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Moss Diversity and Soil Nature in Established Plots in the Montane Forest of Mt. Hamiguitan Range Wildlife Sanctuary, La Union, San Isidro, Davao Oriental

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Abstract

The one-way effect of moss diversity on soil properties was investigated using belt transects in two established 1-ha plots located at 920–1,160 masl in the montane forest of Mt. Hamiguitan Range Wildlife Sanctuary, San Isidro, Davao Oriental. Moss species were identified, and diversity, dominance, and relative abundance were determined. Soil properties were assessed based on soil type, temperature, moisture, pH, and NPK macronutrient levels. Pearson's correlation coefficient was used to determine relationships between moss diversity and soil physicochemical parameters. A total of 28 moss taxa from six orders and ten families were recorded, with 20 species (Plot 1) identified and 21 species in Plot 2. The mean Shannon diversity index was 1.68, indicating moderately high diversity, while the mean Pielou's evenness and McIntosh dominance indices were 0.55 and 0.83, respectively. *Trismegistia calderensis* and Braunfelsia sp. were the most abundant species. Most mosses occurred on epigeous or tree-based substrates rather than on the ground. Both plots had clay loam soil. Mean soil temperatures were 19.7°C and 21.5°C, while soil moisture values were 1.05% and 1.07%, and pH values were 5.4 and 5.3. The NPK levels varied between plots. Correlations between moss diversity and soil parameters differed between plots, particularly for NPK. Temperature showed no correlation in either plot. Overall, the findings suggest that moss diversity influences certain soil properties through ecosystem functions rather than solely through direct substrate contact, supporting the ecological and functional importance of mosses in montane forest ecosystems.

Keywords: Montane, Moss Diversity, Mt. Hamiguitan, Soil Nature, Wildlife

Introduction

"A sanctuary of endemism with outstanding universal value" is Mt. Hamiguitan Range Wildlife Sanctuary and the areas within its peripheral areas as Buffer Zone, proclaimed as a protected area on July 30, 2004, under Republic Act No. 9303. It is acclaimed as the "Bonsai field or Pygmy Forest", noted as a unique forest with ultramafic soil (Berganio, 2009). With its varied ecosystems- from Agroecosystem, Dipterocarp, and Montane to Pygmy Forest previous surveys show that the flora and fauna species found are under conservation status as economically important, ecologically threatened, and rare or endemic (PCARRD, 2011).

The montane forest ecosystem of Mt. Hamiguitan is a site dominated by mosses among other associates, lichens, and epiphytes (Leano, 2009). Mosses are plants that dominate, followed by lichens, in unoccupied areas such as on rocks, sediments, and volcanic lava, or areas that are not yet covered by living organisms. These plants are called "pioneers or colonizers" in primary succession (Blamire, 1994). They contribute to forming a new layer of topsoil for the continued existence of higher plants (Kornfeld, 2007).

There is a need to study moss diversity as well as the soil of montane forests in Mt. Hamiguitan, looking at the significant role it plays. Bryophytes are essential constituents in tropical montane cloud forests such as in Mt. Hamiguitan since they take part in water balance (Holscher et al., 2004), thus preventing disastrous floods in lowlands. In many ecosystems, they play a vital role in rainfall interception (Pocs, 1980; Veneklaas & Van Ek, 1990), nutrient cycling (Coxson, 1990) due to their capability to retain nutrients (Nadkarni, 1986 & Hofstede et al., 1993), as well as shelter for microfauna (De Luna et al., 2003). These mosses are capable of trapping dust in place, thus preventing the occurrence of landslides (Kornfeld, 2007).

As a unique bonsai forest in mainland Mindanao which supports diverse mosses, Mt. Hamiguitan shall be treasured and conserved at all times. As one of the basic life support systems in the Mt. Hamiguitan montane forest, scientific knowledge of moss diversity and soil nature could guide the management of development plans and implementation activities to ensure and sustain high biodiversity and environmental conservation.

Mosses are significant in the areas where they live, as they provide food and refuge for small organisms (Starnes, 2002). Then, this research will ultimately help protect the typical ecosystem of Mt. Hamiguitan and support biodiversity management. The Mt. Hamiguitan Range and Wildlife Sanctuary are now managed, governed, and protected by the Protected Area Management Board (PAMB), which serves as the highest policy-making body. Hence, this study will serve as baseline information for the local communities, articulating the significance of these resources and encouraging their participation and commitment to community-based resource management. This will be needed in implementing programs for society concerning the protection and conservation of natural wealth. The records will provide scientific knowledge that will serve as a reference to various local and national government units, non-government organizations, and line agencies down to barangay levels as to the mentioned programs. This will also serve as a baseline reference for supplementary future studies and research.

