CHARACTERISTICS AND ECOLOGICAL QUALITIES OF SOILS IN A DEGRADED UPLAND IN NEGROS ORIENTAL

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ABSTRACT

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Degraded uplands are widespread in the country but only limited information is available about this type of ecosystem. In view of this, a study was conducted to evaluate the characteristics and ecological qualities of soils in a degraded upland area in Manjuyod, Negros Oriental. Results indicated that the soils have generally poor characteristics and ecological qualities. This can be attributed to pedologic factors such as poor soil development and steep slopes as well as anthropogenic effects particularly cultivation and inappropriate land use systems. It appears that the degradation of the upland area is closely related to the impaired ecological functions of the soil. On-site and off-site ecological impacts of soil degradation occur primarily due to severe erosion and sedimentation.

KEYWORDS: Catena. Degraded upland. Ecological impact. Ecological soil qualities. Soil characteristics.

INTRODUCTION

Land degradation is one of the major ecological problems in the Philippines today. Degraded uplands may total to 10 million hectares or one-third of the country's land area (Sajise, 1986; David, 1988). Inappropriate land use systems which replace the forest are widely considered as the primary factor enhancing land degradation. The United Nations Economic Commission for Asia and the Pacific (1986) reported, for instance, that permanent cultivation of annual crops in upland areas has resulted in a significant increase in barren wastelands in the country. Moreover, the fragile nature of many upland soils and the high rainfall undoubtedly contribute to the widespread land degradation.

The ecological impact of land degradation is basically due to the impaired functions of the soil to support biomass production, regulate water balance in the ecosystem, support the activity of the soil fauna and act as filter and buffer system. Until now, very little is known about the ecological characteristics of degraded uplands in the country. Blum (1983) pointed out that lack of understanding about the ecological relationships in the ecosystem results in trial and error method of land use, leading to soil degradation and other ecological problems. This paper discusses the results of a study which evaluated the characteristics and ecological qualities of soils in a degraded upland area and thus hopes to contribute to the understanding of this type of ecosystem in the country.

METHODOLOGY

Study area

The study was conducted in Candabong watershed in Manjuyod, Negros Oriental. The native vegetation was dipterocarp forest which was replaced by agricultural land use systems in the 1960s. The watershed, which has an area of about 200 hectares, shows indications of land degradation such as dominance of grasses, particularly *Imperata cylindrica* occurrence of erosion and sedimentation, poor crop yield and others. The area has distinct dry and wet seasons. The average annual rainfall and the average temperature are 2,200 mm and 25°C, respectively. The geology of the watershed is characterized by the dominance of volcanics such as basalt and andesite in association with sedimentary rocks particularly limestone, siltstone and conglomerate. A wide undulating plateau terminated by east-facing steep slopes ranging in elevation from 420 to 600 m ASL characterizes the geomorphology of the area.

Field studies, soil sampling and laboratory analyses

A detailed field study was done involving the evaluation of site parameters such as parent material, physiography, land use and vegetation, erosion as well as morpho-physical soil characteristics. The latter were determined on pits measuring 1.5 x 1.0 m dug in each identified soil following the international standard procedure (FAO, 1977). Soil samples were collected from the major horizons for laboratory analysis. These were air-dried, sieved to pass 2 mm (after separating stone fragments) and stored in labeled containers. Soil pH was determined potentiometrically using a soil:water ratio of 1:2.5 (Schlichting and Blume, 1966), organic matter (OM) by Walkley-Black method (ISRIC, 1986), available phosphorus (P) by Olsen method (ISRIC, 1986), exchangeable potassium (K), calcium (Ca) and magnesium (Mg) by ammonium acetate (pH 7.0) extraction, followed by determination in atomic absorption spectrophotometer (Black, 1965), exchangeable aluminum (Al) by the potassium chloride method of Thomas (1982), and cation exchange capacity (CEC) by the ammonium acetate method at pH 7.0 of Black (1965). Bulk density was measured using the core method of Schlichting and Blume (1966).

Evaluation of ecological soil qualities

This was done using the method established by Schlichting and Blume (1966). The method uses measurable soil parameters such as texture, bulk density, CEC, OM, pH and others, to evaluate soil qualities such as rooting depth, rootability, air capacity, water availability, nutrient availability and erodibility. The soil receives a certain score for each quality which is then compared with a given set of criteria to obtain the rating (Table 1). Details and application of the method can also be found in Stahr (1979) and Jahn (1991).

