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Properties of soils in the marginal upland of Sta. Rita, Samar, Philippines

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ABSTRACT

The widespread occurrence of marginal uplands is a serious agricultural and ecological problem in the Philippines. The study evaluated the morphological and physico-chemical properties of soils in the marginal upland of Sta. Rita, Samar. Three soil profiles located at different physiographic positions were examined and sampled. Findings revealed that the marginal upland soils were derived from mudstone. They were characterized by an Ap-Bt-BC horizon sequence and they were clayey with moderate to high porosity and water holding capacity values. The soils were friable in their surface horizons when moist, but plastic and sticky when wet. The soils had pH(water) values ranging from 5.20 to 6.86, indicating that soil acidity was not yet a serious problem in these soils. The soils had moderate soil organic matter contents in their surface horizons but low amounts in subsurface horizons. Total N and available P of the soils were low and a problem for crop production. However, the soils had moderate to high exchangeable bases and cation exchange capacity values. In terms of degree of soil development, the marginal upland soils was observed to be mature as reflected by their horizonation, particularly by the presence of an argillic horizon (B horizon with high clay accumulation). But they still had high base saturation, suggesting that they were not yet highly leached and thus, were classified as Typic Hapludalfs or Haplic Luvisols.

Keywords: marginal upland soils, mudstone, soil characteristics, Alfisols, Luvisols

INTRODUCTION

Soil degradation is the process which lowers the current or future capacity of the soil to produce goods or services. The term implies a long-term decline in soil productivity and its environment-moderating capacity (Lal 2001, Asio et al 2009). It occurs because of drastic changes or disruption in the normal processes of soil formation due to human activities. While soil formation results in the ordering of the soil body (decrease in entropy), soil degradation results in an increase in disorder of the soil body (increase in entropy) (Smeck et al 1983, Addiscott 1995, Asio et al

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2009). Soil degradation is one of the major threats to food security and environmental quality in the Philippines today.

Marginal uplands or degraded uplands are defined as undulating, hilly or steep mountainous lands having very low crop productivity due to poor soil quality, limited water availability and unfavorable socio-economic conditions (Asio 2015). They are prevalent in the country as the result of decades of deforestation and forest conversion into agricultural lands. Agricultural practices and economic pressures have severely degraded the agricultural resource base, causing accelerated soil erosion, siltation of irrigation systems, flooding and water pollution (Briones 2005, Asio 2015).

Marginal uplands in the Philippines 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 et al 2014a&b). Thus, sustainable land management practices and strategies are necessary to improve the productivity of degraded lands.

Until now, limited studies have been published that dealt with the characteristics and fertility status and formation of marginal upland soils. The study aimed to evaluate the morpho-physicochemical characteristics of soils in the marginal uplands of Sta. Rita, Samar, within the framework of the "Marginal Uplands Project", a Commission on Higher Education (CHED)-Philippine Higher Education Research Network (PHERNET) funded project of the Visayas State University (Asio et al 2014b).

MATERIALS AND METHODS

Site Characteristics

The study was conducted in the marginal upland of Caticugan, Sta. Rita, Samar, the project site of the VSU-CHED PHERNET Project. A 200m-long east-west oriented catena consisting of three soil profiles were selected for the study.

Site and profile descriptions were done, following the standard FAO Guidelines for Soil Description (Jahn et al 2006). Site characteristics include location, climate, land use, parent material, landforms, geomorphic position, local relief, slope gradient, erosion, drainage, land-use and predominant vegetation.

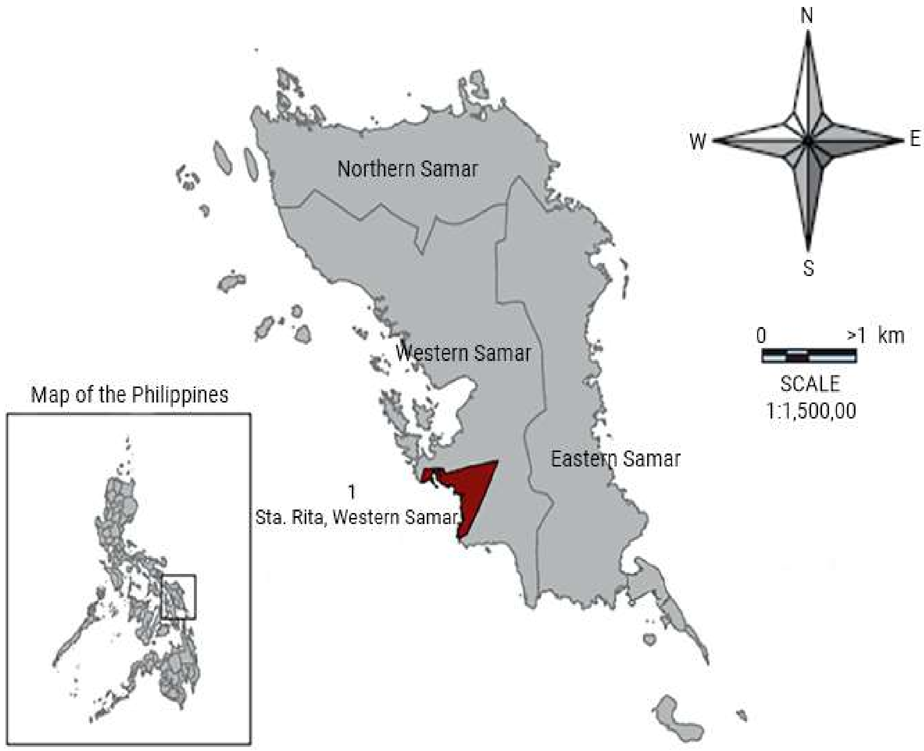

Figure 1. Location of the study site in Caticugan, Sta. Rita, Samar

Table 1. Site characteristics of the marginal upland in Sta. Rita, Samar

Site Characteristics	Soil Profiles		
	1	2	3
Landform	Medium gradient hill	Medium gradient hill	Medium gradient hill
Physiographic Position	Upper backslope	Summit	Summit
Slope gradient	Strongly sloping	Nearly Level	Nearly level
Parent material	Mudstone	Mudstone	Mudstone
Soil moisture Regime	Udic	Udic	Udic
Soil temp. regime	Isohyperthermic	Isohyperthermic	Isohyperthermic
Erosion	Slight	None	Slight
Rock outcrops	None	None	None
Drainage	Good	Good	Good
Land use	Agricultural	Agricultural	Agricultural
Dominant Vegetation	*Chromolaena odorata* *Cocos nucifera*	*Cocos nucifera*	*Chromolaena odorata* *Imperata cylindrica*

