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Characteristics of Soils in the Marginal Uplands of Inopacan, Leyte

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ABSTRACT

Improving the productivity of marginal lands greatly depends on good understanding of the characteristics of the soils. Published data on the nature and characteristics of soils in marginal uplands are still limited. This study was conducted to determine the morphological and physico-chemical characteristics of soils in the marginal upland of Inopacan, Leyte. Five representative soil profiles located in different physiographic positions were examined and sampled. Results showed that the soils were derived from volcanic materials particularly andesite and basalt rocks. Well-developed soils were found on the summit position with the horizon sequence of Ap-Bt-BC while poorly developed soils occurred on the lower slope positions having Ap-AB-Bw-BC horizon sequence. Soils were found to be highly acidic with soil pH close to 5.0. Soil organic matter, total nitrogen and available P were low and decrease with soil depth. Exchangeable bases (Ca, Mg, K and Na) were high in most soil profiles. The results indicate that N and P fertilization as well as organic matter addition are crucial to increasing the productivity of the marginal upland soils. The marginal nature of the soils is the result of decades of unsustainable cultivation practices.

Keywords: soil characterization, catena, marginal upland soils, soil degradation

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INTRODUCTION

Uplands are undulating and steep lands that range in elevation from near sea level to about 1,000 meters in elevation (Garrity *et al.*, 1993; Nelson, 1994; Asio, 2007). Marginal uplands are widespread in the Philippines as a result of soil degradation which in turn was brought about by decades of deforestation and forest conversion into agricultural lands. Thus, soil/land degradation is the major agricultural and environmental problem impacting food security in the Philippines (Asio *et al.*, 2009). Roa (2007) reported that the poorest farmers who are also the most vulnerable and most food insecure households, are living and farming on these marginal lands.

Marginal or degraded lands have very low productivity because of soil physical and chemical constraints like acidic or alkaline pH, low organic matter content, low nutrient status, high electrical conductivity, shallow soil, compaction, low rate of water infiltration, low water holding capacity, and unfavorable slopes (Nelson, 1994; Steiner, 1996; Asio, 2007). Asio et al. (2009) revealed that soil erosion is the most widespread process of soil degradation in the Philippines. Other important but less studied soil degradation processes include loss of nutrients and organic matter, salinization, acidification, pollution, compaction, and subsidence.

The success of any effort to improve the productivity of marginal lands greatly depends on the availability of information on the characteristics of each marginal soil. Moreover, data on soil formation is needed for the prediction and evaluation of the soil's response to intensive human activities and to climate change. Studies have shown that soils can change their properties and behavior significantly in response to climate change (Pregitzir, 1993). Until now very little published data are available on the characteristics and formation of marginal upland soils in the Philippines. Thus, there is an urgent need for detailed characterization studies of such soils to serve as basis for the formulation of appropriate and sustainable soil management strategies. This study which was a component of Project I (Soil and Environment Quality Enhancement of Marginal Upland) of the VSU PHERNET Program was conducted to evaluate the morphological, physical, chemical, and biological characteristics of marginal upland soils in Eastern Visayas.

MATERIALS AND METHODS

Study Area

The study was conducted in the marginal upland of Sitio Batuan, Linao, Inopacan, Leyte (Figures 1 and 2). Selected soil profiles at different positions from summit to toeslope along a catena were selected for detailed examination and sampling.

