*Mindanao Journal of Science and Technology Vol. 20 (1) (2022) 1-22*

# Morphophysical and Nutrient Characteristics of Degraded Soils in Sta. Rita, Samar, Philippines

Jessie R. Sabijon[1*] and Victor B. Asio[2]
[1]Department of Agriculture and Related Programs
Northwest Samar State University – San Jorge Campus
San Jorge, Samar 6707 Philippines
[*]*jessie.sabijon@nwssu.edu.ph*

[2]Department of Soil Science
Visayas State University
Baybay City, 6521 Philippines

Date received: August 9, 2020
Revision accepted: November 27, 2021

## Abstract

*The productivity of degraded soils greatly depends on a good understanding of their characteristics. Hence, the study was conducted to determine the morphological, physical and chemical characteristics of degraded soils in Sta. Rita, Samar, Philippines. Four representative soil profiles located in different physiographic positions were examined, characterized and sampled. The examination was conducted using a pit measuring approximately 1-m wide and 1-m depth. Soil samples were collected from each horizon, processed and subjected to field and laboratory analyses. Results showed that the soils were derived from sedimentary rocks (i.e., shale). Well-developed soils were found on the summit and foot slope position (horizon sequence: Ap-Bt-BC-C), while moderately developed soils were obtained in the middle slope position (horizon sequence: Ah-Bt-C). Soils had a clayey texture with moderate bulk density, porosity and water holding capacity. They were friable to firm when moist, but plastic and sticky when wet. The soils were highly acidic (soil pH close to 5.0). They had a moderate amount of organic matter, low total nitrogen (N) and low available phosphorus (P); all of which had decreased amounts with soil depth. Exchangeable bases (calcium, magnesium, potassium and sodium) were high in most soil profiles. Thus, N and P fertilization and organic matter addition are highly recommended to increase the productivity of these degraded soils. Moreover, the soils were classified as Typic Hapludalfs or Haplic Luvisols because of their development degree. They were mature with the presence of an argillic horizon (B horizon with high clay accumulation) and high base saturation.*

***Keywords****:* morphology, nutrient characteristics, soil degradation

## 1. Introduction

Soil degradation contributes to the decline in nutrient availability and the deterioration of soil's physical, chemical and biological properties, which in turn influence the ecological functions of the soils (Asio *et al.*, 2009). According to a recent report of the United Nations, almost one-third of the world's farmable land has disappeared in the last four decades due to soil degradation (Maximillian *et al*., 2019). In the Philippines, the National Action Plan for 2004 to 2010 identified soil degradation as a major threat to food security (Asio *et al*., 2009). Degraded soil is characterized by a decline in quality and a decrease in ecosystem goods and services; it is considered a major constraint in achieving the required increase in agricultural production (Lal, 2015). The success of any effort to improve the productivity of degraded soils primarily depends on the availability of information on their characteristics.

In the study of Asio *et al.* (2014), results revealed that the degraded upland soils in Inopacan, Leyte, Philippines ranged from poorly developed in the lower slopes to well-developed on the summit slope position. The soils were highly acidic (pH close to 5.0) with low organic matter, total nitrogen (N) and available phosphorus (P) contents.

Samar Island, Philippines is known to have a wide range of degraded soils that are utilized for agricultural activities. These soils have been subjected to massive degradation clearly showing pieces of evidences of low soil fertility level. This problem was initially studied and reported that the soil in the degraded upland of Sta. Rita, Samar showed a less severe degree of degradation and had low fertility status (Asio *et al*., 2015). Hence, there is an urgent need for onsite data on soil formation, nature and characteristics of degraded soils in the said area for the prediction and evaluation of the soil's response to intensive human activities and climate change, thereby improving the crop production. Several studies have 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). Studying crop production improvement in the degraded upland soil of Inopacan, Leyte, Lina *et al.* (2014) found that the application of organic fertilizer (chicken manure) significantly improved the growth and yield of corn grown. More importantly, until now, only a few studies that investigated the characteristics and fertility status and formation of soils in the Philippines were conducted and published. Therefore, this study was carried out to determine the morphological, physical and chemical characteristics of degraded soils as a basis for the formulation of appropriate and sustainable soil management strategies.

## 2. Methodology

### *2.1 Site Description and Characterization*

The study was conducted in the degraded soil of Sta. Rita, Samar, Philippines (Figure 1). The site is known to have a wide range of degraded soils that are elevated, utilized for any agricultural activities and subjected to massive soil degradation. A preliminary survey of the degraded soils was done to have a better selection and initial site characterization.

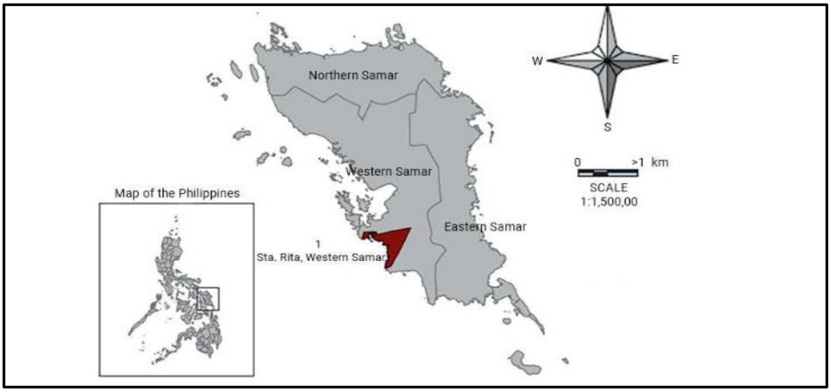


Figure 1. Map showing the study site in Barangay Caticugan, Sta. Rita, Samar

The site characterization was conducted according to the Food and Agriculture Organization of the United Nations (FAO) Guidelines for Soil Description (FAO, 2006a). The descriptions included the location, elevation, parent material(s), landform, geomorphic position, local relief, slope gradient, erosion, drainage, land-use, predominant vegetation and any field note that provided information genesis.

### *2.2 Soil Profile Characterization, Sampling, Processing and Analysis*

A pit measuring approximately 1 x 1 m with a depth of at least 1 m was excavated manually before the soil profile description and sampling. Soil profile description was done following the standard procedure of FAO Guidelines for Soil Description (Jahn *et al*., 2006). Four soil profiles from different physiographic positions (soil profile [SP]; SP1 – summit; SP2 – foot slope; SP3 – summit; and SP4 – middle slope) (Figure 2) were subjected to the detailed field and laboratory studies to evaluate their characteristics and constraints.