Soil Profile Description and Sampling

To describe and sample the soil profiles, soil pits measuring 1mx1m with a depth of at least 1.5m were excavated in different parts of the catena. Soil profile description and sampling were done, following the standard FAO Guidelines for Soil Description (Jahn et al 2006). Soil samples were collected from each horizon of every soil profile by taking three (3) continuous and uniform slices from the uppermost horizon down to the lowest and then mising them thoroughly according to the sampling procedure of Schlichting et al (1999). All samples from the same horizon were mixed. Samples were placed in properly labeled plastic bags and were brought to the Department of Soil Science, VSU, Baybay City, Leyte for processing and analyses. They were freed of leaves and rock fragments and then air-dried, pulverized and sieved in 2mm wire mesh to get the fine earth fraction for the determination of most soil physical and chemical properties. For organic matter and total N determination, enough samples were further pulverized and allowed to pass through a 0.425mm wire mesh.

Soil Physico-chemical Analyses

The fine earth fraction (<2mm) was used for the determination of particle size distribution, water holding capacity, bulk density and porosity. For chemical analysis, fine earth fraction was also used for soil pH, available P, exchangeable bases and acidity and effective CEC. Fine soil sample (0.425mm) was used for soil organic matter and total N determinations. Soil analyses were done at the Pedology and Geo-ecology Laboratory, Department of Soil Science, VSU, Baybay City, Leyte.

Particle size distribution was determined by pipette method (ISRIC 1995), bulk density by paraffin clod method (Blake & Hartge 1986) and water holding capacity (WHC) by gravimetric method (Klute 1986). Soil pH was analyzed potentiometrically in H_2O and KCl, using a soil-water solution ratio of 1:2.5 (ISRIC 1995), SOM by the Loss-on-Ignition method (Schlichting et al 1995), total N by the Micro-Kjeldahl method (ISRIC 1995), available P by the Bray P-2 method using 0.1N HCl and 0.03N NH_4F extractant (Jackson 1958), and exchangeable bases using the 1N NH_4OAc at pH7.0 method and quantified by atomic absorption spectrophotometry (ISRIC 1995). Exchangeable Acidity (Al^{3+} & H^+) (cmolc kg-1) was analyzed using 1N KCl as extractant and quantified by titrating the resulting extract with 0.1N NaOH (Thomas 1982). Effective Cation Exchange Capacity (cmolc kg^{-1}) was calculated by summing up the amount of the exchangeable bases (K, Mg, Ca, & Na) and total acidity (Al^{3+} & H^+).

Data Analysis

Depth function of each soil property was plotted. The values determined for each property were compared with the ranges in Landon (1991) to determine if they are low, moderate or high.

RESULTS AND DISCUSSION

Site Characteristics

The study site is located in Caticugan, Sta. Rita, Samar, a municipality in Western Samar, with a Type IV climate characterized by an even distribution of rainfall throughout the year. The marginal condition of the soil appears to limit the land productivity. The parent material of this well-developed soil is mudstone of Upper Miocene (24 million) to Lower Pliocene (5 million) age. Soils derived from mudstones tend to be clayey, impermeable, little leached and shallow (Buol et al 2003). Travaglia et al (1978) reported that the Catbalogan Formation (Upper Miocene-Lower Pliocene), a marine clastic formation including sandstone, siltstone and shale (mudstone), cover about 40 percent of Samar island.

Imperata cylindrica (Cogon), *Melastoma malabathricum* (Hantutuknaw), *Chromolaena odorota* (Hagunoy), *Saccharum spontaneum* Linn. (Bugang) *Psidium guajava* (Guava), *Elephantopus tomentosus* (Malasambong) and *Saccharum spontaneum* Linn. (Bugang) are dominant in the site, which are indicators of soil degradation (Asio et al 2009, Asio 2015).

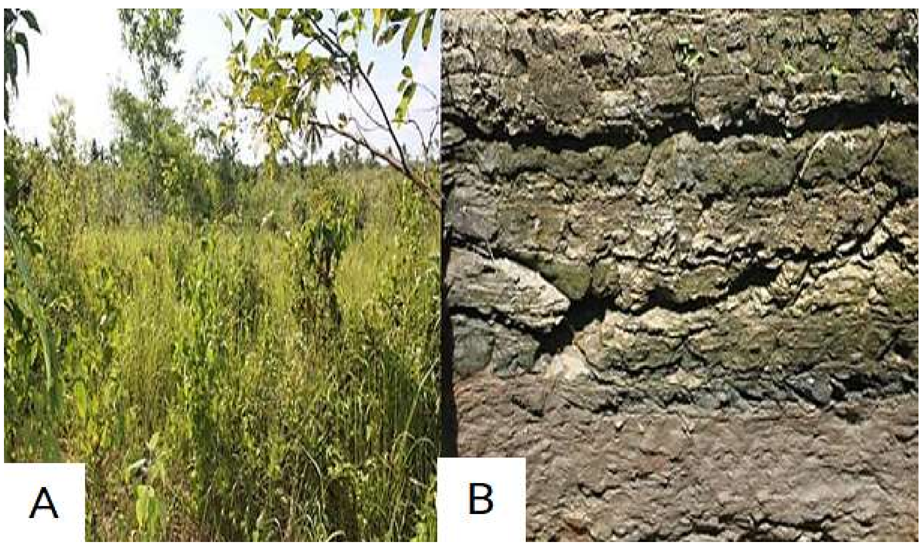

Figure 2. Photographs showing the (A) land use and (B) mudstone parent material of the marginal upland soils in Sta. Rita, Samar

