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Chemical and Physical Properties of Soils in Mt. Apo and Mt. Hamiguitan, Mindanao, the Philippines

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RME, RGT and PBB were involved in the survey, delineation and establishment of the one-hectare permanent plot in each site, collection of soil samples and soil profile description. Author NPD prepared the protocol, performed the analyses of soil samples, interpreted the results, wrote the draft of the manuscript. Author VBA did some corrections and proof reading of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study was aimed to determine the edaphic qualities of two Long-Term Ecological Research (LTER) sites in Mindanao; Mt Apo in Cotabato and Mt. Hamiguitan in Davao Oriental, the Philippines

Study Design: Random soil sampling within the plots

Place and Duration of Study: Analyses of the soil samples collected from each site were performed at Soil and Plant Analysis Laboratory (SPAL), Central Mindanao University, Musuan, Bukidnon, the Philippines from October, 2012 to December 2013.

Methodology: One hectare permanent plot was established in each site. Soil profile description was done in a pit measuring 1m wide, 1.5m long and 1m deep in each site. Soil samples for physicochemical characterization were collected within the plot. Soil physical properties included

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bulk density, particle density, soil texture and water holding capacity while the chemical properties included soil pH, organic matter, extractable P and exchangeable K contents using the methods employed at SPAL.

Results: Results showed that the soils in Mt. Apo were extremely to very strongly acidic, had very high organic matter contents, slightly deficient to very deficient in extractable P, low to very high exchangeable K content, low particle and bulk density values, high porosity, moderate water holding capacity and moderately coarse to moderately fine-textured soils belonging to loamy textural class. On the other hand, the soils in Mt. Hamiguitan were slightly to very strongly acidic, contained adequate organic matter content, low extractable P, low exchangeable K, low particle and bulk density values, high porosity, moderate water holding capacity and are moderately fine to fine-textured belonging to loamy and clay textural classes. Generally, soils in Mt. Apo were more acidic but with relatively higher fertility status and comparable physical make-up with the soils in Mt. Hamiguitan.

Conclusion: It was found that both sites have some soil constraints, particularly in terms of soil acidity and low nutrient availability to plants. Information obtained on this study revealed that identification of soil constraints are indispensable in formulating proper land use and conservation program.

Keywords: Morphological features; soil profile; permanent plot; chemical and physical properties.

1. INTRODUCTION

Soil is one of the natural resources upon which the plants depend for their nutrients, water and anchorage [1]. It performs a huge number of functions and takes part in an indispensable role in environmental quality through interactions with the hydrosphere and the atmosphere. It is a very important component of terrestrial ecosystems, and its properties would determine largely its ability to produce goods and services. It is used as a medium for plant growth, medium for water storage and purification, habitat for soil organisms, system for waste disposal and as a medium of engineering works [2]. The interrelated functions of soil organisms and the effects of human activities in managing land for agriculture and forestry would influence soil health and quality [3]. Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystems boundaries, to sustain plant and animal production, maintain or enhance water and air quality, and support human health and habitation. However, anthropogenic actions, in particular, agricultural and forestry management practices would alter the soil quality.

Healthy soils generally contain vast numbers of diverse living organisms assembled in complex and varied communities [4]. They range from numerous minute microbes like bacteria and fungi to the more familiar large organisms such as earthworms and termites. Plant roots can also be regarded as soil organisms because of their symbiotic relationships and interactions with other soil components. These various organisms interact with one another and with the various plants and animals in the ecosystem, forming a complex web of biological activity. However, their biological activities and functions can be affected by environmental factors such as soil moisture, soil acidity, temperature and other climatic conditions. Results of the recently conducted researches showed that some plants would also emit some greenhouse gases causing global warming and climate change [5]. Moreover, anthropogenic actions, in particular, agricultural and forestry management practices would also alter the soil quality.

Declining soil quality is emerging as an environmental and economic issue of increasing global concern as degraded soils are becoming more prevalent due to intensive use and poor management, often the result of over-population [6]. Due to the interactions between physical, chemical and biological properties of the soil, investigation in this regard is complex, and the understanding of the individuals on soil communities and their interactions is relatively inadequate. The demand for soil resources information has also expanded in recent decades and we have to participate in several multi-agency and international collaborative consortia involving a variety of global issues pertaining to resources management within and outside the traditional agricultural arena [7]. Currently, little practical work is available on how farmers should manage their resources to develop farming practices and systems that would optimise the beneficial activities of this managed soil biota.