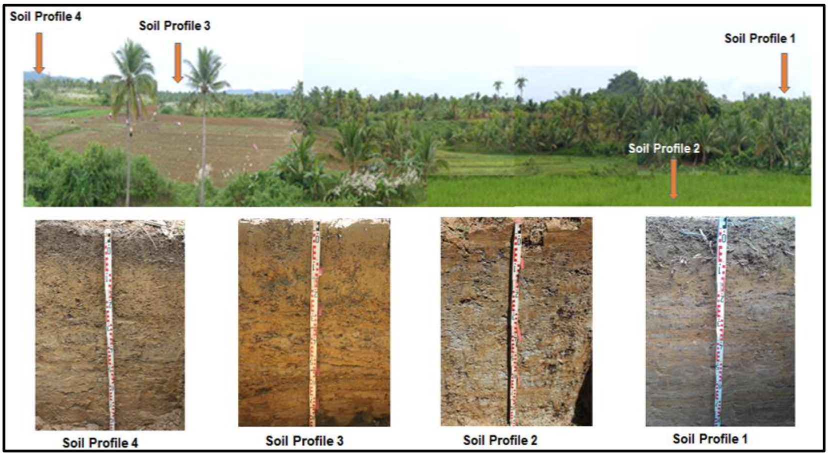


Figure 2. Location of the soil profiles characterized in the degraded soils

Soil samples were collected from each horizon of every soil profile quantitatively by taking three continuous and uniform slices from the uppermost horizon down to the lowest and mixed thoroughly following the procedure of Schlichting *et al.* (1995). Wider soil slice was collected in thin horizons to ensure that the volume of the sample was approximately equal to those from the thicker horizons. All soil samples were placed in properly labeled plastic bags. Collection of undisturbed soil samples was also done for bulk density determination and immediately brought to the screen house of the Department of Soil Science, Visayas State University, Baybay City for processing.

All soil samples were air-dried, pulverized using a wooden mallet and sieved using a 2-mm wire mesh screen to get the fine earth, which was used to obtain the soils' physical and chemical properties. For organic matter and N examination, 100 g of soil samples per horizon were ground and allowed to pass through a 0.425-mm wire mesh screen. Thereafter, soil samples were prepared and analyzed physically for bulk density (g $cm^{-3}$) using the core method; for particle size distribution, pipette method was utilized

(International Soil Reference and Information Center [ISRIC], 1995), while water holding capacity (WHC) and field capacity (FC) were ascertained by gravimetric method (Klute, 1986). Separate samples were collected using a core sampler following the core method. After which, collected soil samples were subjected to bulk density, porosity and water holding capacity tests.

Moreover, the samples underwent a chemical analysis for soil pH determination by the potentiometric method using a soil-solution ratio of 1:2.5 ($H_2O$ and KCl) (ISRIC, 1995); soil organic matter (SOM) (%) by modified Walkley Black method (Nelson and Sommers, 1982); and total N (%) through micro-Kjeldahl method (ISRIC, 1995). In addition, available P (mg $kg^{-1}$) was determined according to the Bray P-2 extraction method using 0.1N HCl and 0.03N $NH_4F$ extractant (Olsen and Sommers, 1982). In addition, exchangeable bases such as Ca, magnesium (Mg), Na and K ($cmol_c$ $kg^{-1}$) were extracted by 1N $NH_4OAc$ (pH 7.0) ammonium acetate method (ISRIC, 1995); effective cation exchange capacity ($cmol_c$ $kg^{-1}$) and exchangeable acidity ($Al^{3+}$ and $H^+$) ($cmol_c$ $kg^{-1}$) were analyzed using 1 N KCl as extractant and quantified by titrating the extracts with 0.1 N NaOH (Thomas, 1982).

## 3. Results and Discussion

### *3.1 Site Characteristics*

The characteristics of the site are shown in Table 1. The parent material of the degraded soils of the area was shale of Upper Miocene (24 million years) to Lower Pliocene (five million years) origin. The soil developed from sedimentary rocks characterized by clayey texture, yellowish-red color, slight acidity and low fertility status. The landform of the area with different physiographic positions was predominantly medium gradient hill. The area has been degraded and only small patches are used for crop production. The area was dominated by the following plants: *Melastoma malabathricum* ('Hantutuknaw'), *Imperata cylindrica* (cogon), *Chromolaena odorota* ('Hagonoy'), *Saccharum spontaneum* Linn. ('Bugang'), *Elephantopus tomentosus* ('Malasambong') and *Psidium guajava* (guava). Similarly, in the study of Asio *et al.* (2014), it was reported that the dominant vegetation of the degraded uplands of Inopacan, Leyte consisted of the same plants, including *Andropogon aciculatus* ('Amorseco') and *Calopogonium muconoides* ('Malabatong'). All of the plants mentioned can be considered as indicators of degraded soil (Asio, 2007; Asio *et al*., 2014).

Table 1. Site characteristics of the degraded soils in Sta. Rita, Samar

| Site characteristics | Soil profiles (SP) | | | |
|---|---|---|---|---|
| | SP1 | SP2 | SP3 | SP4 |
| Landform | Medium gradient hill | Medium gradient hill | Medium gradient hill | Medium gradient hill |
| Physiographic position | Summit | Foot slope | Summit | Middle slope |
| Slope gradient | Nearly level | Level | Nearly level | Gently sloping |
| Coordinates | 11° 19.770’ N 125° 00.585’ E | 11° 19.803’ N 125° 00.481’ E | 11° 19.891 ’N 125° 00.505 ’E | 11° 19.966’ N 125° 00.466’ E |
| Elevation | 30 m | 20 m | 25 m | 22 m |
| Parent material | Shale | Shale | Shale | Shale |
| Soil moisture regime | Isohyperthermic | Isohyperthermic | Isohyperthermic | Isohyperthermic |
| Soil temperature regime | Udic | Aquic | Udic | Udic |
| Erosion | Slight | None | Slight | Evident |
| Rock outcrops/ stoniness | None | None | None | None |
| Drainage | Good | Poor | Good | Good |
| Land use | Agricultural | Agricultural | Agricultural | Grassland |
| Vegetation | *C. nucifera, C. odorata, S. malabathricum* | *Oryza sativa* | *C. odorata, P. guajava, I. cylindrica* | *S. spontaneum, C. odorata, I. cylindrica* |

### *3.2 Morphological Characteristics*

The morphology of the degraded soils in the area varied with the physiographic positions (Table 2). The site had well-developed soils found on the summit (SP1 and SP3) and in the foot slope (SP2) positions with the horizon sequence of Ap-Bt-BC-C and Apg to Bwg, respectively, while moderately developed soils occurred in the middle slope positions (SP4) (horizon sequence: Ah-Bt-C). In the same vein, Asio *et al.* (2014) found that the degraded upland soils in Inopacan, Leyte have well-developed soils on the summit (horizon sequence: Ap-Bt-BC) and poorly developed soils in backslope and toeslope (horizon sequence: Ap-AB-Bw-BC) positions. Likewise, based on the initial study of Asio *et al.* (2015), degraded soils in Sta. Rita were well-developed possessing an Ap-AB-Bt-C horizonation.

