; c) symphonic production system; d) science and technology; e) knowledge and skills sharing; f) resource mobilization and utilization; and g) political commitment and accountability.

Conservation planning on the national level initially involves a general assessment of the hazards of erosion and sedimentation, to the extent that problem or priority areas or regions are identified. The level of resolution could be on political regions or large river basins. Such an assessment could be done by compiling and analyzing rainfall, soil, land slope, land use trends, erosion rates, suspended sediment loads and crop and fishery production information. A macro-level assessment of the on-site and off-site effects on soil erosion, both in financial and environmental terms, is then carried out. Such information are then used as a data base for formulating or reformulating general policies. National level conservation planning also involves the provision of legislation necessary to implement such policies; development of a national framework for validating and monitoring regional plans and programs and setting out of institutions, institutional linkages and mechanisms including support services for the effective implementation of regional plans and programs.

On a regional level, conservation planning basically includes land evaluation and classification, land use planning and allocation, and design of appropriate conservation measures and monitoring and evaluation schemes. Appropriate measures imply soundness from agronomic, engineering, hydrologic, socio-economic and environmental standpoints. The design of such measures requires an understanding of the mechanics of the interrelated processes of erosion and sediment transport, methodologies for quantifying the magnitudes of these processes under varying watershed conditions and well-defined design criteria such as threshold or allowable soil loss levels.

1. *Soil Loss Threshold Levels*

An allowable soil loss level in theory implies optimum and ecologically sustained level of production for a given tract of land for an indefinite period of time. A threshold level, therefore, is the soil loss rate at which the rate of soil formation equals the rate of soil erosion. It is also the level where the benefits from the utilization of the land are *optimum* considering, among others, the on-site and off-site costs of soil erosion. In practice, however, this theoretical state of equilibrium is impossible to achieve, but should rather be regarded as a moving target that varies in space and time, with land use, natural attributes of soil, market forces, and off-site (downstream) effects of soil erosion as variables.

It is quite understandable that most of the recommended allowable soil-loss levels are aimed at less difficult targets. Usually, the off-site effects are not considered and the level is set primarily in terms of soil fertility. That is, the level refers to the maximum soil loss rate at which soil fertility is maintained for, say 15 to 25 years. Such definition of a specific level usually allows for the use of organic and inorganic fertilizers and the projected improvements in agricultural technology (e.g., development of short duration, fertilizer use efficient varieties and improvement in crop cover and management techniques).

Even with the less rigorously defined threshold levels, great difficulties are encountered in arriving at general consensus. Soil fertility is a highly dynamic and complex process. Moreover, soil erosion rates also exhibit great variations across space and time.

Soil fertility is influenced by many factors. Among others, these include soil structure, water retention properties, soil chemical and physical properties, and climate. There is ample evidence in the literature indicating that soil structure is the key to soil fertility (Baver, 1956). Continued cultivation, together with its accompanying erosion of top soil, and exposure of the surface layer to raindrops result in breaking up of soil aggregates, deterioration of soil structure, and compaction of soil strata. Other soil properties which influence soil productivity are likewise affected, such as porosity, soil and air holding capacities, and movement of water and air through soils.

There is substantial experimental evidence in Western countries to the fact that continuous cultivation reduces soil porosity by as much as 18 percent. Furthermore, a difference in porosity of as little as 10 percent (e.g., 60 versus 50 percent) is sufficient to cause yield-differences of as much as 200 percent. In such cases, total porosity, as well as non-capillary porosity (for aeration), influenced the yield levels. On the average, the difference in the non-capillary porosity between forested and bare soils ranges from 10 to 15 percent.

Experimental evidence on the influence of cover disturbance and management practices on soil moisture holding capacities can perhaps be best illustrated by first analyzing the statics of soil water. Consider the equation

$$d_w = \frac{P_w \times As \times D}{100}$$

where d_w is the depth of water stored in a rootzone depth D with moisture content by weight of P_w percent and a bulk density of As. Assuming all other factors remain constant, an increase in bulk density (more compact soil) will increase the water holding capacity of a soil. When we consider the forces acting on the soil water or the availability of the stored water for plant growth, a different picture emerges. Consider further the following hypothetical but realistic cases.