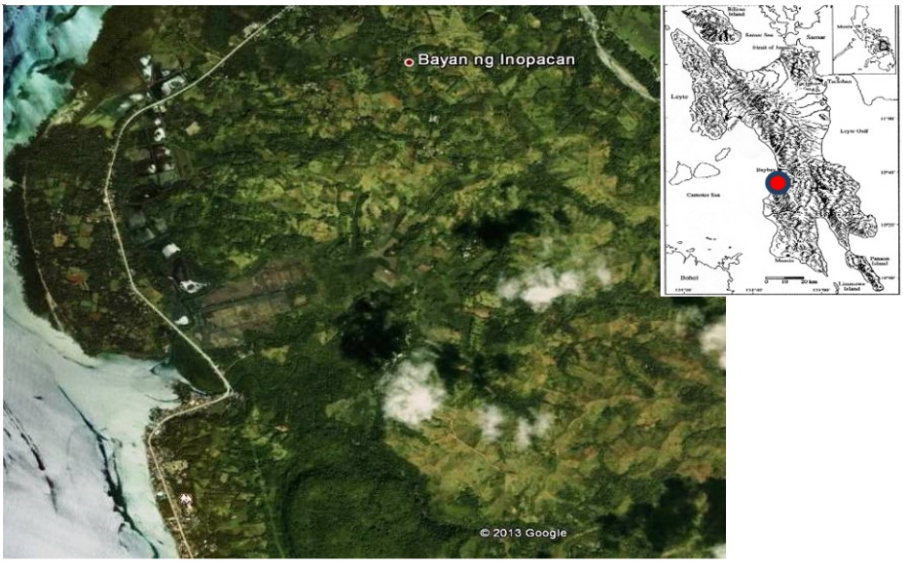

Figure 1. Location of the study area in SitioBatuan, Inopacan, Leyte

Soil Profile Characterization and Soil Sampling

A 1m x 1m pit with a depth of at least 1m was dug to examine the soil profile at different positions in the catena which was selected to cover different soils in the area (Figure 3). Five soil profiles were selected from summit to the toeslope position for soil characterization. Field information and soil characteristics were described using the standard procedure of FAO (2006) such as soil horizon, soil horizon depth, horizon boundaries, soil color, texture, structure, porosity, consistency, plasticity and stickiness, mottling, presence of coarse fragments and roots. Previous land use, dominant vegetation and soil parent material of the area were also

Figure 2. Photo of the marginal upland of Sitio Batuan, Inopacan, Leyte

gathered. Soil samples were collected right after the soil profile characterization. It was done by getting soil samples from every horizon following the quantitative sampling procedure of Schlichting *et al.* (1995). The samples were immediately processed in the screen-house of the Department of Agronomy and Soil Science, Visayas State University, Baybay City, Leyte.

Soil Analyses

Except for samples for bulk density determination, collected soil samples from the five soil profiles investigated were air-dried, quartered, pulverized and sieved using 2-mm (#10) and 0.45-mm (#40)wire mesh for physical and chemical analyses. Undisturbed soil samples were used for bulk density determination by paraffin clod method (Blake and Hartge, 1986). Soil porosity was calculated using the computed bulk density (BD) values and the constant particle density (PD) value of 2.65 g cm^{-3} using the formula:

$$\text{Porosity (\%)} = 1- (BD/PD) \times 100$$

Particle size distribution was determined by pipette method (ISRIC, 1995). Soil separates were completely dispersed using the ultrasonic disntegrator (Hielscher UP100H) with 1N sodium hexametaphosphate as dispersing agent. Soil pH was potentiometrically determined at 1:2.5 soil-waterratio(ISRIC, 1995). Total nitrogen was quantified by micro-kjeldahl method (Bremner and Mulvaney, 1982) and organic matter content was determined using the Walkley-Black method as described by Nelson and Sommers (1982). The available phosphorus was extracted using the Bray-2 method (ISRIC, 1995) and absorbance was read using spectrophotometer (Spectronic 20D$^+$). Exchangeable bases (K, Ca, Mg, and Na) were quantified using the atomic absorption spectrophotometer (Varian Spectra 220 FS).

RESULTS AND DISCUSSION

Site Characteristics

The Municipality of Inopacan lies between 10°28' and 10°33'10” latitude and 124°43'15” and 134°53'45” longitude. According to the Modified Coronas Climatic Classification, the municipality falls under the 4th type of climate which is characterized by rainfall that is more or less distributed throughout the year and the annual average rainfall is about 1,638 mm. The geology of the area could be described as dominated by mixed sediments and pyroclastics particularly basalt and andesite. The landform is predominantly rolling to steep volcanic hills. The area is degraded and only small patches are cultivated for crop production. The dominant vegetation consists of *Melastoma malabathricum* (Hantutuknaw), *Imperata cylindrica* (Cogon), *Chromolaena odorota* (Hagunoy), *Andropogon aciculatus*. (Amorseco), *Saccharum spontaneum* Linn. (Bugang), *Elephantopus tomentosus* (Malasambong) and *Calopogonium muconoides* (Malabatong) (Table 1). These plants can be considered as indicators of marginal upland or degraded soil (Asio, 1996; Asio, 2007). There are site indicators pointing to the major role of human activities particularly unsustainable cultivation practices. (e.g. farming on steep slopes and burning) in the degradation of the soils in the area resulting to their marginal soil conditions.