RESULTS AND DISCUSSION

Soil characteristics and development

Fig. 1 shows the catenary relationship of the soils in the study area as well as their site characteristics. Since the area is located in a small watershed, it can be safely assumed that the soils have developed under the same climate and natural vegetation. Thus, variations in the soils can largely be the function of parent material and relief. The latter can best be understood using the catena concept, defined by Milne (1935) as a sequence of different soils linked by topography.

Tables 2 and 3 show the chemical and morpho-physical characteristics of the soils. The soil in the footslope position (S1) is a moderately developed, medium textured and slightly acidic soil. Despite the fact that the gentle slope is theoretically favorable for soil development, its physiographic position is depositional in nature which relatively retards horizon differentiation. Although basalt and andesite are the parent material of this soil, the

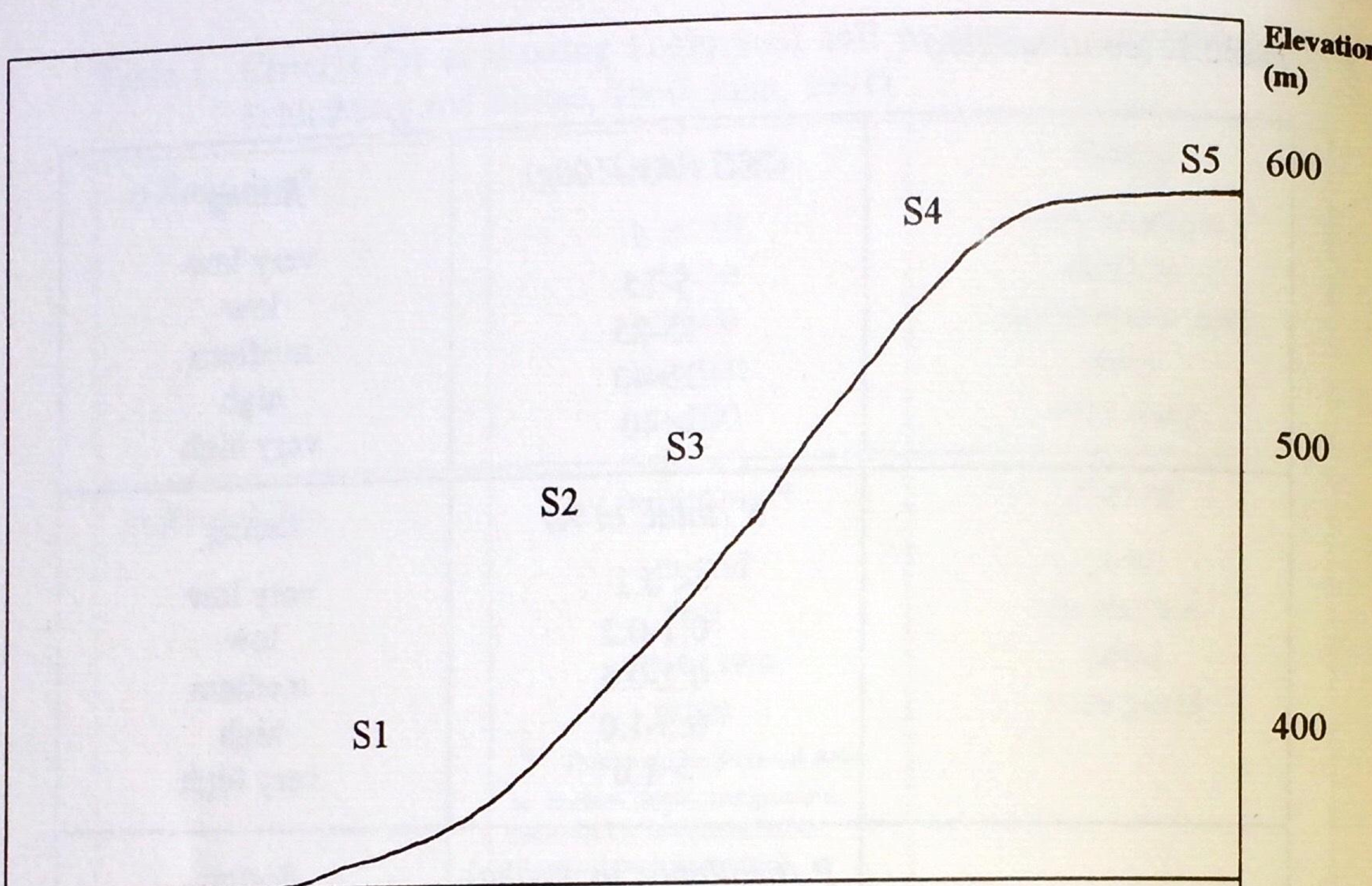
Table 1. Criteria for evaluating ecological soil properties (modified from Schlichting and Blume, 1966; Jahn, 1991).

