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SITE QUALITIY EVALUATION OF SOILS IN DEGRADED UPLANDS OF INOPACAN, LEYTE AND STA. RITA, SAMAR

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Abstract

Marginal lands have received wide attention for their potential role in food production and environmental rehabilitation. Hence, this study aimed to evaluate the ecological qualities of the two degraded upland soils in Inopacan, Leyte and Sta. Rita, Samar. Site properties were evaluated quantitatively in terms of rootability, availability of air, water and nutrients, as well as nutrient reserves. Results showed that both soils have shallow to moderate rooting deep, poor to moderate rootability, low to high air capacity and moderate to high available water supply to the plants. Moreover, both soils obtained higher nutrient reserves for cation exchange and the limiting factor for plant nutrition is given by the very low amount of nitrogen supply.

Keywords: *degraded soil, uplands, site quality evaluation*

INTRODUCTION

Protection of the natural ecosystems is one of the present ecological problems. Previously, the concept of land degradation has evolved over the past decades. From 1980's at present, the emphasis was more on soil degradation, in particular on erosion, but this has shifted towards a broader view of a decline in the quality of the land, and lately of the decreased capacity of the land to deliver "Ecosystems Goods and Services". More importantly, several concerns have been frequently raised regarding the impacts of marginal land use on environment, ecosystem services and sustainability. The agro-ecological conditions in these areas are typically not suited to intensive production systems due to low-quality soils, hilly slopes, limited access to inputs or markets and extremely diverse and site specific conditions (Asio et al., 2009; Tyler, 2004).

Hence, the marginal land concept has evolved to meet multiple management goals and to incorporate the trade-offs of environmental protection, preservation of ecosystem services and long-term sustainability. Moreover, to sustain crop production, marginal lands within the framework of land quality assessment program have become a major management target in countries with food shortages (FAO, 1993). Several studies have also suggested that enhancing food production will require the conversion of marginal lands to appropriate cropland management systems as well as restoration of degraded lands and ecosystems (Lal, 2004; Bigges, 2007).

Furthermore, one example that should be done for a specific purpose is the evaluation for the suitability of a particular site for agricultural use through Ecological Land Evaluation.

Accordingly, site qualities in general are very complex collections of observable and measurable characteristics that have to be appraised for specific land uses (FAO, 1976). In appraising site qualities, several soil properties must be summarized in terms of rooting depth, rootability, moisture content, air capacity and nutrient availability (Schlichting et al., 1995), including knowledge about the geomorphological and pedological history of the landscape. Also, these can be evaluated from soil characteristics by giving a qualitative ratings based on a given set of quantitative criteria related to the plant requirements, site stability and elasticity.

Soil management strategies is site location specific and knowledge of the extent, and quality of marginal lands as well as their assessment and management are limited and diverse. This suggests that every degraded soil has to be evaluated in terms of its properties and constraints. Furthermore, detailed information about the elasticity and stability of a particular site under specific use are needed in order to establish a sustainable land use management in diminishing the negative ecological impact of soil degradation. With the aim of ecological land evaluation, a large number of site characteristics should be summarized in terms of possible rooting depth and rootability as well as water, air energy and nutrient budgets (Schlichting et al., 1995).

MATERIALS AND METHOD

A. Site Description

The study was conducted in the degraded upland soils of Inopacan, Leyte (left) and Sta. Rita, Samar (right) as shown in figure 1. The first site (Inopacan) is located in the south western part of the island which is considered as a 5th district and the fourth income class municipality in the province of Leyte which marks the boundary between the town of Hindang in south and Camotes Sea in the west.

Figure 1.Photos showing the degraded uplands in Inopacan, Leyte (left) and Sta. Rita, Samar (right)

On the other hand, the second site (Sta. Rita) is located in the south western part of the island which is considered also as a fourth income class municipality in the province of Samar. Both sites are known to have a wide range of degraded or marginal uplands that are utilized for any agricultural activities which are elevated with a local relief of about greater than to 300 m above sea level (ASL) or more and subjected to massive soil degradation.