Case	1	2
As, g/cc	1.3	1.1
D, cm	100	100
Total porosity, %	50	57

Moisture content, Pw, % at		
a) Field capacity	30	34
b) Wilting point	15	13
Maximum water holding capacity,		
d_w, cm	65.0	62.7
Depth of stored water available for plant growth, mm	19.5	23.1

Soil compaction, or an increase in bulk density, generally increases the soil maximum water holding capacity. However, it reduces the water available for plant growth and adversely affects other soil properties.

A more important effect of soil compaction is the reduction in infiltration capacity of the soil. Compaction resulting from overgrazing, for example, may lead to a several fold decrease in infiltration rate. Thus the opportunity for rain water conservation in soil rootzone is correspondingly reduced. Pocket penetrometer measurements by Sims (1975) of soil compaction in ungrazed and grazed imperata grasslands of the Upper Talavera watershed in Central Luzon showed average readings of 1.3 and 4.0 tons per square foot, respectively.

It is quite obvious that a threshold level on soil fertility must not only be inferred from soil nutrient status but also from other determinants of soil fertility such as soil structure, water holding capacity and porosity. The currently available information in the Philippines is, however, inadequate for this purpose.

The spatial level of resolution of establishing threshold levels and other design criteria for suitable erosion control measure can be a ticklish issue. The factors influencing soil erosion are mostly stochastic in nature. Some structures (e.g. check dams, terraces) as well as threshold levels, would probably have to be defined on frequency of exceedance or return periods basis. Others, such as erosion rates on farmers' fields, are realistically defined on a seasonal or annual average basis.

Erosion and sedimentation problems also have important spatial dimensions. For example, not all sheet erosion is delivered into the watershed stream channel. Thus, a threshold for an individual farm might differ from that for a larger area or an entire catchment.

A rate of 11 tons per hectare is a widely accepted threshold level for individual farms in the midwestern United States. However, the soils in these areas are deep, very fertile loess soils. For shallower and less fertile soils, levels ranging from 2 to 8 t/ha/yr have been recommended. Such threshold values are unrealistic, however, in areas where erosion rates are naturally high (e.g., mountainous terrains with high rainfall). In such places, higher levels of as much as 25 t/ha/yr have been suggested. Where the threshold is on a basin basis, such as sediment yields of rivers, a much lower threshold may be set depending on the estimated ratio of the sediment delivery to the gross erosion loss.

The above considerations point to several important issues and implications. These include:

(1) levels of spatial and temporal resolution for thresholds.
(2) establishment of realistic thresholds that consider on-site and off-site effects, land use, land natural attributes, and socio-economic, agronomic, and hydrologic factors.
(3) cost-sharing schemes where significant off-site effects are considered in establishing threshold values. Usually, the poor upland farmers are expected to shoulder all the cost of conservation measures.
(4) short, medium versus long term goals as are needed for setting up threshold values, data constraints, needs and practicality.

2. *Off-site Effects of Erosion Control Measures*

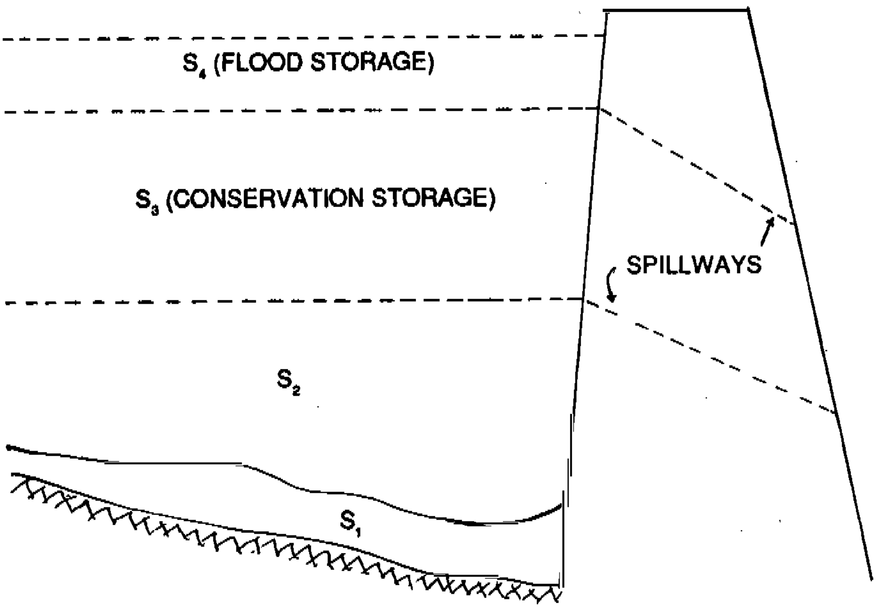
The downstream effects of erosion control upstream depend on the sediment delivery capabilities of the watershed stream system, the actual or potential utilization of downstream resources, and the potential downstream hazards to human lives, structures, and properties. The sediment delivery capacity of a watershed stream system is commonly expressed in terms of the sediment delivery ratio, or the fraction of the gross erosion that is delivered to the point of the river system or drainage area under consideration.