Such a case is true to soils in Mt. Apo and Mt Hamiguitan ecosystems which are considered as ecologically valuable areas in Mindanao. Hence, there is a need to study the soil properties and the strategies that play the important roles and functions of soil for sustainable and productive agriculture and to encourage integrated soil management practices to harness the economic, environmental and food security benefits from better management of soil life. Hence, this study is aimedtodetermine the edaphic qualities at 2 LTER sites in Mindanao inside the one-hectare permanent plot.

2. MATERIALS AND METHODS

2.1 Description of the LTER Sites under Study

Mount Apo is a large solfataric, potentially-active stratovolcano in the island of Mindanao, Philippines (Fig. 1). With an altitude of 2,954 meters above sea level, it is the highest mountain in the country [8] and is located between Davao City and Davao del Sur province in Region XI and Cotabato province in Region XII. Its latitude is 06°59.780´ N and longitude 125° 15.198´ E, with vegetation of mossy forest, and the ground covered with mosses and litters.

Mount Hamiguitan is a mountain located in the province of Davao Oriental. It has a height of 1,620 meters, latitude of 06°43.954´ N, longitude of 126°10.013´ E and with vegetation similar to that in Mt. Apo. The mountain and its vicinity have one of the most diverse wildlife populations in the Philippines.

2.2 Field work

The field activities were carried out after obtaining consent from the heads of the tribal communities. Identification and establishment of the one-hectare permanent plot in each Mindanao LTER sites namely; Mt. Apo in Cotabato and Mt. Hamiguitan in Davao Oriental was done by the survey group.

Transect across the area in each of the two sites was done as a basis for delineating the sampling areas in each site. Based on differences in topographic positions, the permanent plots were divided into four sampling areas. About one kg of composite soil samples (15-20 soil borings) were collected from each sampling area for the analysis of the different chemical and physical properties of the soil. Soil profile description in each LTER site was done based on guidelines [9]. A pit measuring approximately 1 m x 1.5 m with a depth of at least 1 m was dug manually in each site to examine and take samples of each horizon. Description of the soil profile was done following the standard procedure of FAO [10].

2.3 Laboratory Work

Analyses of the physical properties and chemical properties of the soils were performed at the Soil and Plant Analysis Laboratory (SPAL), Department of Soil Science, College of Agriculture, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines. Methods used in the analyses of the different soil properties are given in Table 1.

Fig. 1. Photo of Mt Apo (left) and Mt. Hamiguitan (right)

Table 1. Methods used in the analysis of the chemical and physical properties of soil

Property	Methods of analysis
Chemical properties:	
Soil pH	Potentiometric method (1:5 soil water ratio) [11]
Organic matter content	Walkley- Black method [12]
Extractable P	Bray P_2 (0.1N HCl + 0.03 N NH_4F) [12]
Exchangeable K	1N NH_4OAc extraction/Flame photometer [12]
Physical properties:	
Soil texture	Pipette method [12]
Particle density	Pycnometer method [12]
Bulk density	Core method [12]
Water holding capacity	Wire gauze method [12]

3. RESULTS AND DISCUSSION

3.1 Morphological features of the soil

Table 2 and Fig. 2 show the morphological features of the soils in Mt. Apo and Mt. Hamiguitan. Soil colour and other properties including texture, structure, and consistence are used to distinguish and identify soil horizons (layers) and to group soils according to the soil classification system called Soil Taxonomy [13]. The colour of the soils in Mt. Apo varied from yellow (10 YR 7/6) in the lowest horizon to reddish black (5 YR 2.5/1) in the uppermost horizon at moist condition which indicated high organic matter content of the uppermost horizon. On the other hand, the colour of soils in Mt. Hamiguitan varied from brown (7.5 YR 4/4) to dark brown (10 YR 2/2), indicating its lower organic matter content compared to that in Mt. Apo. In both sites, upper layers were darker than the lower layers which could be attributed to the accumulation of humus in the upper layers. Similar findings on the accumulation of organic matter in the top soil had been reported [14].