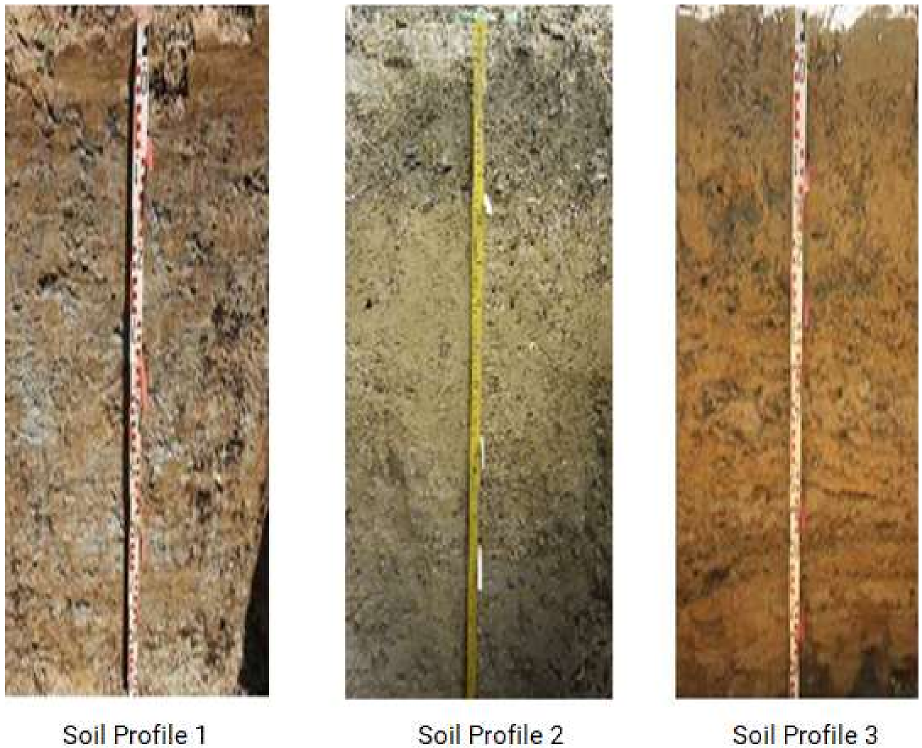

Figure 3. Photographs of soil profiles investigated in the marginal upland in Sta. Rita, Samar

Soil Morphological Characteristics and Soil Horizon Designation

The important morphological characteristics evaluated were soil color, texture, horizon, structure, presence of roots, consistency, abundance of rock fragments, pores and presence of roots. Results revealed variations in some of the above-mentioned soil morphological characteristics among the soil profiles in the catena (Table 2).

Soil horizon designation is an interpretative symbol based on horizon morphology and implied genesis that is used to identify and label horizons (Bridges 1993). All the three soils showed a horizon sequence of Ap-Bt-BC, implying mature soils as indicated by the presence of an argillic (Bt) horizon. The partially weathered mudstone (C horizon) was observed in soil profiles 2 and 3 and confirmed from the nearby well. The presence of Ap horizon indicates that the soils were influenced by human activities such as plowing and cultivation, which contribute to soil mixing (Fanning & Fanning 1989).

Soil Color

The soil color in the surface horizons ranged from brown (10YR 5/3) and yellowish brown (10YR 5/4) to light yellowish brown (10YR 6/4) (Table 2). However, the subsoils of the soil profiles showed a uniform yellowish-brown color. The varying color of the surface horizons reflect the influence of land use and human activities while the uniform color of the subsoils suggests that the soils in the catena have closely related pedogenesis.

Soil Structure

Soil structure is characterized by the spatial arrangement of soil particles and the water and air pore spaces into different positions or into secondary particles, units, or peds (Schlichting et al 1995). Table 2 summarizes the soil structure of the marginal upland soils studied. Soil profiles 1 and 2 had granular structure in the surface horizons and sub-angular blocky structure in the subsurface horizons. Soil profile 3 had a subangular blocky structure in all its horizons.

Soil Consistence

The soils were observed to have friable moist consistence in the surface horizons and firm consistence in the subsurface horizons. The friable consistence in the former horizons is attributed to the granular structure while the firm consistence in the latter horizons can be due to the illuvial accumulation of clay in the B horizon. Moreover, the wet consistence of the soils is characterized by plastic and sticky behavior.

Other Morphological Features

All soils in the study site had medium to fine roots in the A horizons and very fine to fine roots in the B horizons. However, in the lower portion especially in the BC and C horizons of the soil profiles, very few roots were observed. Only few mudstone fragments were observed in the soil profiles.