B. Soil Profile Characterization

In each selected site, a pit measuring approximately 1 m x 1 m and having a depth of at least 1 m was excavated manually in each site prior to soil profile description and sampling. Soil profile descriptions were done following the standard procedure of FAO

Guidelines for Soil profile Description (2006). Soil profile in each site was subjected to detailed field and laboratory studies to evaluate their characteristics and constraints. Soil samples were collected from each horizon of every soil profile quantitatively by taking three (3) continuous and uniform slices from the uppermost horizon down to the lowest and mixed thoroughly, which is based on the procedure of Schlichting et al. (1995). Wider soil slice was collected in thin horizons to ensure that the volume of the sample is approximately equal to those from the thicker horizons. All soil samples were placed in properly labeled plastic bags. Collection also of undisturbed soil samples was done for bulk density determination and immediately brought to the screen house of the Department of Soil Science, VSU, Visca, Baybay City, Leyte for processing and evaluation.

All soil samples were air-dried, pulverized using a wooden mallet, and sieved using a 2-mm wire mesh to get the fine earth for the determination of most soils physical and chemical properties used for soils quality evaluation.

C. Ecological Evaluation

The ecological evaluation of the marginal uplands soils was done following the procedure of Schlichting et al. (1995). The following ecological qualities were evaluated:

C.1. Rooting depth/physiological depth (cm)

This was estimated based on the depth to which the plant roots under a given condition potentially penetrate and are able to develop or spread and rated using the following effective soil depth classes.

Table 1. Evaluation rating for rooting depth or physiological depth

Depth (cm)	<10	30	50	100	150	200	
Rating:	Extremely shallow	Very shallow	Shallow	Moderate deep	Deep	Very Deep	Extremely deep

C.2. Rootability

This was evaluated and quantitatively estimated from within the physiological depth. The following levels of rootability were used:

Table 2. Evaluation rating for rootability

Rating:	Limitations:
Very good	no limitation, favorable sructure,none or very low content of coarse fragments (classes N & V), very low bulk density (class BDI)
Good	low contents of coarse fragments (class F and C) and moderate bulk density (class BD2)
Moderate	unfavourable sructure (coarse prismatic,coarse blocky) or moderate content of coarse fragments (class M),moderate and high bulk density (class BD3 & BD4)
Poor	several or strong limitations are very unfavourable structure(platy,very coarse prismatic,very coarse blocky),high or very high content of coarse fragments(class A & D)very high bulk density(class BD5),compacted and cemented horizons.

C.3. Pore Sizes and Water Budget

These were obtained based on texture and bulk density. Since organic matter and bulk density also greatly influenced pore size distribution, the values are either added or deducted depending on the levels of organic matter. Moreover, the values in % volume can be adjusted for the gravel and stone free soil by multiplying with the factor: (100-% volume of coarse fragments)/100

The following ratings were used:

Table 3.Evaluation rating for Total Pore Volume (TPV)

TPV(% volume)	<30	40	50	60<	
Ratings:	Very low	Low	Moderate	High	Very high

Table 4.Evaluation for Air Capacity (AC)

AC(% volume)	<2	4	12	20<	
Rating:	Very low	Low	Moderate	High	Very high

Table 5. Evaluation for Field Capacity (FC)

FC(Ltr./m² . 1m	<130	260	390	520<	
Rating:	Very low	Low	Moderate	High	Very high

Table 6. Evaluation of Available Field Capacity (aFC)

aFC (Ltr./m². ERS)	<50	90	140	200<	
Rating:	Very low	Low	Moderate	High	Very high

C.4. Saturated Hydraulic Conductivity (K_{sat})

This was roughly estimated from the texture and bulk density using the Table below:

Table 7. Textural classes and corresponding amount of hydraulic conductivity by bulk density

Textural class	Saturated hydraulic conductivity (cm d^{-1}) at bulk density of		
	<1.45	(kg/dm^3)	1.65>
CS, MS	<300	<300	100-300
FS, LS	100-300	40-100	10-40
SL<$10_{\%clay}$	40-100	10-40	1-10
SL>$10_{\%clay}$	100-300	40-100	1-40
L	100-300	10-100	<1-10
Other classes	40-300	10-40	<1-10

Table 8.Evaluation rating for saturated water conductivity

K_{sat} (cm d- 1)	<1	10	40	100	300<	
Rating:	very low	low	moderate	high	very high	exceptionally high

C.5. Nutrient Status

Effective Cation Exchange Capacity

The amount of Effective CEC was estimated based on the soil texture in the Table below:

Table 9.Textural table with corresponding values of Effective Cation Exchange Capacity

Textural class	Cation Exchange Capacity ($cmol_c\ kg^{-1}$)
CS	1
MS, FS	2
LS	3
$SL_{<10\%clay}$	4
$SL_{<10\%clay}$	6

$Sil_{<10\%clay}$	8
Si	10
L, $SiL_{>10\%clay}$	12
SCL	15
CL	18
SiCL, SC	20
C	27
HC	35

Table 10. Evaluation rating for Effective Cation Exchange Capacity

CEC ($cmol_c\ kg^{-1}$)	<5	10	20	40	80<	
Rating:	Very low	Low	Moderate	Moderately high	High	Very high

Saturation value and Base saturation

The S value was calculated friom CEC*BS/100
The recalculation of S values from $cmol_c\ kg^{-1}$ (unit mass) to $cmol_c\ dm^{-3}$ (unit of volume) was done by multiplying the S valuewith the amount of bulk density.
By multiplying the S value with the horizon thickness (dm) results in S value expressed in $mol_c\ m^{-2}$*horizon depth
By summing up the values for the individual horizons within the effective rooting space, results in S value in $mol_c\ m^{-2}$*depth

Table 11. Evaluation rating for S value

S value(mol/m². ERS)	<1	10	50	200<	
Rating:	very low	low	moderate	high	very high

C.6 Nutrient stocks

Organic Matter

Amount of humus was calculated based on the formula:

Humus (kg m^{-2}*We) = humus content (%)*bulk density (kg dm^{-3})*(100-% stone)/100*horizon thickness (dm)

Nitrogen Supply

The nitrogen stock and the easily mineralizable nitrogen was estimated from the organic matter content (C/N relationship)

Table 12.Estimation of Nitrogen Stock (N_t) and Available Nitrogen (N_a)

For mull, N_t (kg m^{-2}) = humus (kg m^{-2})	* 0.05, and Na (g m^{-2}) = humus (kg m^{-2})	* 0.25
For moder	* 0.025	* 0.08
For rohhumus,	* 0.015	* 0.03

RESULTS AND DISCUSSION

Site Qualities of Degraded Upland Soils

The summary of ecological qualities of the degraded upland soils of Inopacan, Leyte and Sta. Rita, Samar is given in Table 13 and 14. Results showed that the rooting deep which is the potential amount of available space for root under a given condition penetrate and spread, is moderately deep in all soils in Inopacan (Profiles 1, 2, 3, 4 and 5) and is shallow in Sta. Rita soils (Profiles 1, 2,3 and 4). However, there were variations in rooting depth among soils, as affected by the position of the soils in the landscape. Based on the soils rootability, results showed that root penetration varied with depth depending upon the bulk density, soil porosity, aggregate stability and percent rock fragments. The rootability of Inopacan soils have a moderate rating except Profile 2 which is poor. This is because of the soils higher bulk density and lower porosity and low organic matter content. Soils compaction affects the way plant roots penetrate into the soil system.