Table 2. Morphological characteristics of degraded soils in Sta. Rita, Samar

| Soil[A] horizon | Depth (cm) | Boundary[B] | Soil color (Munsell color-moist) | Texture[C] | Structure[D] | Consistence[E] | | Roots[F] | Mottles[G] | Rock[H] fragments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Moist | Wet | | | |
| SP1 (Summit - Agricultural) | | | | | | | | | | |
| Ah | 0-15 | cw | 10YR 5/3 (brown) | SiCL | 2cg | fr | s&p | cm | o | o |
| Bt | 15-30 | cs | 10YR 5/6 (yellowish brown) | C | 2csbk | f | s&p | fem | o | o |
| C1 | 30-50 | di | 10YR 5/6 (yellowish brown) | C | 2msbk | f | s&p | vfem | o | o |
| C2 | 50-70 | di | 10YR 5/6 (yellowish brown) | C | 2msbk | f | s&p | o | o | o |
| R | > 70 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| SP2 (Foot slope - Agricultural) | | | | | | | | | | |
| Apg | 0-15 | m | 10YR 3/6 (dark yellowish brown) | C | m | vf | vs&vp | cfi | mfi | o |
| Bwg1 | 15-40 | di | 10YR 4/3 (dark brown) | C | 3csbk | vf | vs&vp | vfefi | cm | o |
| Bwg2 | 40-70 | di | 10YR 7/1 (light gray) | C | 3csbk | vf | vs&vp | vfevfi | cm | o |
| Bwg3 | 70-100 | | 10YR 7/1 (light gray) | C | 3csbk | vf | vs&vp | o | cm | o |
| SP3 (Summit - Agricultural) | | | | | | | | | | |
| Ap | 0-15 | cs | 10YR 6/4 (light yellowish brown) | C | 2csbk | f | s&p | cfi | cc | o |
| Bt | 15-30 | cw | 10YR 5/4 (yellowish brown) | C | 2csbk | f | s&p | fevfi | cfi | o |
| BC | 30-57 | cs | 10YR 5/8 (yellowish brown) | SCL | 1fsbk | fr | ss&sp | fevfi | cfi | o |
| C1 | 57-70 | cw | 10YR 5/8 (yellowish brown) | SCL | 1fsbk | fr | ss&sp | o | o | o |
| C2 | 70-100 | | 10YR 5/8 (yellowish brown) | SCL | 1msbk | fr | ss&sp | o | o | o |
| SP4 (Middle slope - Grassland) | | | | | | | | | | |
| Ah | 0-10 | cs | 10YR 4/2 (dark grayish brown) | SL | 2mg | fr | s&p | cfi | o | o |
| Bt | 10-30 | cw | 10YR 5/4 (yellowish brown) | SC | 2msbk | f | s&p | cvfi | o | o |
| C1 | 30-50 | di | 10YR 5/6 (yellowish brown) | SCL | 2msbk | f | ss&sp | vfevfi | o | o |
| C2 | 50-70 | di | 10YR 6/3 (pale brown) | C | 2msbk | f | ss&sp | vfevfi | o | o |
| R | > 70 | nd | nd | nd | nd | nd | nd | nd | nd | nd |

[A] according to FAO (2006b); [B] – cw – clear wavy, cs – clear smooth, gs – gradual smooth, di – diffuse; [C] SC – sandy clay, C – clay, SL – sandy loam, SCL – sandy clay loam, SiC – silty clay; [D] 1 – weak, 2 – moderate, 3 – high, f – fine, m – medium, c – coarse, sbk – sub-angular blocky, g – granular, [E] fr – friable, f – firm, vf –very firm, s – sticky, ss – slightly sticky, p – plastic; sp – slightly plastic; [F] cm – common medium, fem – few medium, cfi – common fine, cvfi – common very fine, fevfi – few very fine, vfevfi – very few very fine; [G] mfi – many fine, cm – common medium, cc – common coarse, cfi – common fine; [H] – vfe – very few; fe – few; m – many; o – none; nd – not determined

In terms of color development, SP1 and SP3 had colors ranging from brown to light yellowish-brown in the surface and yellowish-brown in the subsurface horizon. Similarly, it was previously observed that the color of the degraded soils in the area was dark yellowish-brown in the surface and light yellowish-brown in the subsurface (Asio *et al.*, 2015). SP2 had colors ranging from dark yellowish-brown to light gray indicating a poorly drained soil that resulted in a reduced form of iron (Fe) oxides linked to the absence of oxygen. The observed grayish soil was mainly due to the inherent characteristics of land converted into a rice field. Grayish color is commonly observed when the amount of water is tightly held by the soil leading to Fe reduction. The grayish color of the soil in SP2 was also attributed to slowly decomposing organic materials from rice, which were deposited in the soil's surface. Likewise, paddy soil was very dark grayish-brown and dark gray in the surface and dark brown in the subsurface (Sarker, 2018).

On the other hand, SP4 showed a humus-induced color of the surface horizon that is dark grayish-brown and slightly, poorly drained subsurface horizon with pale-brown color. The lighter hue or the yellowish-brown soils was due to the abundance of Fe oxides primarily hematite and goethite, which are important weathering products in the soil. In addition, the dark color indicates the effect of the amount and type of organic matter (humus) deposited in the soil and the type of parent material and the composition of weathering products (Shoji *et al.*, 1993). Soil color may also reflect the landscape positions of the sites and indicate soil fertility.

Results also revealed that SP1 and SP4 had a granular structure in the surface because of the humus accumulation and aggregate stability with a sub-angular blocky and massive structure in the subsurface horizon. All other profiles had massive structure and sub-angular blocky in the surface horizon and sub-angular blocky in the subsurface horizon. The surface horizon in SP2 and SP3 had a massive soil structure because of the plowing activities that destroy the soil aggregates.

Moreover, the structure of the soils derived from shale (SP1 and SP2) and the shale mixed with sandstone (SP3 and SP4) with a sub-angular blocky structure in the subsurface (B horizon) is commonly observed in tropical soils. Correspondingly, degraded soils in the uplands of Inopacan, Leyte were found to have a weak sub-angular blocky structure in the surface and moderate sub-angular blocky structure in the subsurface horizon for SP1, SP2, SP3 and SP5 while SP4 had a massive structure due to the influence of plowing (Asio *et al.*, 2014).

In general, the degraded soils in Sta. Rita, Samar had friable consistency and firm consistency in the surface and subsurface horizons, respectively. All soils were sticky to very sticky and plastic to very plastic with depth. Likewise, soil with a sticky and plastic consistency was observed in the other upland parts of Sta. Rita (Asio *et al*., 2015). This observed high stickiness and plasticity of the soil could be ascribed to its origin derived from shale parent materials containing a high amount of clay. Other morphological features described in the profiles had medium to fine roots in the surface horizons and very fine to fine roots in the lower horizons. There was also a small volume of rock fragments observed in the surface horizon, which are common, and high volume in the lower horizons.