Soil Physical Characteristics

Table 2. Morphological characteristics of the marginal upland soils in Sta. Rita, Samar

Horizon[A]	Depth (cm)	Boundary[B]	Color (moist)	Texture[C]	Rock Fragments[D]	Structure[E]	Consistence[F]		Roots[G]
							moist	wet	
			Soil Profile 1						
Ap	0-20	cs	10YR 5/3 (brown)	SiCl	n	2cg	fr	s&p	cm
Bt	20-45	cs	10YR 5/6 (yellowish brown)	C	n	2csbk	fr	vs&p	fem
BC	45-73	gs	10YR 5/6 (yellowish brown)	C	n	2msbk	f	vs&p	fem
CB	73-100	cs	10YR 5/6 (yellowish brown)	C	n	1msbk	f	s&p	vfevfi
			Soil Profile 2						
Ap	0-17	cw	10YR 5/4 (yellowish brown)	SC	n	2cg	fr	s&p	cm
Bt	17-47	cs	10YR 5/4 (yellowish brown)	C	n	2csbk	f	s&p	fevfi
BC	47-67	cs	10YR 5/8 (yellowish brown)	C	n	2csbk	f	vs&p	fevfi
C	67-100	cs	10YR 5/8 (yellowish brown)	C	n	2csbk	f	vs&vp	n

A. Based on IUSS Working Group (WRB) 1998
B. ds, diffuse smooth; cw, clear and wavy; cs, clear and smooth
C. SC, sandy clay; SL, sandy loam; SCL, sandy clay loam; C, clay
D. 1, weak; 2, moderate; 3, strong; vf, very fine; f, fine; m, medium; sbk, sub-angular blocky; abk; angular blocky; g, granular
E. n, no rock fragments; fe; few; c, common
F. fi, firm; vfr, very friable; fr, friable; nst, non-sticky; sst, slightly sticky; st, sticky; vst, very sticky; npl, non-plastic; spl, slightly plastic; pl plastic; pvp, plastic to very plastic; vpl, very plastic
G. vff, very few fine; ff, few fine; cf, common fine; fm, few medium; cm, common medium; fm, fine medium

Table 2 continued

Horizon[A]	Depth (cm)	Boundary[B]	Color (moist)	Texture[C]	Rock Fragments[D]	Structure[E]	Consistence[F]		Roots[G]
							moist	wet	
			Soil Profile 3						
Ap	0-15	cs	10 YR 6/4 (light yellowish brown)	C	n	2csbk	fr	s&p	cfi
Bt	15-30	cs	10YR 5/4 (yellowish brown)	C	n	3msbk	fi	st&vpl	fm
BC	30-57	cs	10YR 5/8 (yellowish brown)	C	n	2csbk	f	s&p	fevfi
C1	57-70	cs	10YR 5/8 (yellowish brown)	SCL	n	1fsbk	fr	ss&sp	fevfi
C2	70-100	cs	10YR 5/8 (yellowish brown)	SCL	n	1fsbk	fr	ss&sp	n

A. Based on IUSS Working Group (WRB) 1998
B. ds, diffuse smooth; cw, clear and wavy; cs, clear and smooth
C. SC, sandy clay; SL, sandy loam; SCL, sandy clay loam; C, clay
D. 1, weak; 2, moderate; 3, strong; vf, very fine; f, fine; m, medium; sbk, sub-angular blocky; abk; angular blocky; g, granular
E. n, no rock fragments; fe; few; c, common
F. fi, firm; vfr, very friable; fr, friable; nst, non-sticky; sst, slightly sticky; st, sticky; vst, very sticky; npl, non-plastic; spl, slightly plastic; pl plastic; pvp, plastic to very plastic; vpl, very plastic
G. vff, very few fine; ff, few fine; cf, common fine; fm, few medium; cm, common medium; fm, fine medium

Particle Size Distribution

Soil texture refers to the relative proportion of the different particle-size separates (sand, silt & clay) in a given soil volume. Soil texture can affect porosity, pore size distribution, water holding capacity and permeability (Hillel 2004, Blume et al 2016). Table 3 presents the data on the particle size distribution of marginal upland soils evaluated.

Table 3. Physical characteristics of the marginal upland soils in Sta. Rita, Samar

Horizon	Depth (cm)	Sand	Silt (%)	Clay	Textural Class	Bulk Density (g cm^3)	Porosity (%)	WHC (%)
					Soil Profile 1			
Ap	0-20	6.30	48.65	45.05	Silty Clay	1.29	51.00	49.68
Bt	20-45	12.97	18.70	68.33	Clay	1.48	44.00	47.23
BC	45-73	11.12	13.70	75.18	Clay	1.52	43.00	58.24
CB	73-100	12.72	23.34	63.94	Clay	1.50	43.00	49.52
					Soil Profile 2			
Ap	0-17	7.25	45.62	47.13	Clay	1.32	50.00	75.10
Bt	17-47	12.71	23.35	63.94	Clay	1.41	47.00	59.85
BC	47-67	12.97	18.70	68.33	Clay	1.48	44.00	59.56
C	67-100	3.54	25.36	71.11	Clay	1.50	43.00	59.27
					Soil Profile 3			
Ap	0-15	29.31	17.73	52.96	Clay	1.30	51.00	42.76
Bt	15-30	24.60	20.16	55.24	Clay	1.30	51.00	38.90
BC	30-57	50.60	14.88	34.52	Sandy Clay	1.40	47.00	n.d.
C1	57-70	57.79	5.30	36.90	Sandy Clay	1.40	47.00	n.d.
C2	70-100	63.35	6.15	30.50	Sandy Clay Loam	1.40	47.00	n.d.

WHC-water holding capacity

As can be seen, soil profiles 1 and 2 had very high amount of clay (average 56.11%), moderate silt (average 34.08%) and low sand (9.81%), giving a texture ranging from silty clay to clay in the surface horizons. In addition, very high amount of clay (63.94-75.18%), moderate values of silt (13.70-25.36%) and very low amount of sand (3.54-12.97%) were found in the subsurface horizons. Soil profile 3 had moderate to high contents of clay ranging from 30.50-53.96%, high content of sand ranging from 50.60-63.35% and low content of silt (5.30-14.88%).

The high clay content of the soils is due to the influence of the mudstone parent material. The increasing clay with depth in all soil profiles suggests clay accumulation through illuviation and in situ weathering of the mudstone parent rock. This indicates the important contribution of parent rock to the clay content of soils (Jahn et al 2006).