Morphological and Physical Characteristics

The soils in the marginal uplands of Inopacan, Leyte vary from poorly developed to well-developed soils depending on their positions in the catena. All the soils described have developed from volcanic rocks particularly andesite and basalt. Soils located at the summit positions (soil profile 1 and 2) are well-developed soils having an Ap-Bt-BC horizon sequence (Table 2). However, there are variations in terms of the morphological characteristics of the soils. Soil color ranges from strong brown (7.5YR 5/6) in the surface horizon to reddish yellow (7.5YR 6/8) in the subsurface horizons in profile 1. Soil structure is sub-angular blocky throughout the soil profile which is weak in the Ap and BC horizons and moderate in the Bt horizons. Consistency of the soil varies from friable on the surface to firm on the subsurface. Soil profile 2, on the other hand, has a soil color of very pale brown (10YR 7/3) on the surface and dark yellowish brown (10YR 4/6-10YR 5-8) in the subsurface. Structure is different on the surface which is granular but subangular blocky in the subsurface horizons. It is firm in all the soil horizons in the profile.

Poorly-developed soils are found on the backslope (soil profile 3) and toeslope (soil profile 4) positions of the catena as indicated by an Ap-AB-Bw-BC horizon sequence (Figure 2). Bw horizon indicates the presence of a cambic horizon characterized by a poorly developed soil structure. Soil color on the surface horizons (Ap and AB) is yellowish brown (10YR 5/4) to brown (10YR 5/3) while the subsurface horizons are yellowish brown (10YR 5/6). Soil structure is weak fine subangular blocky for both soil profiles 3 and 4. However, the surface horizon in soil profile 4 has a massive soil structure as a result of plowing activities which destroy the soil aggregates. Consistency is friable for most horizons of profile 3 while firm for profile 4. Soil profile 5 located at the lower backslope of the catena (Figure 3) is a well-developed soil. Horizon sequence is Ap-BA-Bt-BC.

Chemical properties

Soil pH

The pH of the soil expresses the activity of the hydrogen ions in the soil solution. It affects soil formation processes and the availability of mineral nutrients to plants. Most of the soil profiles have pH values closer to 5.0 (Figure 4) which do not change much with soil depth. The values also indicate a highly acidic soil reaction (Landon, 1991) which is less favorable to the growth and development of most agricultural crops. However, the native plants appear to be growing well indicating that they have the ability to cope with the acidic condition of the soil.

Organic Matter

Organic matter refers to all decomposed, partly decomposed, and undecomposed materials of plant and animal origin and is generally synonymus with humic substances (FAO, 2006). Figure 5 shows that the surface horizons of the soils contain considerably higher organic matter than the lower horizons. This can be expected considering the fact that OM comes from the residue of plants and animals living on the surface soil.

Total Nitrogen

Total nitrogen for all soil profiles were high at the surface and decreased with depth similar to that of the organic matter content (Figure 6). This is because 95 percent of N in the soil is derived from OM. Based on Landon (1991), the total N of the soils can be considered low or deficient. This result implies that N application is needed to improve soil fertility and increase crop yield in the area.

Available Phosphorus

Figure 7 shows that most of the soil profiles examined have low or deficient (below 10 mg/kg) available P which is not surprising considering the acidic and degraded nature of the land. This means that P application is crucial to the management of the marginal upland since it is not added through rainfall or there is no natural source except for the mineral apatite in the soil.

The sufficient amount of P in the surface of profiles 2 and 5 suggest human influence in the form of fertilizer application.

Figure 3. Location of the soil profiles investigated in the marginal landscape in Inopacan, Leyte

Table 1. Characteristics of the sampling sites in the marginal uplands of Inopacan, Leyte.