The sediment delivery ratio is dependent on the size of the catchment, watershed characteristics such as relief, drainage network, length of stream, sediment properties, the amount of sediment in transit, the sediment storage capabilities of flood plains and streams, the hydraulic characteristics of the transport system and streamflow patterns. Although many empirical equations for sediment delivery ratio have been proposed, most of these only consider catchment size and, hence, are of very limited locational applicability.

In most watersheds in the Philippines, a considerable volume of sediments is in transit along the river system. The sediment discharges of such river systems are mainly dependent on flow and sediment properties. In such rivers as Magat and Pantabangan, 95 percent of their sediment discharges are carried out by 2 percent of the extreme flows. In such rivers, control of erosion upstream will have very little short and medium term effects on their sediment discharges. Thus the concept of sediment delivery system as based on watershed size is of no practical value in predicting the impact of upstream erosion control on sediment yields.

On the basis of the studies of David and Collado (1987) and David (1978), the sediment delivery ratios of the Magat and Pantabangan rivers at their damsites are in the order of 40 to 50 percent. These are way above the usual delivery ratios of less than 1 percent for such large watersheds. The reason is obvious. The sources (sediment in transit) are very near the point of reference and are already in the waterways. The only effective sediment yield control measures are streamflow regulation and river training and control. In other words, the feasible measures are those that will reduce the stream system sediment delivery capabilities.

The actual or potential water resources utilization downstream are many and varied, given a certain watershed and time frame. To illustrate possible downstream effects, consider the case of a dam and reservoir project. In the analysis of the effects of erosion and siltation of a storage reservoir, the following storages as illustrated are usually considered.



where S_1 = sediment pool or natural or geologic erosion induced sediment inflow
S_2 = sediment storage pool as a consequence of accelerated soil erosion

$S_1 + S_2$ = total sediment pool

If the catchment is undisturbed and if there are no irrigated areas or other constraints downstream, then S_3 and S_2 may both be used for active or conservation storage. But the utilization of the watershed upstream renders S_2 amount of storage unavailable for irrigation and perhaps power generation for the life span of the project. The effects of accelerated erosion in this case include the loss of irrigation command area and power generation corresponding to S_2 volume of storage. In the case where only S_3 amount of storage is required, the cost is that of a larger dam and bigger pond area.

Where the dam and reservoir are existing, the more significant cost of increased sediment yield as a result of accelerated soil erosion include: (1) reduction in storage capacity with time and (2) increased O & M cost due to siltation once the sediment pool is filled up. Actually a certain amount of sediments in transit within the reservoir area gets deposited into the active storage pool even before the sediment pool gets filled up.

The effects downstream of the dam include less sediment discharges since from 94 to 97 percent of the sediments are initially trapped in the reservoir. The financial value of this again depends on the actual and potential uses of the downstream land and aquatic resources.

VI. Land Evaluation, Land Classification and Land Use Planning

As mentioned before, the basic procedure for regional or local conservation planning includes land evaluation and classification, land use planning and allocation, and design and development of suitable conservation structures. Since the key to erosion control is putting land resources to their best or proper uses, there can be no effective conservation plans and programs without proper land evaluation and classification and land use planning and allocation.