The texture of the soils was found to vary from silty loam to loam in Mt. Apo and from clay loam to loam in Mt. Hamiguitan indicating that these soils are moderately fine-textured. Loamy soils retain nutrients well and retain water while still allowing excess water to drain away [2]. The A-horizons in both sites had granular structure while the lower layers have sub-angular and angular block structures. This may be due to the climatic conditions [15] in Mt. Apo and Mt. Hamiguitan with Type IV (climatic condition wherein rainfall is relatively distributed throughout the year) and Type II (climatic condition where there is no lengthy dry season but with very pronounced rainfall from November to December), respectively which would favor the formation of blocky soil structure in the B-horizons. Granular structure would allow free movement of water within the surface layer, implying its good drainage condition but the blocky structure of the soil may impose limitation on water movement [16]. The soil at Mt. Apo was classified as Kidapawan clay loam while that in Mt. Hamiguitan was classified as Malalag loam.

The depth of the organic horizon in Mt. Apo at 6.2 cm is comparable to that in Mt. Hamiguitan which is 6 cm. The depths of the A horizons in the two sites did not differ much. The absence of the B-horizon in Mt. Apo implied limited soil development hence, the soil is relatively young [2].

3.2 Chemical Properties of the Soils

Table 3 shows the chemical properties of the soil within the one-hectare permanent plot in Mt. Apo and Mt. Hamiguitan.

3.2.1 Soil pH

Soil pH is an important chemical parameter that influences nutrient availability and microbial activity [17]. The pH of the surface soil (A horizon) collected from the four sampling areas within the one-hectare permanent plot in Mt. Apo ranged from 4.03 to 4.34 with a mean value 4.18 implying that these soils are extremely acidic [18]. The subsoil (B horizon) had higher pH values ranging from 4.45 to 4.57 with a mean value of 4.51 indicating that the subsoil was very strongly acidic [18]. The acidic nature of the soil can be ascribed to the leaching of the basic cations which is favored by high rainfall [19] considering that the area is under Type IV and may indicate that availability of most macronutrients may be low but availability of most micronutrients is very high and may become toxic to plants [18]. Hence, plant growth may be poor to moderately good.

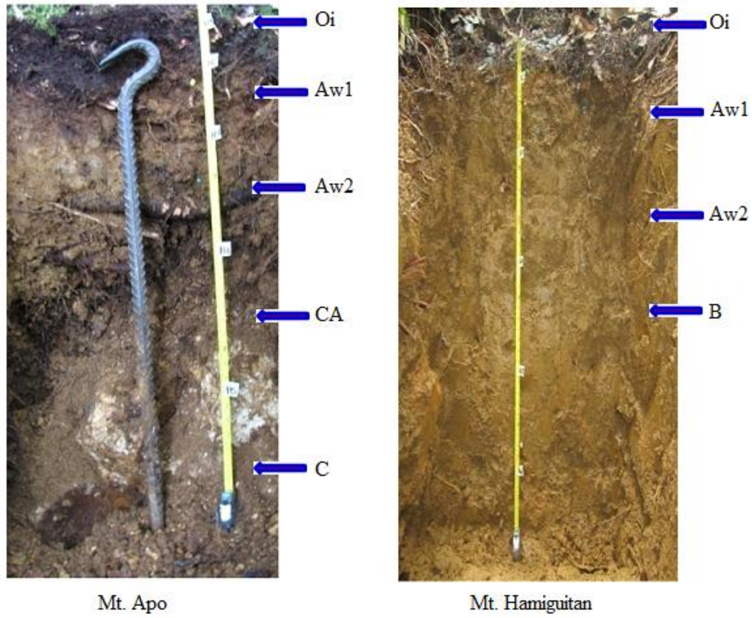

Fig. 2. Soil profile characteristics of Mt. Apo (left) and Mt. Hamiguitan (right)

On the other hand, the pH of the surface soils (A horizon) and the subsoils (B horizons) in Mt. Hamiguitan had pH values of 5.35±0.27 and 5.71±0.27, respectively suggesting that these soils were strongly to moderately acidic [18]. Again, this may be attributed to the leaching of bases that is favored by high rainfall in these soils taking into account that this site is under Type II climatic condition. The higher pH values of the soils in Mt. Hamiguitan as compared to those in Mt. Apo may indicate higher availability of the essential nutrients to plants, hence, plant growth may be moderately good to good.