Bulk Density

Soil bulk density is used as an index of compaction and porosity of soils and it directly affects root development and the movement of water, gas and solutes in the soil. According to Jahn et al (2006), bulk density refers to the mass of soil solids per unit bulk volume, including the volume of the voids which is expressed in g cm^{-3}. Results showed that soil bulk density in the marginal upland of Sta. Rita ranged from 1.29-1.52g cm^{-3}. Bulk densities from surface horizons were generally lower

Porosity

Porosity or pore space is the amount of air space or void space between soil particles. Infiltration, groundwater movement and storage occur in these voids. The high porosity of the soils confirms the abundance of fine pores, which were easily observable during morphological examination in the field (Jahn et al 2006).

Porosity values were relatively higher in the surface horizons than in the subsurface horizons (Table 3). This could be due to the higher humus content of the surface horizons than in the subsurface horizon. The higher porosity values in the surface horizon can also be explained by the abundance of fine pores due to root activities and high organic matter content, which improves soil aggregation.

Water Holding Capacity

Water holding capacity is the maximum amount of water that a soil can retain at saturation, while field capacity is the amount of water in the soil after the gravitational water has drained away. The marginal upland soils exhibited relatively high water holding capacity (38.90-75.10%). These values were generally due to the high amount of clay which influenced the moisture retention of the soil. Similar to clay, SOM is able to hold and retain large quantities of soil moisture and thus, increases the water holding capacity, infiltration and porosity of the soil (Carter 2002).

Soil Chemical Characteristics

Soil pH

Soil pH affects the availability of mineral nutrients to plants. It also affects many soil chemical and soil-forming processes (Blume et al 2016). Soil pH was determined using H_2O and 1M KCl. The use of 1M KCl is based on the premise that K-ions can replace weakly adsorbed H- and Al-ions, which is not possible with H_2O (Schlichting et al 1995).

Results revealed that, generally, the soil pH (H_2O) in the marginal upland soils ranged from slightly to strongly acidic (5.20-6.86) (Figure 3). The values of pH (KCl), on the other hand, ranged from extremely acidic to very strongly acidic (3.50-4.84). Pansu and Gautheyrou (2003) mentioned that pH in KCl usually gives lower pH values than pH in water. The difference can be as much as one pH unit. This is because pH in KCl takes into account exchangeable aluminum and hydrogen ions that are adsorbed on the exchange complex called potential acidity.

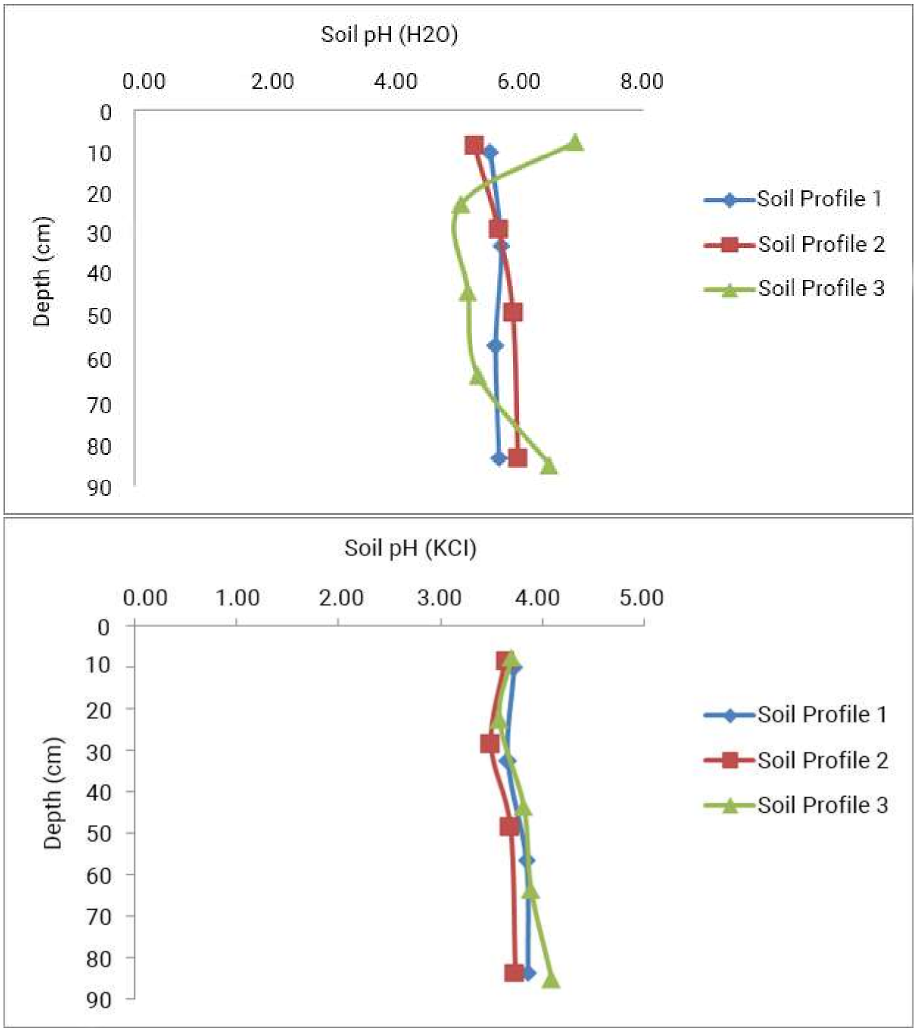

Figure 3. Depth function of pH(water) and pH(KCl) of the marginal upland soils in Sta. Rita, Samar

Soil Organic Matter and Total Nitrogen

Soil organic matter (SOM) consists of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms and substances synthesized by soil organisms (Brady & Weil 1999, Blume et al 2016). Results showed that the surface horizons of all soil profiles had considerably higher SOM than the subsurface horizons. Lower SOM content can be expected in subsurface horizons considering that SOM comes from the residue of plants and animals living on the surface soil. The SOM contents of the soils were more variable in surface than in subsurface horizons suggesting the important role of land use on the SOM content of soils particularly in their surface horizons.