Land Classification

Land capability classification is the commonly used scheme of land evaluation for conservation planning. The rationale for such a classification system is that lands have identifiable bio-physical characteristics and that the importance of each characteristic varies with location and land use. Thus some lands are more suited to certain uses than others and their correct use is the best means of erosion control and ecologically sustained production.

Many land capability classification systems are used for land evaluation in the Philippines. The Bureau of Soils and the Bureau of Forest

Development use systems that are basically adaptations of that developed by the U.S. Department of Agriculture Soil Conservation Service (SCS). The National Irrigation Administration (NIA) employs a modified version of the U.S. Bureau of Reclamation classification system, a system that was developed primarily for assessing the suitability of lands for irrigation.

The Bureau of Soils land-suitability classification system divides lands into nine capability classes. Each class is subdivided into sub-classes on the basis of the extent and degree of use limitations, with emphasis on erosion risk, slope, drainage condition and soil depth. Under this classification scheme, only four general land classes are considered suitable for arable farming (Classes A, B, C and D). The primary criterion used for suitability is slope. Class D lands with 15-25 percent slopes are restricted to pastures and industrial tree farms.

All lands having more than 25 percent slope are classified as unfit for cultivation. Two land classes (L and M) are classified as suitable only for pastures and industrial tree plantations. These are the level swampy or stony areas and those that have from 25-40 percent slope. The rest of the land classes (N, X, Y) are restricted to forest or wildlife lands by virtue of their having over 80 percent slopes or wet most of the time (swamps and marshes).

In conservation planning, the primary purpose of land classification is to provide base line information regarding limitations on land use as well as guidelines on proper use and conservation and management practices. The Bureau of Soils land classification system does not give clear guidelines but rather vague, general land use recommendations and their management requirements, which do not directly relate to the erosion processes and subprocesses at work or to working mechanics of soil conservation measures. The system as such does not provide a base for decisionmaking for differential effectivities of various erosion control measures, modification of erosion control measures and adoption of new technologies. Its qualitative and subjective assessment of erosion risks could restrict the use of land resources for utilization objectives for which they are suited.

A Proposed Land Classification System

To be very useful and flexible, a land suitability classification for conservation planning must provide a data base for quantifying erosion rates and soil productivity levels under varying conditions of slope, climate, soil physical and chemical properties, land use and cover management conditions. This implies collection and/or mapping of information relating to process or parameters that influence soil erosion, sediment transport and soil productivity status.

The processes or parameters relevant to soil loss estimation include slope, rainfall erodibility, soil erosivity, land use and cover management conditions. Those for soil productivity are many and varied. Among others; these include soil depth, water holding capacity, drainage conditions, soil structure and porosity, organic matter content, levels of major and trace elements, rate of soil regeneration or formation, soil water-air movement parameters and soil toxicity levels. Many of these are dynamic properties, but their range of fluctuation can be predicted from theoretical or empirical information.

The proposed land classification scheme should guide alternative location-specific decisions on erosion rates and soil productivity levels for varying conditions of land use, cropping systems, management practices and agricultural production technologies given certain physical constraints (e.g., soil texture, slope and rainfall patterns) that are expensive or difficult to modify. This again implies location-specific basic information.

In the case of soil erosion rates, the basic information includes slope, rainfall erodibility value, particle size distribution, soil organic matter content, pH and existing land use (those relating to fix land use fixtures such as built-up areas, cemeteries, roads and of special historical interests). From this information the soil erosion rates may be estimated under varying land use trends, cover conditions and conservation and management practices using empirical equations such as the modified USLE.

The essential features of the proposed land classification scheme may be briefly enumerated as follows:

(1) Collection of basic location-specific information on the processes and parameters known to influence soil erosion and soil productivity. The mappable properties should be mapped preferably on a 1:25,000 scale.

(2) Compilation of available information or maps on soil erosion and soil productivity levels.

(3) Superimposition of base maps weighted on the basis of the information in item (2) to produce alternative decisions or decision maps erosion hazards, erosion rates and land suitability for various utilization objectives. These should include management guidelines for the various land-use alternatives.