a) Root depth	*Depth (cm)*	*Rating*
	< 15	very shallow
	15-30	shallow
	30-60	moderately deep
	60-100	deep
	> 100	very deep
b) Rootability	*Limitations**	*Rating*
	several	poor
	few	moderate
	one or two	good
	none	very good
	* This could be physical such as shallow depth, compaction, unfavorable structure, etc. or chemical such as nutrient deficiency and toxicity, etc.	
c) Air capacity	*Air volume (%)**	*Rating*
	< 3	very low
	3-7	low
	7-12	moderate
	12-18	high very high
	* based on bulk density and texture	
d) Water availability	*Volume of water (L/m³)*	*Rating*
	< 50	very low
	50-90	low
	90-140	moderate
	140-200	high
	> 200	very high
e) Nutrient availability	*OM (%)*	*Rating*
	< 2	very low
	2-4	low
	4-10	medium
	10-20	high
	> 20	very high

Table 1. *(continuation)*

	CEC (m.e./100g)	*Rating*
	< 5	very low
	5-15	low
	15-25	medium
	25-40	high
	> 40	very high
	N (total, in %)	*Rating*
	< 0.1	very low
	0.1-0.2	low
	0.2-0.5	medium
	0.5-1.0	high
	> 1.0	very high
	P (available, in mg/kg)	*Rating*
	< 5	very low
	5-10	low
	10-15	medium
	> 15	high
	K (exchangeable, in m.e./100g)	*Rating*
	< 0.15	deficient
	0.15-0.30	marginal
	0.30-0.50	adequate
	> 0.50	rich
f) Erodibility	*Value*	*Rating*
	0-0.10	very low
	0.10-0.25	low
	0.25-0.50	moderate
	0.50-0.75	high
	0.75-0.80	very high

Note: Criteria for nutrient availability are based on Jahn (1991) and Landon (1991).



Site Characteristic	S1	S2	S3	S4	S5
Classification (Soil Taxon.)	Tropept	Troporthent	Troporthent	Tropept	Humult
Parent Material	basalt, andesite	conglomerate, siltstone	breccia, andesite	limestone	shale siltstone
Physiographic Position	footslope	backslope	backslope	shoulder	summit
Slope (%)	5-10	60-70	50-60	8-15	3-6
Land use	fallow, cultivated	fallow, cultivated	fallow, cultivated	fallow, cultivated	fallow, cultivated
Vegetation	grass, corn, coconut	grass, sugarcane	grass, trees, corn	grass, sugarcane	grass, sugarcane
Degree of Erosion	moderate	severe	severe	moderate	slight

Figure 1. The catenary relationship of soils (S1, S2, S3, S4 and S5) in the watershed and their site characteristics

Table 2. Chemical characteristics of the soils studied (major horizons only).

Soil	Horizon	Depth (cm)	pH	OM (%)	Nt (%)	P avail (mg/kg)	K	Mg	Ca	Al	CEC
							-------------(m.e./100g) ------------				
S1	Ap	0.12	5.3	1.7	0.09	2.8	0.3	52	25	1.5	18.5
	BC	12-25	5.4	1.3	0.07	5.9	0.2	29	25	0.8	20.0
S2	Ap	0-15	8.0	1.6	0.08	2.0	0.2	37	46	tr	10.0
	C	15 below	7.3	0.6	0.03	9.2	0.2	51	51	tr	6.0
S3	Ap	0-5	6.5	2.3	0.12	7.3	0.2	25	20	0.2	19.4
	AC	5-30	7.4	1.1	0.06	2.0	0.1	25	19	0.2	17.0
S4	Ap	0-15	7.6	2.9	0.14	2.5	0.1	46	47	tr	19.2
	BC	15-40	7.0	2.4	0.12	8.8	0.1	49	47	tr	10.5
S5	A	0-6	4.8	5.3	0.23	7.0	0.2	14	13	13	8.0
	Bt	6-30	4.6	1.8	0.09	1.4	0.1	6	3	17	7.8

Note:

OM = organic matter
Nt = total N
P avail = available P (Olsen)
K, Ca, Mg and Al = exchangeable
CEC = cation exchange capacity
tr = trace amount

Table 3. Morphological characteristics of the soils studied.