Site Characteristics	Soil Profiles				
	1	2	3	4	5
Landform Physiographic position	Volcanic Hill Summit	Volcanic Hill Summit	Volcanic Hill Backslope	Volcanic Hill Toeslope	Volcanic Hill Lower Backslope
Slope gradient	Nearly level	Nearly level	Strongly Sloping	Level	Strongly Sloping
Parent material	Basalt/Andesite	Basalt/Andesite	Basalt/Andesite	Alluvial Sediments	
Soil Moisture Regime	Udic	Udic	Udic	Aquic	Udic
Soil Temp Regime	Isohyperthermic	Isohyperthermic	Isohyperthermic	Isohyperthermic	Isohyperthermic
Erosion	Slight	Slight	Very Evident	Nneo	Very Evident
Rock outcrops/ Stoniness	Many	Many	Common	Few	Common
Drainage	Very Good	Very Good	Very Good	Poor	Very Good
Land-use	Agricultural	Agricultural	Grassland	Agricultural (Lowland Ricefield)	Agricultural (Abandoned upland farm)
Vegetation	*Imperata cylindrica* (cogon), *Melastoma malabathricum*	*Saccharum spontaneum, Melastoma malabathricum*	*Imperata cylindrica* (cogon), *Melastoma malabathricum*	Low land rice (*Oryzasativa Linn.*)	*Andropogonaciculatum, Melastoma malabathricum*

Table 2.Morphological characteristics of the marginal upland soils of Inopacan, Leyte.

Soil Profile/Horizon[A]	Depth (cm)	Boundary[G]	Soil Color (MunsellColor-dry)	Texture[B]	Structure[C]	Consistence[D]		Roots[E]	Pores[E]	Rock Fragments[F]
						Moist	Wet			
Profile 1 (Summit)										
Ap	0-10	cw	7.5YR 5/6 (strong brown)	SiC	1fsbk	fr	sst&spl	mc	mc	c
Bt1	10-27	di	7.5YR 6/8 (reddish yellow)	C	2msbk	fi	st&spl	mm	ff	c
Bt2	27-42	di	7.5YR 6/8 (reddish yellow)	C	2msbk	fi	st&spl	ff	ff	c
BC1	42-73	dw	7.5YR 6/8 (reddish yellow)	SC	1msbk	vfi	sst&spl	n	ff	c
BC2	>73		7.5YR 6/8 (reddish yellow)	SC	1msbk	vfi	sst&spl	n	ff	c
Profile 2 (Summit)										
Ap	0-17	cs	10YR 7/3 (very pale brown)	SiC	g	fi	st&pl	mc	fvf	c
BA	17- 29	dw	10YR 4/6 (dark yellowish brown)	SiC	2fsbk	vfi	st&pl	mm	fvf	f
Bt1	29-52	dw	10YR 5/6 (yellowish brown)	SiC	3fsbk	vfi	st&pl	ff	fvf	f
Bt2	52-73	dw	10YR 5/6 (yellowish brown)	SiC	3fsbk	vfi	st&pl	ff	fvf	f
BC	73-100		10YR 5/8 (yellowish brown)	C	2fsbk	vfi	st&pl	ff	fvf	f
Profile 3 (Backslope)										
Ap	0-19	aw	10YR 5/4 (yellowish brown)	SiL	2fsbk	fr	sst&spl	mm	mm	f
AB	19-36	dw	10YR 5/3 (brown)	SiL	2fsbk	fr	sst&spl	fm	mm	f
Bw	36-60	dw	10YR 5/6 (yellowish brown)	SiC	2msbk	fr	sst&spl	ff	mm	f
BC	>60		10YR 5/6 (yellowish brown)	SC	1fsbk	fi	sst&spl	n	Fc	f
Profile 4 (Toeslope)										
Ap	0-18	as	10YR 4/6 (dark yellowish brown)	CL	m	fi	st&pl	ff	fvf	f
AB	18-40	gs	10YR 5/8 (yellowish brown)	CL	1fsbk	fr	st&pl	fvf	fm	f
Bw	40-73	as	10YR 4/4 (dark yellowish brown)	SiCL	1fsbk	fr	sst&spl	fvf	mm	f
BC	>73		10YR 4/4 (dark yellowish brown)	SiC	1msbk	fi	sst&spl	n	mc	c
Profile 5 (lower backslope)										
Ap	0-15	cw	10YR 7/3 (very pale brown)	SiL	3msbk	fr	sst&spl	mm	mm	c
BA	15-35	aw	10YR 5/6 (yellowish brown)	SiL	3msbk	fr	sst&spl	mm	mm	f
Bt	35-52	aw	10YR 5/3 (brown)	SiC	3msbk	fr	sst&spl	ff	mc	f
BC1	52-75	as	10YR 7/4 (very pale brown)	SC	1msbk	fi	sst&spl	n	fc	f
BC2	>75		10YR 7/4 (very pale brown)	SC	1msbk	fi	sst&spl	n	fc	f