### *3.3 Physical Characteristics*

Table 3 presents the physical characteristics of the degraded soils of the area. The soils were medium-textured in SP1 and SP2 containing a high amount of clay, moderate silt and low sand that gave silty-clayey to clayey texture in the surface. The subsurface horizon also indicated a very high amount of clay, moderate values of silt and a very low amount of sand. Meanwhile, SP3 and SP4 exhibited a moderate amount of clay, high content of sand and low content of silt. The results can be attributed to the contribution of mixed composition of sedimentary nature of parent material, specifically shale. A medium-textured soil was noticed in the degraded upland soils in Inopacan, Leyte (Asio *et al*., 2014) and in some other parts of Sta. Rita, Samar (Asio *et al*., 2015).

The high clay content of the soils was probably inherited from the shale parent material rather than from the neoformation of clay from weathering processes. The increasing clay with depth in SP1, SP3 and SP4 suggested clay accumulation through clay illuviation and in situ weathering of the shale parent material. This likewise demonstrated the important role of weathering of parent material in young to moderately weathered soils that contributed to the high clay content in the soil. It was greatly affected by the clay content and soil structure (Hillel, 2004). This may be due to the Type IV climate of the study site where rainfall is more or less evenly distributed throughout the year with an average annual rainfall of 2,545 mm. This climate type closely resembles the Type II climate since it has no dry season.

On the other hand, the increase of clay content in SP2 was caused by the inherent effect of parent material through weathering events. In contrast, the increase in clay in the rice field was associated with the clay illuviation because of rice cultivation. In the study of Bahmanyar (2007), it was observed that no illuviation and eluviation of clay minerals occurred as a consequence of rice cultivation.

Results also showed that soils had a higher bulk density ranging from 1.30 to 1.50 g $cm^{-3}$. It was observed that SP1, SP3 and SP4 had a lower bulk density values in the surface horizons compared with sub-surface horizons. The lower bulk density values in the surface horizons may be attributed to the high organic matter coming from the decomposed root system of grasses as well as the contribution from the tree leaf litters (Navarrete *et al*., 2000). A lower bulk density values of surface soils suggested better soil aggregation leading to better aeration. SP2 had a higher bulk density value in the surface horizon and subsurface horizon. This was enhanced due to frequent plowing of the surface soil in the rice field.

Furthermore, increasing bulk density values on the subsurface horizons in all profiles were due to the weight of overlying layers, lower organic matter and the presence of partially weathered and unweathered rock or parent material and higher clay content. This observation was in accordance with the study of Brady and Weil (2002), who highlighted that long-term cultivation tended to lower total porosity and increase bulk density because of the decrease in SOM and large peds. Meanwhile, the porosity values of the SP1, SP3 and SP4 were relatively higher in the surface horizons than in the subsurface horizons. They had relatively higher porosity values which ranged from 51% (surface) to 47% (subsurface) and decreasing percentages of pore spaces with depth. This observation was ascribed to the humus which gave a large number of pore spaces and higher surface area. SOM can hold and retain large quantities of pores and has been shown to increase infiltration and porosity (Carter, 2002).

Some instances happened that percent porosity in the surface resembles the percent porosity in the subsurface. However, SP2 had lower porosity values in the surface and subsurface horizons. This can be explained by the data in Table 3, which shows that soils in the rice field exhibited higher bulk density resulting in relatively lower porosity of the soil. This may be attributed to the anthropogenic compaction of soil surfaces such as cultivation and foot markings. Long-term cultivation lowers total porosity because of the decrease in SOM and large peds (Brady and Weil, 2002).

Table 3. Physical characteristics of degraded soils in Sta. Rita, Samar

| Soil profile/ horizon | Depth (cm) | PSA (%) | | | Textural class | Bulk density (g $cm^{-3}$) | Porosity (%) | Field capacity (%) | Water holding capacity (%) | Available water (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | | | | | |
| SP1 (Summit - Agricultural) | | | | | | | | | | |
| Ah | 0-15 | 6.32 | 48.64 | 45.03 | Silty clay | 1.30 | 51.00 | 21.44 | 39.13 | 17.69 |
| Bt | 15-30 | 12.72 | 23.34 | 63.94 | Clay | 1.50 | 43.00 | 22.40 | 33.82 | 11.42 |
| C1 | 30-50 | 12.97 | 18.70 | 68.33 | Clay | 1.50 | 43.00 | nd | nd | nd |
| C2 | 50-70 | 11.11 | 13.72 | 75.17 | Clay | 1.50 | 43.00 | nd | nd | nd |
| SP2 (Foot Slope - Agricultural) | | | | | | | | | | |
| Ap | 0-15 | 2.17 | 30.96 | 66.87 | Clay | 1.50 | 43.00 | 19.24 | 41.45 | 22.21 |
| Bwg1 | 15-40 | 5.34 | 21.55 | 73.10 | Clay | 1.50 | 43.00 | 17.75 | 37.86 | 20.11 |
| Bwg2 | 40-70 | 5.67 | 19.69 | 74.65 | Clay | 1.50 | 43.00 | nd | nd | nd |
| Bwg3 | 70-100 | 5.48 | 19.94 | 74.58 | Clay | 1.50 | 43.00 | nd | nd | nd |
| SP3 (Summit - Agricultural) | | | | | | | | | | |
| Ap | 0-15 | 29.31 | 17.73 | 52.96 | Clay | 1.30 | 51.00 | 20.98 | 42.62 | 21.64 |
| Bt | 15-30 | 24.60 | 20.16 | 55.24 | Clay | 1.30 | 51.00 | 21.09 | 38.90 | 17.81 |
| BC | 30-57 | 50.60 | 14.88 | 34.52 | Sandy clay | 1.40 | 47.00 | nd | nd | nd |
| C1 | 57-70 | 57.79 | 5.30 | 36.90 | Sandy clay | 1.40 | 47.00 | nd | nd | nd |
| C2 | 70-100 | 63.35 | 6.15 | 30.50 | Sandy clay loam | 1.40 | 47.00 | nd | nd | nd |
| SP4 (Middle Slope - Grassland) | | | | | | | | | | |
| Ah | 0-15 | 71.13 | 12.89 | 15.98 | Sandy loam | 1.30 | 51.00 | 25.48 | 33.60 | 8.12 |
| Bt | 15-30 | 57.98 | 6.49 | 35.54 | Sandy clay | 1.50 | 43.00 | 22.56 | 32.77 | 10.21 |
| C1 | 30-50 | 52.05 | 6.41 | 41.54 | Sandy clay | 1.40 | 47.00 | nd | nd | nd |
| C2 | 50-70 | 42.16 | 13.64 | 44.20 | Clay | 1.40 | 47.00 | nd | nd | nd |

w – cambic horizon, t – argillic horizon, h – humus, p – plowed layer, g – stagnic property, nd – not determined

On the other hand, degraded soils in Sta. Rita, Samar exhibited moderate water holding capacity (32.77-32.39%) and relatively higher field capacity (17.75-25.48%). Higher available water in all soils was also observed. The increase in values can be explained by the high amount of clay that influenced the moisture retention of the soil. The amount of moisture retained in the soil is increased when soil is high in clay content. The same result was obtained in the study of Pathak *et al.* (2002) wherein the moisture retained by the soil increased with an increased clay content. In addition, it was observed that the surface horizon held more water than the subsurface or more or less similar in moisture content because of the high amount of organic matter accumulated in the soil. Similar to clay, SOM can hold and retain large quantities and increase water holding capacity, infiltration and porosity (Carter, 2002). Likewise, the higher the SOM content, the greater is the water storage capacity of the soil (Wang *et al*., 2013).