Soil	Horizon	Depth (cm)	Bulk Density (g/cm^3)	Color (Munsell clr. not'n)	Texture	Structure	Consistence	Pores	Roots	Rock Fragments
S1	Ap	0-12	1.2	10YR 4/6	CL	SBK	P,S	few fine	many fine	---
	BC	12-25	1.3	10YR 6/4	SiC	SBK	P,S	few fine	few fine	many
	C	below 25	---	10YR 6/4	SiC	SBK	P,S	very few fine		very high
S2	Ap	0-15	1.2	10YR 4/3	SiCL	Gr.	slightly P, slightly S,	few fine	few fine	few
	C	below 15	---	10YR 4/2	SiCL	SBK	slightly P, slightly S,	---	---	very high
S3	Ap	0-5	1.3	10YR 3/2	SiC	Gr.	slightly P,S	few fine	many fine	few
	AC	5-30	1.4	10YR 4/6	SiC	SBK	P,S	few fine	few fine	many
	C	below 30	---	---	---	---	---	---	---	very high
S4	Ap	0-15	1.2	10YR 4/4	SiC	Gr.	P,S	many fine	many fine	---
	BC	15-40	1.3	5YR 4/3	C	SBK	P,S	few fine	few	many
S5	A	0-6	1.1	5YR 4/4	SiC	Gr.	slightly P,S	many fine	---	---
	Bt1	6-30	1.3	2.5YR 5/8	C	SBK	P,S	few fine	---	---
	Bt2	30-80	---	2.5YR 6/8	C	SBK	P,S	---	few	few

Texture: CL = clay loam; SiL = silty clay; SiCL = silty clay loam; C = clay

Structure: SBK = subangular blocky; Gr = granular

Consistence: P = plastic; S = sticky

(---) indicates no valid data

contribution of the other parent materials in the upper slope are believed to be significant as indicated, for instance, by the presence of siltstone fragments in the soil profile. The soils in the backslope position (S2 and S3) have developed from different parent materials which partly explains their differences in texture, pH and exchangeable Ca and Mg contents. Both are poorly developed owing to the steepness of their location which enhances soil erosion and consequently slows down soil formation. Despite the fact that surface runoff is maximal in the shoulder position (Hall, 1983), the soil here (S4) is more developed compared with those in the backslope position (S2 and S3). This can be explained by lesser soil disturbance (less intensive cultivation) in the shoulder position than in the backslope. The easy weatherability of the limestone parent material may have also contributed to this. The high pH and fine texture of the soils are typical soils developed from limestone. The soil in the plateau or summit (S5) is the most well-developed member of the catena due to less erosion and easy weatherability of the siltstone and shale parent materials. It is deep as a result of vertical water movement which is generally greater in the summit than in the other landscape positions (Hall, 1983). The intensive weathering also explains the red color, high clay accumulation in the subsoil (Bt horizon), and the acidic soil reaction.

It has been reported that man's modification of the soil-climate-vegetation ecological system could have either positive or negative impact on the soil (Jung, 1976). In the study area, the change in land use as well as soil disturbance due to cultivation have enhanced soil erosion and decomposition of OM resulting in the generally low OM contents of the soils. Consequently, N content is generally low and the soils show significant degree of compaction particularly in their subsoils as indicated by bulk density values of 1.3 to 1.4 g/cm^3. Landon (1991) indicated that, for clayey tropical soils, a bulk density of 1.3 g/cm^3 already shows compaction problem. This is related to the results of Ohta et al. (1992) which showed that undisturbed red soils under dipterocarp forest in Kalimantan, Indonesia, have bulk density values ranging from about 0.8 to 1.2 g/cm^3. Although no clay mineral data are available, it could be inferred that the type of clay minerals as well as the low OM content are important reasons for the low CEC of the soils.

Ecological soil qualities

Ecological soil qualities are complex parameters derived from measurable soil properties. These basically include rooting depth; rootability; air and water capacity; nutrient budget; and erodibility (Schlichting and Blume, 1966). These qualities are more meaningful than individual soil properties when assessing the soil as an integral part of the ecosystem. The ecological qualities of the soils evaluated are presented in Tables 4 and 5.

Table 4. Ecological qualities of the soils in the degraded upland of Manjuyod, Negros Oriental.

Soil	Rooting Depth (cm)	Rootability	Air Capacity	Water Availability	Nutrient Availability	Erodibility
S1	shallow	poor	moderate	very low	low	low
S2	shallow	poor	moderate	very low	low	high
S3	shallow	poor	moderate	low	low	high
S4	moderately deep	moderate	moderate	low	low	high
S5	deep	poor	moderate	moderate	medium to low	moderate

Table 5. Rating of nutrient status of the soils studied.