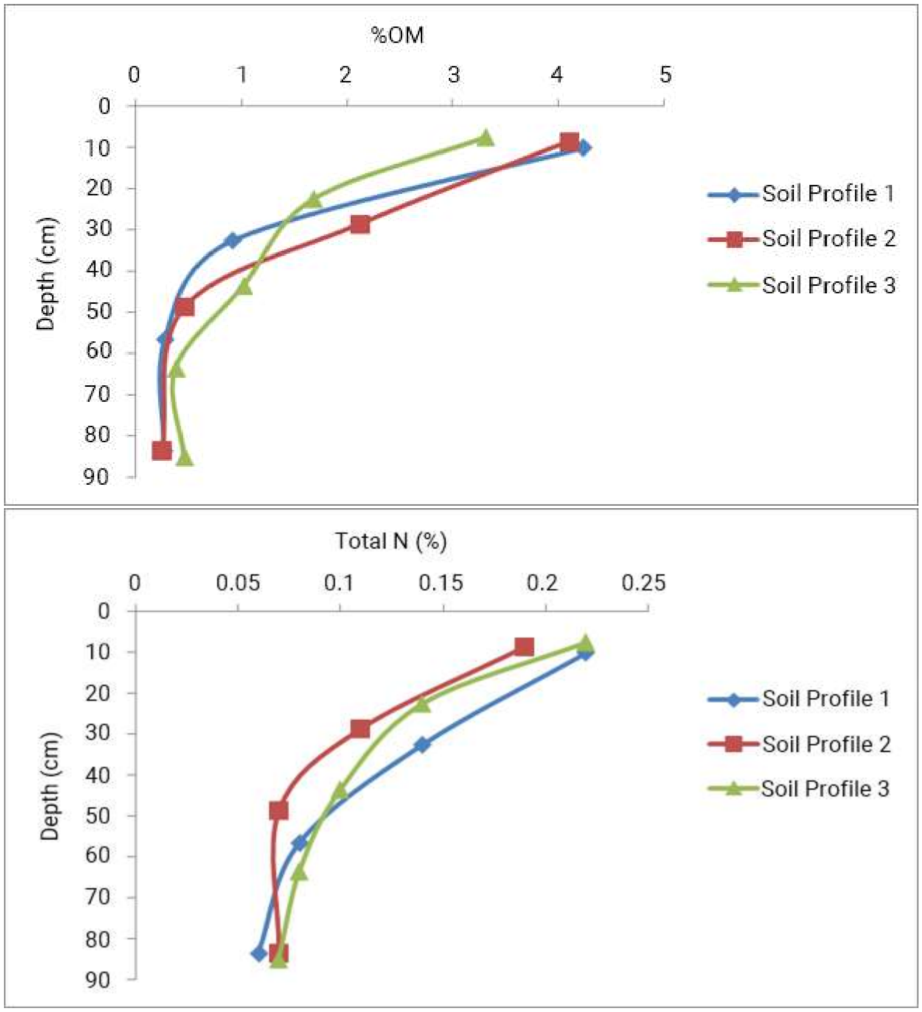

Figure 4. Depth of function of SOM and total N of the marginal upland soils in Sta. Rita, Samar

Nitrogen is one of the essential mineral elements in soils and it can be used as soil quality and productivity indicators. The behavior of this nutrient was generally similar to that of SOM in that it decreased with soil depth (Figure 4). Blume et al (2016) noted that more than 95 percent of soil N is found in organic compounds. Based on Landon (1991), the total N of the marginal upland soils can be considered as low or deficient.

Available Phosphorus

Phosphorus occurs in different forms in the soil. The plant "available P" is that form of P that is extracted using weak acid extractants that dissolve portions of the calcium, iron and aluminum phosphates in the soil. Generally, soils in tropical and sub-tropical regions are phosphorus deficient, thus limiting crop yield (Begum & Islam 2005, Blume et al 2016).

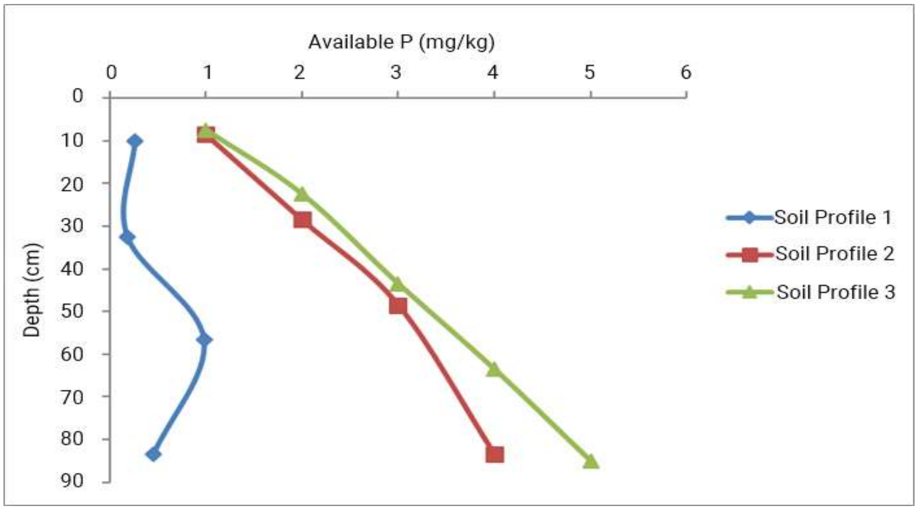

Figure 5. Depth function of available P (mg/kg) of the marginal upland soils in Sta. Rita, Samar

Results showed that the marginal upland soils in Sta. Rita had low available P (<3mg kg^{-1}), notably below the sufficient amount of 8–15mg kg^{-1}(Landon 1991). The increasing amount of available P with depth in the two soil profiles suggests that the parent material is an important source of P.