### *3.4 Nutrient Characteristics*

#### 3.4.1 Soil pH

Soil pH expresses the activity of hydrogen in the soil solution that affects the availability of mineral nutrients to the plants. Results revealed that most soil profiles had pH values in water that were within the range of 5.0-7.0 (Figure 3). The soils were strongly and slightly acidic which could limit the growth and development of the plants. The pH using KCl showed extremely acidic and very strongly acidic values (3.70 to 4.84). The observed values indicated generally acidic soil reaction, which is less favorable to the growth and development of most crops (Landon, 1991).

The results suggested that acidification occurs with crop cultivation which can be expected because of the losses of nutrients due to crop removal. Acidification indicates that soil pH can be an indicator of chemical soil degradation. However, the native plants on the site appeared to be growing well which demonstrated that they could cope with the acidic condition of the soil in the degraded uplands (Asio *et al*., 2014, 2015). It was also shown that soil pH levels in other profiles increased with depth – surface horizon had lower pH or more acidic than the subsurface horizons. The higher acidity of the surface horizon can be due to the higher amount of organic matter from leaf litter and other organic materials. The decomposition of these organic materials produced organic and inorganic acids, thereby lowering the pH (Genenew, 2008).

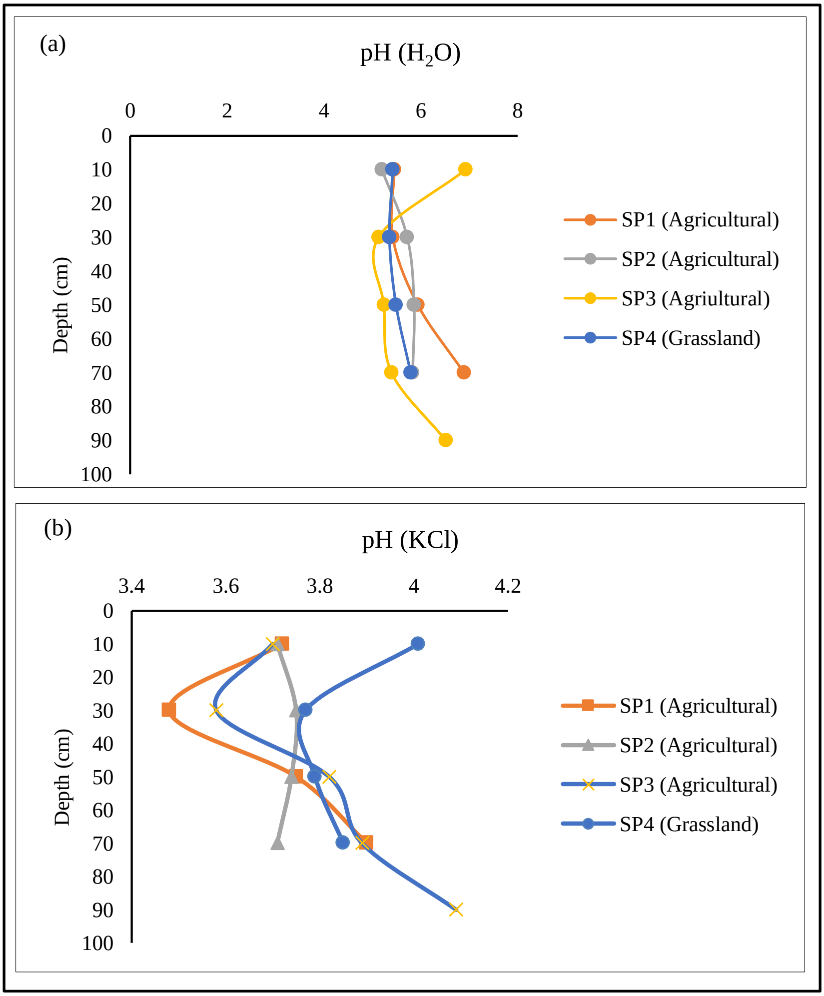


Figure 3. Depth function of pH ($H_2O$) (a) and KCl (b) values of the degraded soils in Sta. Rita, Samar

3.4.2 SOM and Total N

Schaeffer (2015) highlighted that SOM is essential for the stability and ecosystem services of soils. Nitrogen plays a critical role in the growth and development of a certain plant. Figures 4 and 5 show that the surface horizons of all soils contained considerably higher organic matter and N than the subsurface horizons. The surface soil contained a higher percent organic matter (2.8 to 4.5%), while the subsurface horizons had a lower percentage (0.3 to 0.7%). The values explained that degraded soils possessed very low N content, which is unsuitable for crop production based on the criteria used for describing the level of nutrients in the soil (Landon, 1991). The higher organic matter in the surface can be expected considering that organic matter comes from the residue of plants and animals living in the surface soil. The high percentage of organic matter in the surface horizon promotes darker color and better aggregation (Genxu *et al*., 2004).

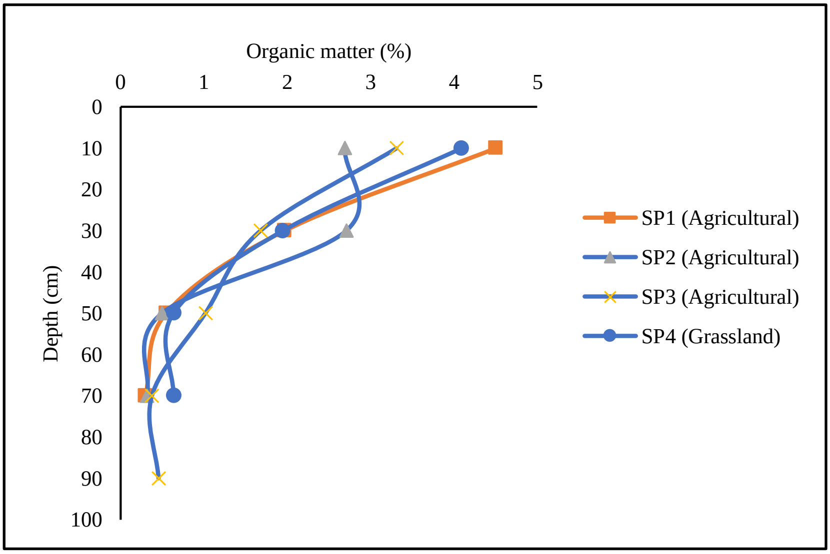


Figure 4. Depth function of percent organic matter of the degraded soils in Sta. Rita, Samar

Meanwhile, the soils had relatively low N content (0.17 to 0.22%) in the surface horizon and the subsurface horizon (0.06 to 0.10%). The result implied that N application is needed to improve soil fertility and increase crop yield. The result agrees that total N content of all soil profiles in the degraded soils were relatively high at the surface and decreased with depth following a similar trend to that of the organic matter content (Asio *et al*., 2014, 2015).