A range of poor to moderate rooting ability also is exhibited by the soils in Sta. Rita. In similar way, the area is characterized with a clay rich soil and higher bulk density due to long term-cultivation history. In this connection, bulk density is an index of compaction and porosity and directly affects root development and gas movement in the soil (FAO, 2006). Moreover, the soils erodibility in both sites indicated their very low to low prone to soil erosion. The relatively low values for the erodibility factor can be due to the very high clay content of both degraded soils. A slight variation was observed in terms of erodibility due to soils different physiographic positions, those found in the strongly sloping gradient have the higher tendency for soil erosion.

Furthermore, the results indicated that the air capacity and drainage of all soils in both sites have low to high rating. This implies that the available air for biological activity will depend upon the soil condition and properties such as texture, bulk density, porosity and moisture content. For instance, low bulk density indicates high porosity and accordingly, excellent gas exchange between the roots and atmosphere. The profile 2 in Sta. Rita soil indicated a low drainage and air capacity because of its aquic soil moisture regime which is saturated with water therefore giving anaerobic condition. With regard to water and available water capacity, the rating in both sites ranges from low to high in all soil profiles. This explains that both soils have the capabality to provide available water for plant absorption especially during drought. In relation to water movement, as can be seen, results provided additional information about water availability such as giving a moderate to higher rating of water conductivity was obtained by all soils in Inopacan and Sta. Rita (Table 13-16).

In terms of nutrient availability, moderate to high amount of nitrogen was obtained by the soils in Inopacan and appears low in Sta. Rita. Results revealed that nitrogen is a limiting nutrient in the degraded upland soil.

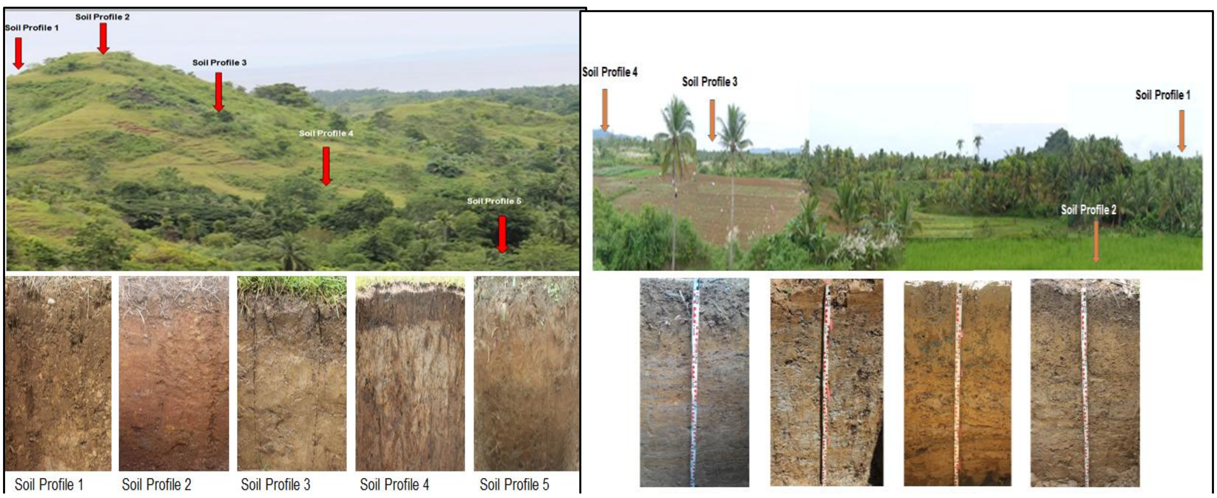

Figure 2. Location of the soil profiles investigated in the degraded uplands of Inopacan, Leyte (left) and Sta. Rita, Samar (right)