A According to IUSS Working Group WRB (2006)
B SC, Sandy Clay; SCL, Sandy Clay Loam; SiCL, Silty Clay Loam; SiL, Silt Loam; SiC, Silty Clay; C, Clay
C 1, weak; 2, moderate; 3, strong; f, fine; m, medium; sbk, sub-angular blocky; m, massive
D fr, friable; fi, firm; vfi, very firm; st, sticky, sst, slightly sticky; pl, plastic; s lightly plastic
E mc, many coarse; mm, many medium; ff, few fine; fvf, few very fine; fm, few medium; none
F c, common; f, few
G cw, clear wavy; di, diffuse irregular; dw, diffuse wavy, cs, clear smooth; as, abrupt smooth; gs, gradual smooth

Exchangeable bases (K, Ca, Mg and Na)

Figures 8 to 11 show the exchangeable bases of the soil profiles examined and sampled in the marginal uplands of Inopacan, Leyte. As can be seen from the figures, the amounts of the exchangeable bases are relatively above the critical levels reported by Landon (1991). In other words these nutrient elements are not deficient in the soils probably due to the abundance of rock fragments of basalt and andesite which are important sources of these nutrient elements. It can also be noted that the levels of the exchangeable bases in the soil profiles varied considerably between the soils. Those found in the lower physiographic positions such as lower backslope and toeslope generally have higher amounts of the exchangeable bases. This suggests the possible role of transport of elements by water from the upper paarts of the landscape to the lower parts.

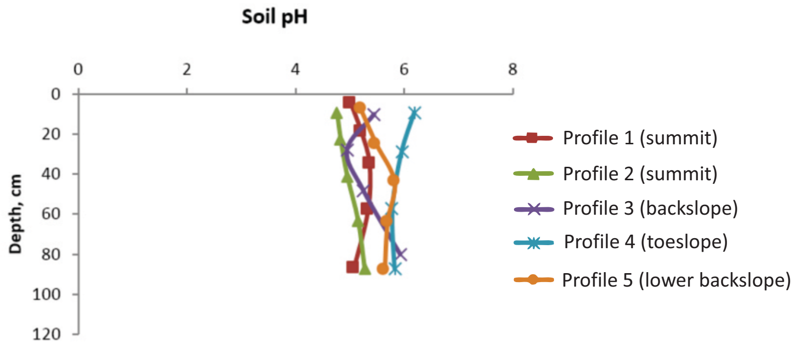

Figure 4. Depth function of the soil pH (in water) in marginal upland soils of Inopacan, Leyte