There was variation among the SOM and total N with physiographic positions because of the differences in vegetation cover, land use and human activities among sites. Nevertheless, it was found that when organic matter increased, the total N also increased and vice versa. The close agreement between the behavior of total N and organic matter can be explained by the fact that more than 95% of N is bound to the organic substance (Pagel *et al*., 1982).

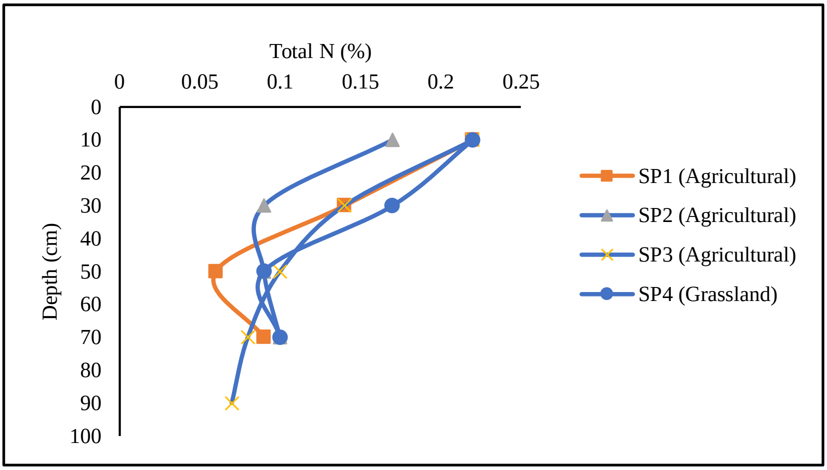


Figure 5. Depth function of total N of the degraded soils in Sta. Rita, Samar

### 3.4.3 Available Phosphorus

In all soils, the availability of P was relatively low, which is not suitable for crop production (Table 4). The availability of P (< 3 mg $kg^{-1}$) in all soils was notably below the suitable amounts of 8 to 15 mg $kg^{-1}$ (Landon 1991) suggesting that P was the limiting nutrient in these degraded soils (Navarrete *et al*., 2007; Navarrete and Tsutsuki, 2008). The trend observed was an increase of P content in SP1 and SP3 in the subsurface horizon. This was due to the availability and exposure of the parent rock in the subsurface horizon.

The available phosphorus in SP2 and SP4 decreased with depth. The low P availability in the SP2 and SP4 was ascribed to the low P content of the parent material by the alkaline or acidic chemical condition of the soils to the reaction of P with noncrystalline Al and Fe oxides resulting in the formation of insoluble metal-P compounds (Shoji *et al*., 1993). Likewise, acidic soils have a high P-fixing capacity leading to limited P supply for the crops (Thomas *et al*., 1999).

Moreover, P content can also be an inherent characteristic of the parent material that influences the amount of P that is either released during weathering and retained in soils or lost through leaching and erosion (Yang *et al*., 2013). Hence, the results demonstrated that P application is crucial to the management of the degraded soils since it is not added through rainfall or there is no natural source except for the mineral apatite in the soil.

### 3.4.4 Exchangeable Bases, Acidity and Effective Cation Exchange Capacity

Exchangeable bases reflect the contribution of parent material and the influence of soil management practices. The amounts of exchangeable bases regulate the soil's pH; thus, they are important factors of soil fertility. The amount of exchangeable calcium (Ca), Mg, potassium (K) and sodium (Na) were determined by $NH_4OAc$ (pH7) with values given in Table 4. The amounts of the exchangeable Ca, Mg and Na were relatively higher but exchangeable K in all soils was low. The values ranged from 1.96 to 24.10 $cmol_c\ kg^{-1}$ soil Ca; 3.68 to 18.05 $cmol_c\ kg^{-1}$ soil Mg; 0.38 to 0.96 $cmol_c\ kg^{-1}$ soil Na; and 0.02 to 0.27 $cmol_c\ kg^{-1}$ soil K. In a similar study, it was reported that the soils in the degraded uplands in Inopacan, Leyte contained a high amount of exchangeable Ca, Mg and Na with exchangeable K (Asio *et al*., 2014).

Results indicated that these exchangeable nutrients were not a limiting factor for crop production. The observed higher values of the exchangeable bases can be attributed to the contribution of the parent material particularly feldspar, which is an important source of these nutrient elements. It was noticed that these nutrients increased with increasing depth of the soil profile. It can also be noted that the levels of the exchangeable bases in the soil profiles varied considerably between soils. As can be seen from the results, their relative amounts follow the order: Ca > Mg > Na > K. In addition, very high percent base saturation in all degraded soils of the area was observed (Table 4). This was due to the evidently considerable content of exchangeable bases in all the soil profiles. This suggested the contribution of parent material to the exchangeable base status of the soils. These results may also be explained by the impact of land use and soil management practices employed.

Table 4 presents the values for exchangeable acidity and effective cation exchange capacity (CEC eff.). The exchangeable Al and H were relatively higher in all soils. The amount of exchangeable Al with depth corresponded to the decrease of pH-$H_2O$ and pH-KCl. Asio *et al.* (1992) reported that exchangeable $Al^{3+}$ increased considerably below pH 5.0 in both $H_2O$ and in $CaCl_2$ at a 1:1 soil/solution ratio. The increase in $Al^{3+}$ could be linked to the active aluminum oxides that can boost soil acidity by releasing Al-ion. The result indicated that under acid conditions, $Al^{3+}$ is the major cation in the soil (Kamprath, 1980).