Table 13. Ecological qualities of degraded upland soils in Inopacan, Leyte

Soil Profile/ Horizon	Depth (cm)	Rooting Depth	Roota-bility	Soil Erodibilty	Total Porosity	Air Capacity	Water Capacity	Avail. Water Capacity	Water Conduc-tivity	Effective CEC	Organic Matter	Nitrogen Stock	S Value
Soil profile 1 (Upper backslope)													
Ah	0–20	MoD	Mo	VLo	VH	H	H	H	VH	Mo	Mo	H	H
Bw1	20–40	MoD	Mo	VLo	H	Lo	H	H	Mo	MoH	Lo	H	H
Bw2	40–60	MoD	Mo	VLo	Mo	Lo	H	H	Mo	MoH	Lo	H	H
BC1	60–72	MoD	Mo	VLo	Mo	Lo	H	H	Mo	MoH	Lo	H	H
BC2	72–100	MoD	Mo	VLo	Mo	Mo	H	H	Mo	Mo	Lo	H	H
Soil profile 2 (Summit)													
Ap	0–16	MoD	Po	VLo	H	Lo	H	Lo	Mo	MoH	Mo	H	H
BA	16–30	MoD	Po	VLo	H	Lo	H	Lo	Mo	MoH	Lo	H	H
Bt1	30–52	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	Lo	H	H
Bt2	52–75	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	Lo	H	H
BC	75-100	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	Lo	H	H
Soil profile 3 (Middle slope)													
Ap	0–27	MoD	Go	VLo	H	Lo	Mo	H	VH	MoH	VLo	Lo	H
BC1	27–50	MoD	Mo	VLo	Lo	Mo	Mo	H	H	Lo	VLo	Lo	H
BC2	50–77	MoD	Mo	VLo	Lo	H	Mo	H	H	VLo	VLo	Lo	H
BC3	77–100	MoD	Mo	VLo	Lo	H	Mo	H	H	VLo	VLo	Lo	H
Soil profile 4 (Lower backslope)													
Ap	0–15	MoD	Mo	VLo	H	Mo	H	H	VH	MoH	Mo	MoH	H
BC1	15–50	MoD	Mo	VLo	Mo	Mo	H	H	Mo	Mo	Mo	MoH	H
BC2	50–80	MoD	Mo	VLo	Mo	Mo	H	H	Mo	Mo	Lo	MoH	H
BC3	80–100	MoD	Mo	VLo	Mo	Mo	H	H	Mo	Mo	VLo	MoH	H
Soil profile 5 (Toeslope)													
Ap	0–15	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	Lo	Mo	H
AB	15–35	MoD	Mo	VLo	Mo	Lo	H	Lo	Mo	MoH	Lo	Mo	H
Bw1	35–55	MoD	Mo	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	Mo	H
Bw2	55–57	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	Mo	H
Bw3	75–100	MoD	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	Mo	H

MoD - Moderately Deep
Mo - Moderate
Lo - Low
VLo - Very Low
Po - Poor
VH - Very High
H - High
Go - Good
Mo - Moderately High