Generally, soil pH values in Mt. Hamiguitan were higher compared to those of soils in Mt. Apo. However, soils in both sites were extremely to moderately acidic in reaction, hence, application of lime on these soils is imperative to improve the soil pH.

3.2.2 Organic matter content

Organic matter is an important source of plant essential nutrients after their decomposition by microorganisms [17]. It is considered as the sole source of nitrogen (N) in the soil [2]. The organic matter contents of the surface soils of the one-hectare permanent plot in Mt. Apo ranged from 25.30 to 29.13% with a mean value of 27.41% whereby sampling area 3 was having the lowest value and sampling areas 1 and 2 were having the highest value. The subsoils had the organic matter content of 27.41±1.01% with sampling area 3 and sampling area 2 having the lowest and the highest contents, respectively. These values were relatively higher than the ideal soil organic matter content of 5% [1] and very much higher than most of the soils in the Philippines. Organic matter contents of the soil are very high and are considered as more than adequate for plant use [20].

Likewise, the organic matter contents of the surface soils in Mt. Hamiguitan ranged from 8.44 to 16.15% with a mean value of 12.48% and sampling area 3 and sampling area 1 exhibiting the lowest and the highest values, respectively. The subsoils had organic matter contents of 5.87 ± 1.78% with sampling area 1 and sampling area 3 having the lowest and the highest values, respectively. Based on the qualitative description of the organic matter content values, the surface soils had organic matter contents that are more than adequate , while the subsoils had more than adequate values [20]. Organic matter have several beneficial functions such as: promoting soil aggregation thereby improving soil porosity, major source of nitrogen (N), phosphorus (P) and sulfur (S), improving water holding capacity of the soil, improving nutrient holding capacity of soil, source of energy of heterotrophic microorganisms and increasing the buffering capacity of the soil [2,21].

Table 2. Morphological features of the soil profile in Mt. Apo and Mt. Hamiguitan

Soil	Horizon	Depth (cm)	Color	Texture	Structure	Boundary
Mt. Apo	Oi	0-6.2	Reddish black (5 YR 2.5/1	Loam	Granular structure	gradual/ broken
	Aw1	6.2-13.5	Reddish brown (5 YR 4/4)	Loam	Granular structure	Gradual
	Aw2	13.5-30	Strong brown (7.5 YR 5/8)	Silty loam	Sub-angular blocky	Diffuse
	CA	30-56.3	Dark brown (7.5 YR 3/4)	Silty loam	Angular blocky	Diffuse
	C	> 56.3	Yellow (10 YR 7/6)			
Mt. Hamiguitan	Oi	0-6	Dark brown (10 YR 2/2)	Loam	Granular structure	Gradual/ smooth
	Aw1	6-15	Dark yellowish brown (10 YR 3/4)	Loam	Granular structure	Diffuse
	Aw2	15-36	Dark brown (7.5 YR 3/3)	Clay loam	Sub-angular blocky	Diffuse
	B	36-97	Brown (7.5 YR 4/4)	Clay loam	Angular blocky	Diffuse

Table 3. Chemical properties of the soil in the one-hectare permanent plot

Sampling area	Hori-zon	Soil pH		O.M. (%)		Extractable P (mg/kg)		Exchangeable K (cmol/kg)	
		Mt. Apo	**Mt. Hami-guitan**	**Mt. Apo**	**Mt. Hami-guitan**	**Mt. Apo**	**Mt. Hami-guitan**	**Mt. Apo**	**Mt. Hami-guitan**
1	A	4.33	4.94	29.13	16.15	6.14	1.37	0.69	0.59
	B	4.54	5.49	19.93	4.04	1.72	0.41	0.30	0.17
2	A	4.34	5.29	29.13	10.64	2.93	0.73	0.40	0.30
	B	4.45	5.35	20.70	6.97	0.86	0.68	0.23	0.13
3	A	4.03	6.12	25.30	8.44	5.82	0.55	0.26	0.23
	B	4.57	6.29	13.80	7.34	0.88	0.28	0.14	0.14
4	A	4.03	5.03	26.07	14.68	3.27	0.36	0.45	0.38
	B	4.49	5.69	18.40	5.14	0.63	0.60	0.21	0.15
MEAN (A)		4.18	5.35	27.41	12.48	4.54	0.75	0.45	0.38
S (A)		0.18	0.54	2.02	3.56	1.67	0.44	0.18	0.16
$S\bar{x}$ (A)		0.09	0.27	1.01	1.78	0.84	0.22	0.09	0.08