Table 4. Other chemical properties of the degraded soils in Sta. Rita, Samar

| Soil profile/horizon | Depth (cm) | Available P (mg/kg) | Exchangeable K | Ca | Mg | Na | $H^+$ | $Al^{3+}$ | Eff. CEC | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cmol$_c$ kg$^{-1}$ soil) | | | | | | | |
| SP1 (Summit - Agricultural) | | | | | | | | | | |
| Ah | 0-15 | 0.26 | 0.27 | 6.55 | 10.53 | 0.69 | 1.56 | 0.96 | 20.56 | 87.7 |
| Bt | 15-30 | < 0.001 | 0.08 | 7.81 | 10.98 | 0.68 | 5.91 | 1.00 | 26.46 | 73.9 |
| C1 | 30-50 | < 0.001 | 0.04 | 9.50 | 11.22 | 0.66 | 1.44 | 1.00 | 23.86 | 89.8 |
| C2 | 50-70 | 69.42 | 0.03 | 18.32 | 16.19 | 0.65 | 0.47 | 0.00 | 35.66 | 98.7 |
| SP2 (Foot slope - Agricultural) | | | | | | | | | | |
| Ap | 0-15 | 0.41 | 0.13 | 8.23 | 7.67 | 0.38 | 1.12 | 0.66 | 18.19 | 90.2 |
| Bw1 | 15-40 | < 0.001 | 0.07 | 11.47 | 12.12 | 0.67 | 0.72 | 0.00 | 25.05 | 97.1 |
| Bw2 | 40-70 | 0.04 | 0.07 | 12.98 | 14.67 | 0.96 | 0.37 | 0.00 | 29.05 | 98.7 |
| Bw3 | 70-100 | 0.06 | 0.08 | 12.21 | 15.45 | 1.01 | 0.48 | 0.00 | 29.23 | 98.4 |
| SP3 (Summit - Agricultural) | | | | | | | | | | |
| Ap | 0-15 | 0.18 | 0.15 | 1.96 | 3.68 | 0.41 | 1.44 | 1.00 | 8.64 | 71.7 |
| Bt | 15-30 | < 0.001 | 0.06 | 3.44 | 4.87 | 0.42 | 2.55 | 1.02 | 12.36 | 71.1 |
| BC | 30-57 | < 0.001 | 0.26 | 10.34 | 11.39 | 0.61 | 1.51 | 0.75 | 24.86 | 90.9 |
| C1 | 57-70 | 14.42 | 0.12 | 10.88 | 11.07 | 0.78 | 0.00 | 0.25 | 23.10 | 98.9 |
| C2 | 70-100 | 30.20 | 0.16 | 17.62 | 18.05 | 0.81 | 0.46 | 0.00 | 37.10 | 98.8 |
| SP4 (Middle Slope - Grassland) | | | | | | | | | | |
| Ap | 0-15 | 0.36 | 0.11 | 8.95 | 4.83 | 0.46 | 0.65 | 0.33 | 15.33 | 93.6 |
| Bt | 15-30 | 0.18 | 0.04 | 7.63 | 4.29 | 0.50 | 0.59 | 0.46 | 13.51 | 92.2 |
| C1 | 30-50 | < 0.001 | 0.02 | 18.35 | 7.95 | 0.90 | 0.60 | 0.07 | 27.89 | 97.6 |
| C2 | 50-70 | < 0.001 | 0.08 | 24.10 | 10.32 | 0.70 | 0.66 | 0.60 | 36.46 | 96.5 |

Moreover, cation exchange capacity (CEC) is defined as the sum total of exchangeable cations such as K, Na, Ca and Mg present in the soil expressed in $cmol_c\ kg^{-1}$ soil. The most useful measure of cation retention capacity is CEC eff.. Likewise, Driessen and Dudal (1991) pointed out that CEC eff. represents the CEC at field conditions; hence, it is of great practical importance, particularly in plant nutrition. This is a distinctive property of the soil as it affects reactions and interactions of elements and nutrients present in the soil. With its importance, results showed that the soil exhibited a relatively low to a high amount of CEC eff. with a value range from 8.64 to 37.10 $cmol_c\ kg^{-1}$. The soils also contained high amount of percent base saturation as affected by a considerable amount of exchangeable bases present in the soil.

Results implied that soils had a higher amount of readily exchangeable nutrients for plant uptake and utilization. Due to the clay-rich nature of the degraded soils, higher surface area or negative charges was available for cation exchange reaction. The finer texture of the soil, the higher the negative charges, the higher the amount of exchangeable nutrients is readily available for plant utilization.

## 4. Conclusion and Recommendation

The degraded soils evaluated were derived from sedimentary rocks, particularly shale. They were moderate to well-developed soils characterized by an Ap-Bt-BC-C horizon sequence on the summit, Apg-Bwg horizon sequence in the middle slope and Ap-Bt-BC in the foot slope. Most soils had clayey texture, moderate bulk density, low to moderate porosity and high-water holding capacity. The soils were friable in the surface horizons when moist but plastic and sticky when wet. On the other hand, the soils were slightly acidic indicating that soil acidity is not yet a serious problem for crop production. The soils had a moderate amount of organic matter in the surface horizon and low in the subsurface horizons. They had low total N and low available P contents which can be a problem in crop production. However, the soils had moderate to high exchangeable bases and cation exchange capacity values. In terms of the degree of soil development, the soils were mature as reflected by their horizonation, particularly by the presence of argillic horizons (B horizons with high clay accumulation). However, they still had high base saturation suggesting that they are not yet highly leached; hence, they are classified as Typic Hapludalfs or Haplic Luvisols.

With the low N and P contents of the studied soils, it is recommended to conduct a constant assessment and monitoring of these soils. There is also a need to provide an efficient and effective measure to mitigate soil degradation by implementing appropriate and desirable soil management strategies including cover cropping, natural vegetative strips, planting indigenous tree species and acid-tolerant crops, and organic fertilization.

## 5. Acknowledgement

The authors would like to acknowledge the Commission on Higher Education, Philippine Higher Education Network (CHED – PHERNET) for the financial support given to this research with Dr. Victor B. Asio as the Project Leader of the project titled “Soil and Environmental Quality Evaluation of Marginal Uplands” (SEQUEMU).

## 6. References

Asio, V.B., Armecin, R.B., & Bautista, A.T. (1992). Relationship between exchangeable aluminum and pH in some acidic Philippine soils. Philippine Journal of Science, 121(4), 383-390.

Asio, V.B. (2007). Characteristics, fertility status, and management of degraded upland soils in Leyte. Laguna, Philippines: Philippine Agricultural Resources Research Foundation Incorporated (PARRFI).

Asio, V.B., Jahn, R., Perez, F.O., Navarrete, I A., & Abit, S.M., Jr. (2009). A review of soil degradation in the Philippines. Annals of Tropical Research, 31(2), 69-94.

Asio, V.B., Lina, S.B., Maranguit, D.S., Bolledo, A.B., Doguiles, R.T., Quiñones, C.M.O., Sabijon, J.R., & Demain, K.L.B. (2014). Characteristics of Soils in the Marginal Uplands of Inopacan, Leyte. Annals of Tropical Research 36(Supplement), 1-15.

Asio, V.B., Demain, K.L.B., Olguera, D.T., & Villasica, L.J.D. (2015). Characteristics and and nutrient status of two degraded upland soils in Samar, Philippines. Annals of Tropical Research, 37, 142-166

Bahmanyar, M.A. (2007). The influence of continuous rice cultivation and different waterlogging periods on morphology, clay mineralogy, Eh, pH and K in paddy soils. Pakistan Journal of Biological Sciences, 10(17), 2844-2849.