Exchangeable Bases, Acidity and Effective Cation Exchange Capacity

Exchangeable bases are commonly defined as the alkali and alkaline earth metals (principally calcium, magnesium, potassium & sodium) attached to the clay and organic constituents of soils which can be exchanged with each other and with other positively charged ions in the soil solution. Exchangeable bases reflect the contribution of parent material and the influence of soil management practices. The amounts of exchangeable bases regulate the pH of the soil and thus, are an important factor of soil fertility. The amount of exchangeable Ca, Mg, K and Na are determined by NH_4OAc (pH7) (Table 5).

Exchangeable Ca, Na and Mg values of the marginal soils in Sta. Rita were relatively high. Figure 6 presents the behavior of exchangeable K, Na, Ca and Mg with depth in the soils.

Exchangeable K revealed a variable distribution with depth in all soil profiles, suggesting the possible contribution of the parent material and agricultural practices, particularly fertilization. Some of the samples taken showed values above the critical level (>0.20cmolc kg^{-1}).

Exchangeable Ca was adequate in all soils showing an average value of 10.23cmolc kg^{-1} in profile 1, 10.50cmolc kg^{-1} in profile 2 and 11.06cmolc kg^{-1} in profile 3. Moreover, exchangeable Mg were also moderate to high, ranging from 3.68-18.05cmolc kg^{-1}. Low amounts of exchangeable Na were also found ranging from 0.04 to 0.81cmolc kg^{-1}. Based on the results obtained, it can be implied that these exchangeable bases are not a limiting factor for crop production in Sta. Rita.

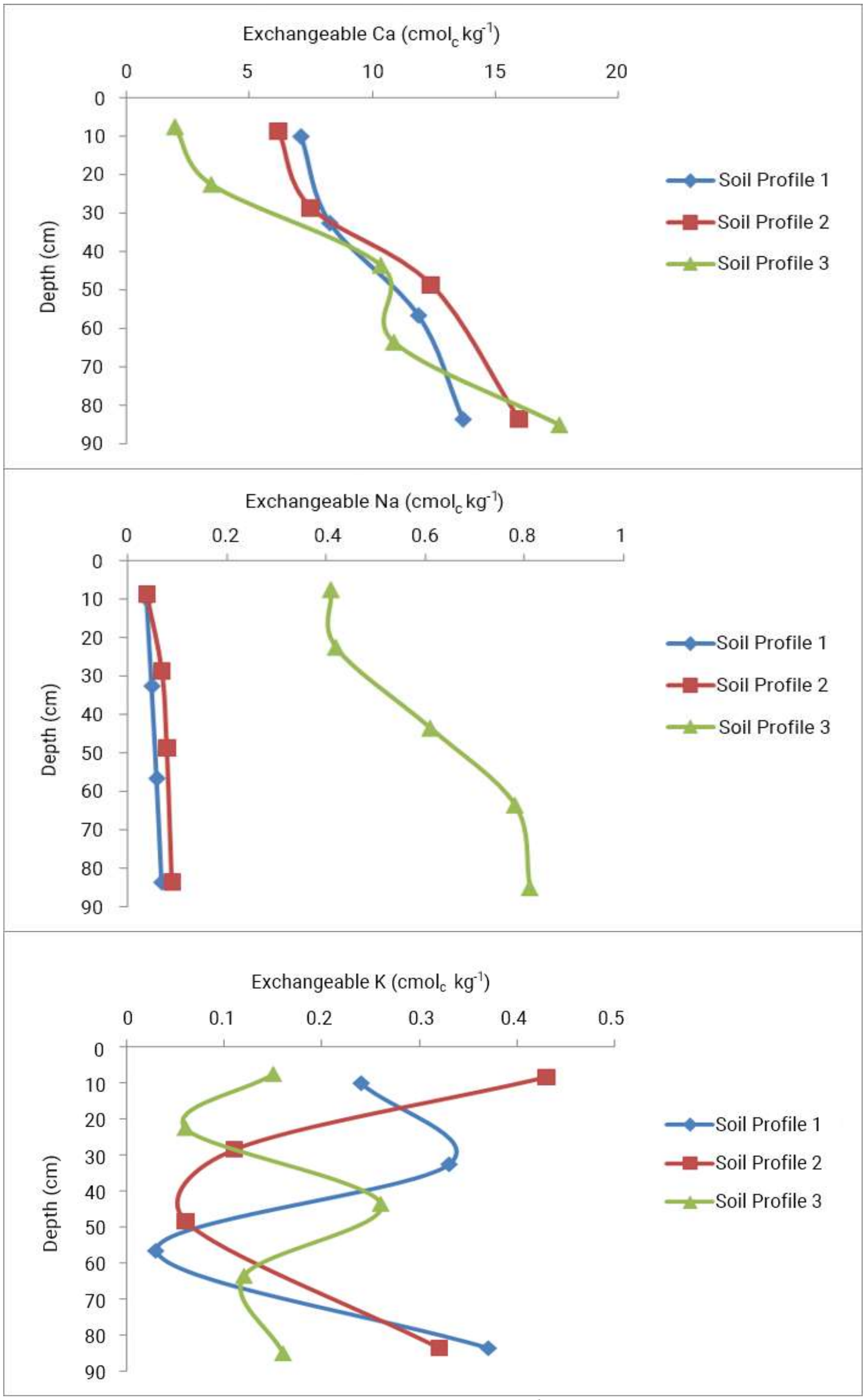

Figure 6. Depth of function of exchangeable bases (cmol$_c$ kg^{-1}) of the marginal upland soils in Sta. Rita, Samar