Sampling area	Hori-zon	Soil pH		O.M. (%)		Extractable P (mg/kg)		Exchangeable K (cmol/kg)	
		Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan
CV (A), %		4.30	10.10	7.37	28.53	36.78	58.47	40.00	42.67
MEAN (B)		4.51	5.71	18.21	5.87	1.02	0.49	0.22	0.15
S (B)		0.18	0.54	2.02	3.56	1.67	0.44	0.18	0.16
$S\bar{x}$ (B)		0.09	0.27	1.01	1.78	0.84	0.22	0.09	0.08
CV (B), %		3.99	9.47	11.09	60.62	163.33	89.34	81.82	108.47

S = standard deviation; $S\bar{x}$ = standard error; CV = coefficient of variation

Table 4. Physical properties of the soil in the one-hectare permanent plot

Sampling area	Hori-zon	ρ_p(g/cm^3)		ρ_b(g/cm^3)		Porosity (%)		WHC (%)		Soil Texture	
		Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan	Mt. Apo	Mt. Hami-guitan
1	A	2.56	2.23	0.90	0.81	65.0	64.0	53.7	61.3	SL	L
	B	2.49	2.78					30.1	35.5	SCL	CL
2	A	2.65	2.07	0.99	0.70	63.0	66.0	55.6	50.8	SCL	C
	B	2.69	2.30					32.8	35.8	SCL	C
3	A	2.15	2.39	0.93	0.92	57.0	62.0	54.2	45.8	SCL	SCL
	B	2.20	2.62					46.2	35.6	SL	SC
4	A	2.12	2.10	0.93	0.90	56.0	57.0	61.8	53.8	SCL	SC
	B	2.05	2.66					47.6	38.3	SCL	C
MEAN (A)		2.37	2.20	0.94	0.83	60.25	62.25	56.33	52.93		
S (A)		0.27	0.15	0.04	0.10	4.43	3.86	3.74	6.49		
$S\bar{x}$ (A)		0.14	0.07	0.02	0.05	2.21	1.93	1.87	3.24		
CV (A), %		11.39	6.83	4.27	12.01	7.35	6.20	6.64	12.26		
MEAN (B)		2.36	2.59					39.18	36.30		
S (B)		0.29	0.20					9.01	1.34		
$S\bar{x}$ (B)		0.14	0.10					4.50	0.67		
CV (B), %		12.30	7.72					23.00	3.69		

S = standard deviation *$S\bar{x}$ = standard error* *CV = coefficient of variation*
ρ_p - particle density *% PS - % porosity*
ρ_b - bulk density *WHC - water holding capacity*
SL - sandy loam *SCL - sandy clay loam*
L - loam *CL - clay loam*
C - clay *SC - sandy clay*

Generally, soils in Mt. Apo had higher organic matter contents than those in Mt. Hamiguitan which may be due to slower organic matter decomposition owing to lesser microbial activity in soils with lower soil pH values. The soils in both sites, however, had more than adequate organic matter contents; hence, application of N-containing fertilizer is not needed.

3.2.3 Extractable phosphorus (P)

Phosphorus is an essential element for plant and animal growth [22], being a component of nucleic acids, cell membranes and the energy-carrying compounds namely adenosine diphosphate (ADP) and adenosine triphosphate (ATP) and involved in cell division, fruit development and early ripening [23]. The extractable P contents of the surface soils in the one-hectare permanent plot in Mt. Apo were very deficient to slightly deficient while those of the subsoils were very low or deficient with values of 4.54 ± 0.84 mg/kg [24]. The extremely acidic condition of the soils may have played an important role in the low extractable P contents of the soils (r = -0.703; P = 0.05). pH is one of the factors that affect P availability in the soils. Highly acidic or basic soils have almost no P available to the plant, except that which is released from decaying organic matter [2]. The extractable P contents of the subsoil at 1.02 ± 0.84 mg/kg were lower than those of the surface soils implying very P-deficient status.