The data and data handling requirements of such a land classification scheme seem to be insurmountable at first glance. Considerable groundwork aimed at operationalizing such a scheme has, however, been carried out by the author and his colleagues at the College of Engineering and Agro-Industrial Technology at UPLB. These include the following: (a) a data bank on rainfall in the Philippines; (b) a computerized Resource Mapping System (RMS) for resource inventory and location mapping on a grid basis; (c) computerized hydrometeorology packages for climatological and hydrologic data analyses and (d) a computerized land use decision mapping system that produces decision maps by computerized overlaying, on a grid to grid basis, base maps weighted according to their relevance to the desired land use decision. The RMS package features various interpolations schemes and produces base maps of interpolated values on a grid basis from irregularly-spaced data point inputs.

A Proposed Land Use Planning and Allocation Scheme

It is suggested that the problem of efficient use and utilization of limited land resources to meet desired objectives be resolved through programming models. Figure 1 presents the framework of land use allocation models compatible and complementary to the proposed land classification scheme.

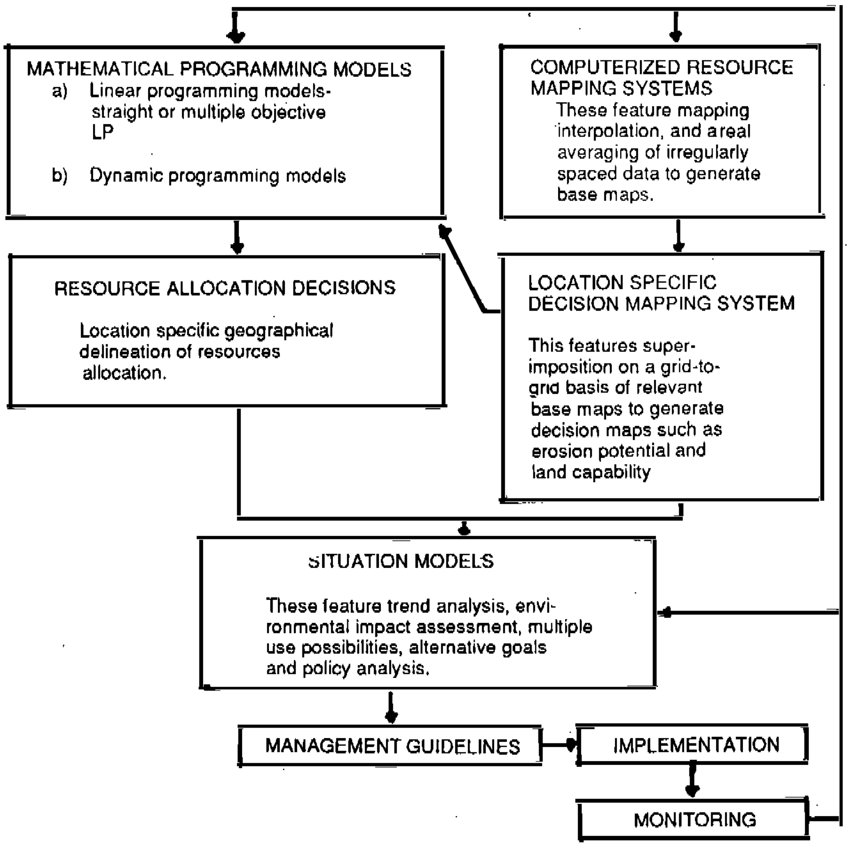


Figure 1
CONCEPTUAL FRAMEWORK OF THE PROPOSED LAND CLASSIFICATION AND LAND USE ALLOCATION SCHEME

The scheme generates land use allocation and land use management guidelines. Non-mappable and dynamic parameters such as socio-economic factors are best considered in the programming model. The programming model may take the form either of linear or dynamic programming models. These allow for multi-objective or multipurpose allocation or planning. The outputs of the programming models are gross areal allocations given certain objectives and constraints. This limits the number of decision variables for feasibility of solutions. Location-specific allocation is carried out through the use of RMS and decision mapping systems. For flexibility in upgrading management guidelines and for the purpose of predicting the impacts of future changes in policies and management technologies, a long term goal of using descriptive models is suggested.

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