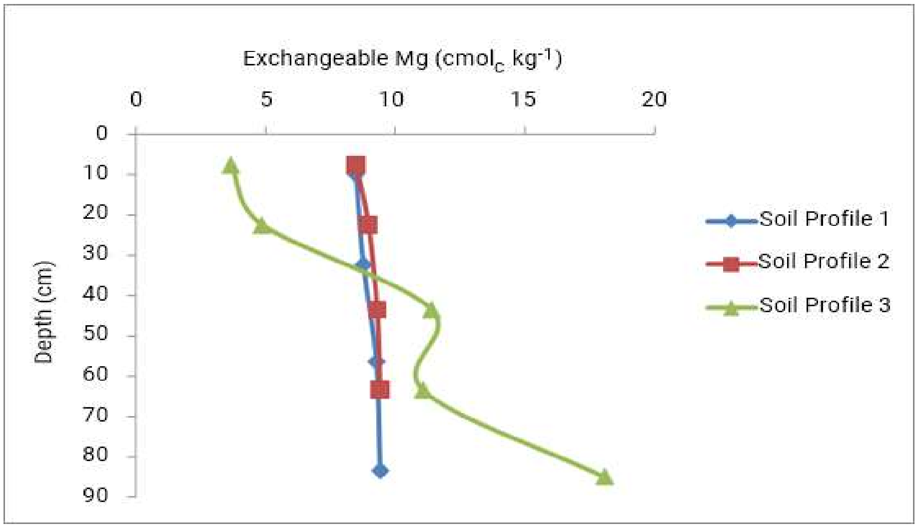

Figure 6 continued

The study also found notable amounts of exchangeable Al especially in the surface horizons but were below the toxic levels for plants which are 2-3cmolc kg^{-1} soil (Landon 1991). This suggests that Al toxicity is not expected in the study area.

Cation exchange capacity (CEC) is defined as the sum total of exchangeable cations such as potassium (K), sodium (Na), calcium (Ca) and magnesium (Mg) present in the soil, expressed in cmolc kg^{-1} soil. The most useful measure of cation exchange capacity of soils is effective cation exchange capacity is (CEC_{eff}). Results revealed that soil profiles 1 and 2 had medium to high values of CEC_{eff} (Landon 1991), ranging from 21.17 to 27.25cmolc kg^{-1}. Soil profile 3 on the other hand, had low to high values of CEC_{eff}, ranging from 24 to 36.63cmolc kg^{-1}. Results imply that the soils in the study site have nutrient retention capacity which generally translates to higher amounts of nutrients for plant uptake and utilization. The moderate to high CEC values of the soils can be attributed to the high amount of clay of the soils and to the clay mineralogy of the soils (see below).

Table 5. Chemical properties of the marginal upland soils in Sta. Rita, Samar

Soil Profile/ Horizon	Depth (cm)	Avail. P (mg kg^{-1})	Exchangeable (cmol$_c$ kg^{-1} soil)						CEC_{eff}
			K	Ca	Mg	Na	H^+	Al^{3+}	
				Soil Profile 1					
Ap	0-20	0.26	0.24	7.08	8.48	0.04	5.89	1.23	22.96
Bt	20-45	0.18	0.33	8.26	8.77	0.05	5.28	2.56	27.25
BC	45-73	0.98	0.03	11.88	9.27	0.06	2.37	0.51	24.13
CB	73-100	0.45	0.37	13.70	9.42	0.07	1.56	0.34	25.46

Table 5 continued

Soil Profile/ Horizon	Depth (cm)	Avail. P (mg kg^{-1})	Exchangeable ($cmol_c$ kg^{-1} soil)						CEC_{eff}
			K	Ca	Mg	Na	H^+	Al^{3+}	
Soil Profile 2									
Ap	0-17	0.41	0.43	6.17	8.47	0.04	4.99	1.08	21.17
Bt	17-47	<0.001	0.11	7.49	8.96	0.07	6.60	1.90	25.13
BC	47-67	0.50	0.06	12.38	9.31	0.08	2.57	0.56	24.96
C	67-100	0.45	0.32	15.97	9.43	0.09	1.46	0.32	27.59
Soil Profile 3									
Ap	0-15	0.18	0.15	1.96	3.68	0.41	1.44	1.21	n.d.
Bt	15-30	<0.001	0.06	3.44	4.87	0.42	2.55	2.25	n.d.
CB	30-57	<0.001	0.26	10.34	11.39	0.61	1.51	1.16	23.77
C1	57-70	14.42	0.12	10.88	11.07	0.78	0.00	0.25	23.10
C2	70-100	30.20	0.16	17.62	18.05	0.81	0.46	0.00	36.63

n.d. = no data

Clay Mineralogy and Classification

A previous characterization of a soil profile a few hundred meters from the study site, conducted by a team of soil scientists from the U.S. Department of Agriculture and the Bureau of Soil and Water Management in Quezon City, revealed that the upland soil in Sta. Rita, Samar has a mixed clay mineralogy composed of montmorillonite, vermiculite and kaolinite, in that order of abundance (PCARRD 1988). The soils are mature, having argillic horizons and base saturation (BS) values by sum of cations of more than 35 percent (all the soils have more than 60 percent BS). Thus, they are classified as Typic Hapludalfs (U.S. Soil Taxonomy, 2014 edition) or Haplic Luvisols (World Reference Base or WRB).

CONCLUSIONS

The marginal upland soils evaluated were derived from mudstone. They are characterized by an Ap-Bt-BC horizon sequence and they are clayey with moderate to high porosity and water holding capacity values. The soils are friable in their surface horizons when moist, but are plastic and sticky when wet.

The soils have pH (water) values ranging from 5.20 to 6.86, indicating that soil acidity is not yet a serious problem in these soils. They have moderate soil organic matter contents in surface horizons but low amounts in subsurface horizons. Total N and available P of the soils are low and a problem for crop production. However, the soils have moderate to high exchangeable bases and cation exchange capacity values.

In terms of degree of soil development, the marginal upland soils are mature as reflected by their horizonation particularly by the presence of argillic horizons (B horizons with high clay accumulation). However, they still have high base saturation, suggesting that they are not yet highly leached and thus, are classified as Typic Hapludalfs or Haplic Luvisols.

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