Whilst, the extractable P contents of the surface and the subsoils in Mt. Hamiguitan at 0.75 ± 0.22 and 0.49 ± 0.22 mg/kg, respectively were much more P-deficient than the soils in Mt. Apo. Similarly, the strong to moderate acidity of the soils might have played an important role in the low extractable P contents of the soils (r = -0.558; P = 0.05). As stressed out, highly acidic or basic soils have almost no P available to the plant, except that which is released from decaying organic matter. Therefore, application of P-containing fertilizers is deemed necessary.

3.2.4 Exchangeable potassium (K)

Next to N and P, potassium (K) is the third most important essential nutrient that limits plant productivity [25]. K increases crop yield and improve its quality. It is required for numerous plant growth processes and in the regulation of plants responses to light through opening and closing of stomata [23]. Exchangeable K contents of the surface soils in Mt. Apo ranged from 0.26 to 0.69 cmol/kg with a mean value of 0.45 cmol/kg and coefficient of variation of 40%. The subsoils have exchangeable K contents at 0.22 ± 0.09 cmol/kg. These imply that the surface soils have medium to high exchangeable K contents while subsoils have low or deficient K contents [24].

The surface soils in Mt. Hamiguitan had medium to high exchangeable K contents with values of 0.38±0.08 cmol/kg and coefficient of variation of 42.67%. The subsoils had low or deficient exchangeable K contents [24] with values ranging from 0.13 to 0.17 cmol/kg and a mean value of 0.15 cmol/kg.

Generally, the surface soils in both sites have adequate K contents while the subsoils have low or deficient K contents, hence, application of K-fertilizer on these soils is imperative for deep-rooted plants but not for shallow-rooted plants

3.3 Physical Properties of the Soils

3.3.1 Particle density (ρ_p)

Particle density is an important soil property for calculating soil porosity expressions [2]. The particle density values of the surface soils in Mt. Apo ranged from 2.12 to 2.65 g/cm^3 with a mean value 2.37 g/cm^3 and variability of 11.39%. Sampling area 4 and sampling area 2 were having the lowest and the highest values, respectively (Table 4). The subsoils had particle values ranging from 2.05 to 2.69 g/cm^3 with a mean of 2.36 g/cm^3. The particle density values are moderately high despite of the high organic matter contents of the soil which may imply that these soils might have been developed from heavy minerals.

The particle density values of the surface soils in Mt. Hamiguitan ranged from 2.07 to 2.39 g/cm^3 with a mean of 2.20 g/cm^3 while those of the subsoils ranged from 2.3 to 2.78 g/cm^3 with a mean value of 2.59 g/cm^3. The particle density values of the subsoils were generally higher than the particle density values of the surface soils. This might be due to the higher organic matter content of the surface soil resulting to their lesser weight (r = -0.800; P = 0.05). The low particle density values of surface soils despite of their not so high organic matter content may indicate that these soils might have been formed from light minerals.

3.3.2 Bulk density (ρ_b)

Bulk density is the ratio of the mass of dry soil to the bulk volume of soil expressed in g/cm^3. It is considered as an index of compaction and porosity and directly influences root development as well as water and gas movement [2]. Bulk density values of soils in Mt. Apo ranged from 0.90 to 0.99 g/cm^3 witha mean of 0.94 g/cm^3 which is far below the ideal bulk density of soil which is 1.33 g/cm^3. These values were unusually low for mineral soils. However, the fact that these soils have high organic matter contents, these ρ_b values seemed plausible. Organic particles are usually less than 1.0 g/cm^3 while mineral particles are higher. Hence, soils with high organic matter contents have relatively low bulk density. The results implied that these soils are porous.

On the other hand, the bulk density values of the surface soils in Mt. Hamiguitan at 0.83 ± 0.05 with a coefficient of variation at 12.01% indicating low variability of bulk density values which were lower than the ideal bulk density value and that these soils were generally porous thus enhancing air and water movement. Again, these low bulk density could be attributed to the high organic matter contents which would promote granulation or aggregation (r = -0.410; P = 0.05).