Soil	Reaction	OM	N	P	K	CEC
S1	slightly acidic	very low	low	low	marginal	medium
S2	basic	very low	very low	low	marginal	low
S3	slightly basic	low	low	low	marginal	medium
S4	slightly basic	low	low	low	deficient	medium
S5	acidic	medium	low to medium	low	deficient	low

Rooting depth is the potential amount of available space for the root system of the plant. The results show that only the soil in the summit position (S5) is deep enough to provide anchorage to most plants. The other soils are limited by shallow solum explained earlier as pedologic. Rootability which indicates the ease or difficulty with which roots penetrate the soil, is favorable only in S4. The others are limited by shallow depth, abundance of stones, compact subsoil and chemical limitations such as Al toxicity and N, P and K deficiencies. Air capacity which relates to oxygen availability is generally favorable in all soils. On the contrary, water availability is very limited in the soils (except S5) as a result of shallow solum, abundance of stones, compact subsoil and steep slopes. This soil quality is, however, modified by the climate in the area. This means that moisture stress is expected only during the dry season but not during the rainy season due to the high amount of rainfall. In fact, the high rainfall is a major contributor to the severe soil erosion. Sajise (1986) reported that marginal upland areas have excess water during the wet season and little or no water during the dry season. In terms of nutrient availability, all soils in the study area have low availability of N, P and K. This agrees with the general observation that N and P problems are common to upland soils making them a constraint in vegetation establishment for crop production (Sajise, 1986). Erodibility represents the K parameter in the Universal Soil Loss Equation (Wischmeier and Smith, 1960) and it indicates the susceptibility of soil to erosion. Except S1 and to some extent S5, the soils in the area are highly susceptible to erosion. This is exacerbated by the steep slopes of their position in the catena which also enhance faster surface runoff. Actual observations of soil erosion in the field confirm this. For instance, rills are easily formed during heavy rainfall events in cultivated fields resulting in sediment accumulation in the lower slopes as well as in the streams draining the watershed. Moreover, soil erosion measurements in the backslope (S2 and S3) revealed rates of 180 t/ha/yr and 210 t/ha/yr under sugarcane and corn, respectively. Likewise, some portions of the watershed which appear reddish (hematitic) are actually severely eroded areas whose reddish subsoil are already exposed due to erosion of the dark A horizon. This supports the findings that the effect of rain on surface erosion is aggravated by the absence of natural vegetation, steep slopes and shallow and highly erodible soils whose low permeability contributes to rapid surface runoff (DuBois, 1990).

Ecological implications

The study has shown that the degraded nature of soils in the watershed is attributable to both pedologic and anthropogenic factors. Soil formation was slow in most soils resulting in rapid degradation once the ecological system was disturbed through the removal of the natural vegetation and its replacement with inappropriate land use systems. This supports the idea that land degradation also depends upon the characteristics of soils (Schlichting, 1986).

The degraded nature of the upland area studied is mirrored in the poor ratings of the soils' ecological qualities. The results are low yield of agricultural crops and income of farmers, lack of drinking water during the dry season, and severe soil erosion and stream sedimentation during the rainy season. Sajise (1986) reported that the low productivity and instability of the upland resource base are reflected not only in the poor economic status of the uplanders, but also in the lives of adjacent lowland communities affected by floods, drought and siltation. For instance, one major factor which contributed to the Ormoc flood in 1991 was the degraded nature of soils and the inappropriate land use system in the watershed above the city (Eller and Asio, 1991). Likewise, DuBois (1990) in his study in Sequijor, concluded that the negative impact associated with poor upland land use practice in combination with the watershed's biophysical processes can affect coastal land and water uses.

CONCLUSIONS AND RECOMMENDATION

The poor characteristics and ecological qualities of the soils in the upland area studied are attributable to pedologic (poor soil development, steep and unstable slopes) and anthropogenic (inappropriate land use systems and cultivation) effects. They also explain the degraded nature of the upland area. On-site and off-site ecological impacts are readily observable primarily due to severe erosion and sedimentation. The socio-economic impact is recommended to be studied.

To minimize the negative ecological impact of the degraded watershed, focus should be on improving the physical, chemical and biological characteristics of the soils through OM management, minimizing surface run-off through the establishment of vegetation cover and minimal soil disturbance particularly in the backslope and shoulder positions. Agroforestry could be an effective strategy for the rehabilitation of the watershed.

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