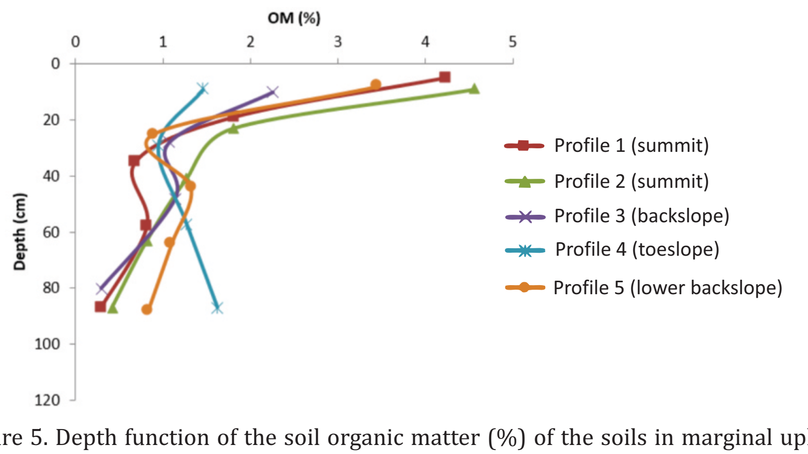

Figure 5. Depth function of the soil organic matter (%) of the soils in marginal upland o Inopacan, Leyte

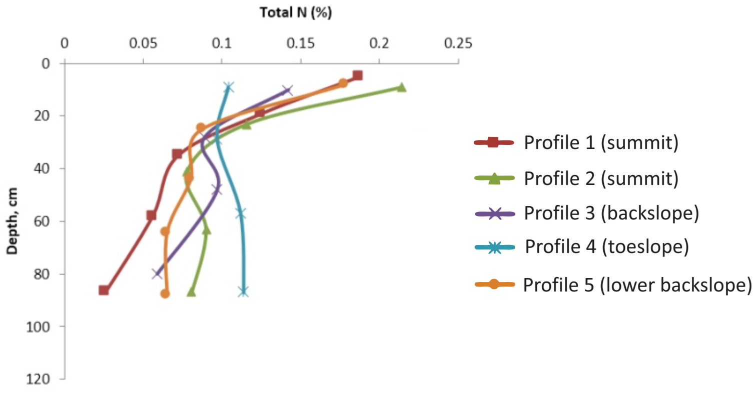

Figure 6. Depth function of the total N (%) of the marginal upland soils of Inopacan, Leyte

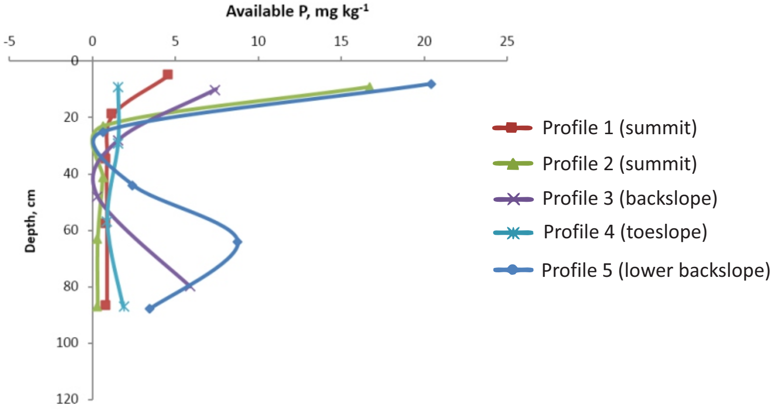

Figure 7. Depth function of available phosphorus (mg kg^{-}) in marginal upland soils of Inopacan, Leyte

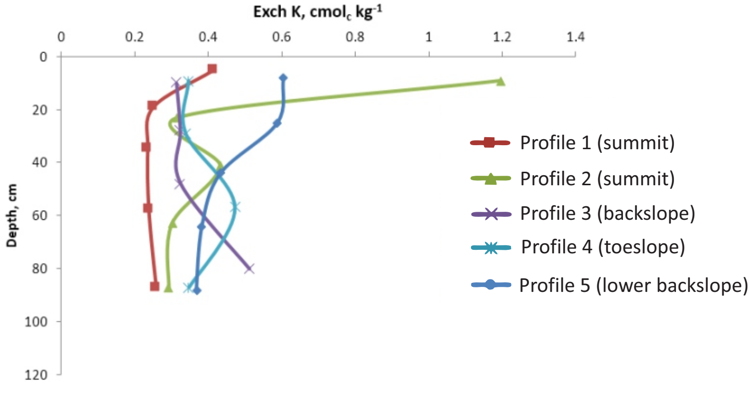

Figure 8. Depth function of exchangeable K (cmol$_c$ kg^{-1}) in marginal upland soils of Inopacan, Leyte