Bigges, A. (2007). The landscape and marginal cropping lands-inherent and induced. Tropical Grasslands, 41(3), 133.

Brady, N.C., & Weil, R.R. (2002). The nature and properties of soils (13$^{th}$ ed.). New Jersey, United States: Pearson Education, Inc.

Carter, M.R. (2002). Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agronomy Journal, 94(1), 38-47. https://doi.org/10.2134/agronj2002.3800

Driessen, P.M., & Dudals, R. (1991). The major soils of the world. Lecture notes on their geography, formation, properties, and use. Wageningen, the Netherlands: Agricultural University of Wageningen and Katholieke Universiteit Leuven.

Food and Agriculture Organization of the United Nations (FAO). (2006a). Guidelines for soil description (4$^{th}$ ed.) Rome, Italy: FAO.

Food and Agriculture Organization of the United Nations (FAO). (2006b). World reference base for soil resources 2006. Rome, Italy: FAO

Genxu, W., Haiyan, M., Ju, Q., & Juan, C. (2004). Impact of land use changes on soil carbon, nitrogen and phosphorus and water pollution in an arid region of northwest China. Soil Use and Management, 20(1), 32-39. https://doi.org/10.1111/j.1475-2743.2004.tb00334.x

Hillel, D. (2004). Introduction to environmental soil physics. United States: Elsevier.

International Soil Reference and Information Center (ISRIC). (1995). Procedures for soil analysis. Wageningen, The Netherlands: ISRIC and Food and Agriculture Organization of the United Nations.

Jahn, R., Blume, H.P., Asio, V.B., Spaargaren, O., & Schad, P. (2006). Guidelines for soil and description (4$^{th}$ ed.). Italy, Rome: Food and Agriculture Organization of the United Nations.

Kamprath, E. (1980). Soil acidity in well-drained soils of the tropics as a constraint to food production. Priorities for alleviating soil-related constraints to food production in the tropics. Los Baños, Laguna, Philippines: International Rice Research Institute.

Klute, A. (1986). Methods of soil analysis part 1: Physical and mineralogical (2$^{nd}$ ed.) Wisconsin, United States: American Society of Agronomy Inc. and Soil Science of America, Inc.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. Sustainability, 7(5), 5875-5895. https://doi.org/10.3390/su7055875

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. Geoderma, 123(1-2), 1-22. https://doi.org/10.1016/j.geoderma.2004.01.032

Landon, J.R. (1991). Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Essex, England: Longman Scientific and Technical Group.

Lina, S.B., Maranguit, D.S., Asio, V.B., Sabijon, J.R., Demain, K.L.B., & Bolledo, A. B. (2014). Growth performance of corn as influenced by the combined application of organic and inorganic fertilizers in a marginal upland soil. Annals of Tropical Research, 36(Supplement), 16-29.

Maximillian, J., Brusseau, M.L., Glenn, E.P., & Matthias, A.D. (2019). Pollution and environmental perturbations in the global system. In: M.L. Brusseau, C.P. Gerba & I.L. Pepper (Eds.), Environmental and pollution science (pp. 457-476). London, United Kingdom: Academic Press.

Navarrete, I.A., Asio, V.B., Jahn, R., & Tsutsuki, K. (2007). Characteristics and genesis of two strongly weathered soils in Samar, Philippines. Australian Journal of Soil Research, 45(3), 153-163. https://doi.org/10.1071/SR06103

Navarrete, I., Asio, V., Balbarino, E., & Tulin, A. (2000). The physicochemical properties of rhizosphere soil of vetiver grass grown in a degraded upland. Grassland Society of the Philippines Journal, 4, 29-34.

Navarrete, I.A., & Tsutsuki, K. (2008). Land-use impact on soil carbon, nitrogen, neutral sugar composition and related chemical properties in a degraded Ultisol in Leyte, Philippines. Soil Science and Plant Nutrition, 54(3), 321-331. https://doi.org/10.1111/j.1747-0765.2008.00244.x

Nelson, D.W., & Sommers, L.E. (1982). Methods of soil analysis (Part 2). Wisconsin, United States: American Society of Agronomy-Soil Science Society of America.

Olsen, S.R., & Sommers, L.E., (1982). Methods of soil analysis, Part 1. Wisconsin, United States: American Society of Agronomy-Soil Science Society of America.

Pagel, H., Enzmann, J., & Mutscher, H. (1982). Pflanzennährstoffe in tropischen Böden - ihre Bestimmung und Bewertung. Berlin, Gemany: VEB Deutscher Landwirtschaftsverlag.

Pathak, P., Wani, S.P., Singh, P., Sudi, R., & Rao, C.S. (2006). Hydrological characterization of benchmark agricultural watersheds in India, Thailand, and Vietnam. Journal of SAT Agricultural Research, 2(1), 1-47.

Sarker, K.R., Mian, M.J.A., Barman, S.C., & Kader, M.A. (2018). Effects of land use on soil properties. International Journal of Natural and Social Sciences, 5(1), 7-14.

Schaeffer, A., Nannipieri, P., Kästner, M., Schmidt, B., & Botterweck, J. (2015). From humic substances to soil organic matter-microbial contributions. In honour of Konrad Haider and James P. Martin for their outstanding research contribution to soil science. Journal of Soils and Sediments, 15(9), 1865-1881. https://doi.org/10.1007/s11368-015-1177-4

Schlichting, E., Blume, H.P., & Stahr, K. (1995). Bodenkundlichespractkum (2nd ed). Berlin, Germany: Blackwell.

Shoji, S., Nanzyo, M., & Ahlgren, R.A. (1993). Volcanic ash soils. Genesis, properties and utilization. Developments in Soil Science 21. Amsterdam, Netherlands: Elsevier.

Genenew, T. (2008). Assessment of soil acidity in different land use types: The case of Ankesha Woreda, Awi Zone, Northestern Ethiopia (Thesis). Addis Ababa University, Ethiopia.

Thomas, G.W. (1982). Exchangeable cations. In A.L. Page (Ed.), Methods of soil analysis, part II. Chemical and microbiological Properties (2nd ed., pp. 159-165). Wisconsin, United States.

Thomas, R.J., Ayarza, M., & Lopes, A.S. (1999). Management and conservation of acid soils in the savannahs of Latin America: Lessons from the agricultural development of the Brazilian cerrados. Vienna, Austria: International Atomic Energy Agency.

Wang, C., Zhao, C.Y., Xu, Z.L., Wang, Y., & Peng, H.H. (2013). Effect of vegetation on soil water retention and storage in a semi-arid alpine forest catchment. Journal of Arid Land, 5(2), 207-219. https://doi.org/10.1007/s40333-013-0151-5

Yang, X., Post, W.M, Thornton, P.E., & Jain, A. (2013). The distribution of soil phosphorus for global biogeochemical modeling. Biogeosciences, 10, 2525-2537. https://doi.org/10.5194/bg-10-2525-2013