3.3.3 Total soil porosity

The surface soils in Mt. Apo were very porous with total porosity values of 60.25 ± 2.21% which are higher than the ideal total porosity of 50%. Again, the high total porosity of these soils might be due to their high organic matter contents which would promote aggregation thereby, increasing soil porosity (r = 0.952; P = 0.01). Whilst, the porosity of the surface soil in Mt. Hamiguitan ranged from 57.0 to 66.0% with a mean value of 62.95% which are also higher than the ideal total porosity value of the soil. Again, this high total porosity value of these soils is attributed to their high organic matter contents.

3.3.4 Water holding capacity

Water holding capacity (WHC) refers to the ability of soils to hold a specific volume of water. It is directly related to the porosity and indirectly related to the bulk density. Furthermore, it is mainly influenced by the soil texture as it takes the pore volume to be filled and hold a certain water volume [26]. The water holding capacity of the surface soils in Mt. Apo ranged from 53.7 to 61.8% with a mean value of 56.33% and low variability at 6.64%. The subsoils on the other hand, have low water holding capacity at 39.18 ± 4.50%. The water holding capacity of the subsoils were lower than those of the surface soils which could also be attributed to the enhancing effect of organic matter on the water holding capacity of the soil (r = 0.574; P = 0.05).

The water holding capacity of the surface soils in Mt. Hamiguitan ranged from 45.8 to 61.3% with a mean of 52.93% while the sub soils had water holding capacity at 36.30 ± 0.67% with low coefficient of variation of only 3.69%. These values were lower than the expected water holding capacity of loamy soils at about 70.0%. The water holding capacity of the soil is affected by soil texture [15] and organic matter content (r = 0.941; P = 0.01).

3.3.5 Soil texture

Soil texture refers to the relative proportion of the three soil separates; sand, silt and clay in a soil mass [2]. It generally affects an array of physical, chemical and biological properties and processes in soils. Several effects are mostly indirect, that is, texture influences property that directly affects plant growth. The surface and subsoils in Mt. Apo were moderately coarse to moderately fine-textured soils belonging to sandy loam and sandy clay loam textural classes which exhibit light and heavy properties in about equal proportion. These results implied that these soils have medium water holding capacity, moderate aeration and drainage rate, medium to high ability to hold and store plant nutrients and medium buffering capacity [15,27].

The soils in Mt. Hamiguitan are moderately fine to fine-textured soils belonging to the loam and clay textural classes.

3.4 Fertility Constraints and Implications

Both sites have some chemical fertility constraints. Generally, soils in both sites are acidic which could be attributed to the leaching of basic cations from the soil. It has to be noted that Mt. Apo and Mt. Hamiguitan fall under Type IV and Type II climatic condition, respectively which would cause leaching of bases. Moreover, leaching of basic cations in these soils was enhanced by their high porosity through which water can readily percolate. At low soil pH or when soils are acidic, most of the macronutrients are deficient while most micronutrients are in toxic quantities hence, plant growth is poor. Furthermore, soil acidity retards the microbial activities, organic matter decomposition and biochemical processes. The high acidity in these soils imposes difficulty in neutralizing its acidity due to the high buffering capacity associated with high organic matter content [28]. In this regard, proper soil management practices should be employed in these areas.

4. CONCLUSIONS

Based on the results, the following conclusions may be drawn:

1. The soils in Mt. Apo were generally more acidic compared to those in Mt. Hamiguitan but both areas have to be limed to neutralize the soil acidity.
2. The organic matter contents of the soils in Mt. Apo were higher than those of soils in Mt. Hamiguitan. However, both sites had more than adequate organic matter contents thus, N fertilizer application is not needed.
3. The extractable P contents of the soils in both sites were very deficient thus requiring addition of P-containing fertilizers.
4. Exchangeable K contents of the surface soils and subsoils in both sites were medium to high and low or deficient, respectively hence, it is imperative to apply K fertilizers for deep-rooted plants but not for shallow-rooted plants.
5. Most of the soil physical parameters included in the study do not pose limitations on plant growth. However, it is suggested that other physical properties should be studied for futureresearch.
6. Information on the current status of the soil properties is indispensable for proper land use and soil conservation program.
7. Appropriate soil management practices might be employed in the two LTER sites; Mt. Apo and Mt. Hamiguitan.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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