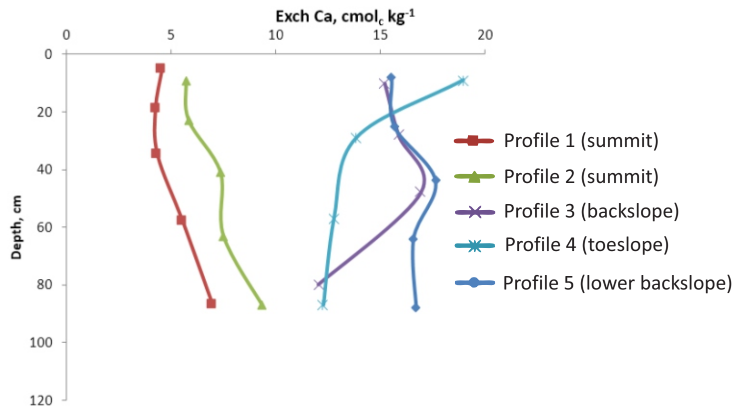

Figure 9.Depth function of exchangeable Ca (cmol$_c$ kg^{-}) in marginal upland soils of Inopacan, Leyte

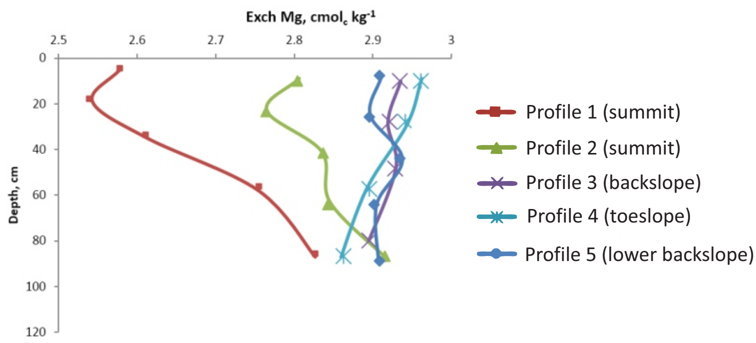

Figure 10. Depth function of exchangeable Mg (cmol$_c$ kg^{-}) in marginal upland soils of Inopacan, Leyte

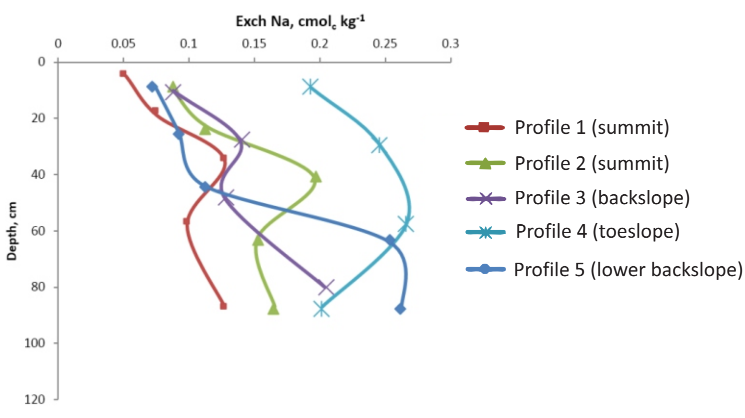

Figure 11. Depth function of exchangeable Na (cmol$_c$ kg^{-}) in marginal upland soils of Inopacan, Leyte

CONCLUSION

Findings of the study revealed that the five soils in the marginal upland studied were derived from volcanic materials particularly andesite and basalt rocks. Well-developed soils were found in the more stable summit position while poorly developed soils occurred in the less stable lower slope positions. The soils were highly acidic with soil pH close to 5.0. Soil organic matter, total nitrogen and available P were low and decrease with soil depth. Exchangeable bases (Ca, Mg, K and Na) were high in most soil profiles. The results indicate that N and P fertilization as well as organic matter addition are crucial to increasing the productivity of the marginal upland soils. Lastly, the study indicate that the marginal nature of the soils is the result of decades of unsustainable cultivation practices which caused soil erosion and nutrient depletion processes.

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