Table 14. Ecological qualities of degraded upland soils in Sta. Rita, Samar

Soil Profile/ Horizon	Depth (cm)	Rooting Depth	Roota-bility	Soil Erodibilty	Total Porosity	Air Capacity	Water Capacity	Avail. Water Capacity	Water Conduc-tivity	Effective CEC	Organic Matter	Nitrogen Stock	S Value
Soil profile 1 (Summit)													
Ah	0–15	Sh	Mo	VLo	VH	Lo	Mo	Lo	VH	MoH	VLo	VLo	Mo
Bt	15–30	Sh	Po	VLo	Mo	Lo	Mo	Lo	Mo	MoH	VLo	VLo	Mo
C1	30–50	Sh	Po	VLo	Mo	Lo	Mo	Lo	Mo	MoH	VLo	VLo	Mo
C2	50–70	Sh	Po	VLo	Mo	Lo	Mo	Lo	Mo	MoH	VLo	VLo	Mo
Soil profile 2 (Foot slope)													
Ap	0–15	Sh	Po	VLo	H	Lo	H	Lo	Mo	MoH	VLo	VLo	H
Bwg1	15–40	Sh	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	VLo	H
Bwg2	40–70	Sh	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	VLo	H
Bwg3	70-100	Sh	Po	VLo	Mo	Lo	H	Lo	Mo	MoH	VLo	VLo	H
Soil profile 3 (Summit)													
Ap	0–15	Sh	Mo	VLo	H	Mo	H	H	VH	Mo	VLo	VLo	VH
Bt	15–30	Sh	Mo	VLo	H	Mo	H	H	Mo	MoH	VLo	VLo	VH
CB	30–57	Sh	Mo	VLo	Mo	Mo	H	H	Mo	MoH	VLo	VLo	VH
C1	57–70	Sh	Mo	VLo	Mo	Mo	H	H	Mo	MoH	VLo	VLo	VH
C2	70-100	Sh	Mo	VLo	Mo	Mo	H	H	Mo	Mo	VLo	VLo	VH
Soil profile 4 Middle slope)													
Ah	0–15	Sh	Go	Lo	H	H	Mo	Mo	VH	Lo	VLo	VLo	Mo
Bt	15–30	Sh	Mo	Lo	Mo	Mo	Mo	Mo	VH	MoH	VLo	VLo	Mo
C1	30–50	Sh	Mo	Lo	Mo	Mo	Mo	Mo	VH	MoH	VLo	VLo	Mo
C2	50–70	Sh	Mo	Lo	Mo	Mo	Mo	Mo	VH	MoH	VLo	VLo	Mo

Sh - Shallow
Mo - Moderate
Lo - Low
VLo - Very Low
Po - Poor
VH - Very High
H - High

Go - Good
Mo - Moderately High

Table 15.Summary of the ecological qualities of degraded upland soils in Inopacan, Leyte

Soil Profile	1	2	3	4	5
Rooting Depth			---Moderate Deep---		
Rootability	Moderate	Poor	Moderate- good	Moderate	Poor-Moderate
Soil Erodibilty			--- Very Low---		
Total porosity	Moderate-Very high	Moderate-High	Low-High	Moderate-High	Moderate
Air capacity	Low-High	Low	Low-High	Moderate	
Water capacityHigh	High	Moderate	High	High	Low
Available water capacity	High	Low	High	High	Low
Saturated water conductivity	Moderate-Very High	Moderate	High-Very high	Moderate	Very High
Eff. CEC	Moderate- Moderately high	Very Low	Moderate	Moderately High	Moderately High
Organic Matter (kg m^2)			---Low---		
Nitrogen Stock	High	High	Low	Moderately high	Moderate
S value			---High---		

Table 16.Summary of the ecological qualities of degraded upland soils in Sta. Rita, Samar

Soil Profile	1	2	3	4
Rooting Depth			---Shallow---	
Rootability	Poor-Moderate	Poor	Moderate	Moderate-Good
Soil Erodibilty		--- Very Low---		
Total porosity	Moderate-Very High	Moderate-High	Moderate-High	Moderate-High
Air capacity	Low	Low	Moderate	Moderate-High
Water capacity	Moderate	High	High	Moderate
Available water capacity	Low	Low	High	Moderate
Saturate water conductivity	Moderate-Very high	Moderate	Moderate-Very high	Very high
Eff. CEC	Moderately High	Moderately high	Moderate-High	Low-Moderately high
Organic Matter (kg m2)		--- Very Low---		
Nitrogen Stock		---Very low---		
S value	Moderate	High	very High	Moderate

CONCLUSION

The study revealed that both degraded upland soils possess ecological qualities that limit use of the land for crop production. These include shallow rooting depth, poor to moderate rootability, generally low air capacity, low to moderate water availability, and deficient nutrients especially nitrogen and phosphorus supply.

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