Most peculiar is also the fact that mosses favor poor soil qualities with low levels of nutrients as well as acidic conditions to live (Moss Acres, 2010). Conversely, in soil fertility, the soil requires micro- and macro-organisms, that include particularly mosses, to absorb the necessary macronutrients as well (Dailey, 2007). Soil is a vital abiotic component in a natural ecosystem, such as the montane forest in Mt. Hamiguitan, and plays an essential role in the survival of the many life forms on Earth. It is true that soil nature influences the productivity of the Earth's biosphere. The fact remains that soil is formed naturally as a result of weathering agents, which include plants, among others such as animals, weather, time, and topography (Pidwirny, 2006 & Naik, 2010)

Generally, the study was conducted to assess and describe the diversity status of mosses and the nature of the soil in the established plots of the montane forest of Mt. Hamiguitan in San Isidro, Davao Oriental. Specifically, this study aimed to identify the collected moss species taxonomically and determine their diversity and abundance indices; describe the nature of mossy soils in the established montane forest plots according to soil type; describe the soil characteristics based on observed values of soil temperature, soil moisture, soil pH, and NPK macronutrients; and determine the correlation between the moss diversity index and the selected

soil parameters, including soil temperature, soil moisture, soil pH, and NPK macronutrient levels.

This study is therefore conceived from this hypothesis that invasion of mosses is associated with low soil fertility; there is compaction of the soil due to poor drainage of water, excessive shade, too acidic soil, poor circulation of air, or a combination of these factors.

Materials and Methods

Study area

The establishment of the study was conducted in Mt. Hamiguitan, located at Sitio Tumalite, Barangay La Union of San Isidro Municipality. The study site was situated in the montane ecosystem with an altitude ranging from 920- 1160 m above sea level, which falls between 06○ 44' 08'' N and 126○ 20' 08'' E and 126○ 20'' coordinates. In addition, a GPS (Global Positioning System) was used to locate and determine the accurate direction of the area or slopes (Figure 1).

Collection of species

a) Manner of collection

A transect line was laid in the montane forest ecosystem of Mt. Hamiguitan. Two (2) plots measuring one (1) hectare each were established at left and right orientations, placed from the transect point. In each plot, there were five (5) sampling stations of 20 m × 20 m forming a Z pattern. Within each station, there were five substations of 5 m × 5 m placed in a Z pattern (Figure 2). These were used for both moss collection and soil sampling. However, if mosses were not present in the plot, the surroundings or vicinities where they could be found were collected.

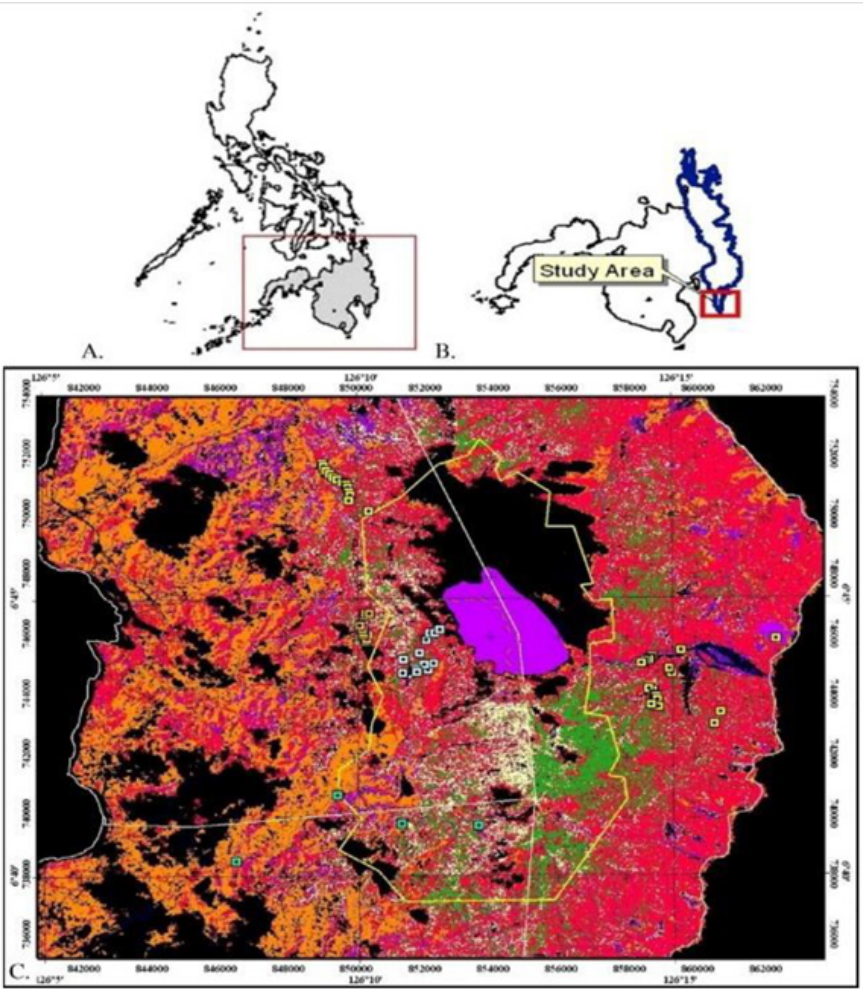


Figure 1. (A–C) Philippine map showing the location of Hamiguitan Range Wildlife Sanctuary. (A) Map of the Philippines showing Mindanao Island in the southern portion of the archipelago. (B) Mindanao Island shows the location of the study area. (C) Vegetation types (mossy-pygmy forest; montane and mossy forests; dipterocarp forest; agro-ecosystem). (Source: Amoroso, V.B. & Aspiras, R.A. (2010).

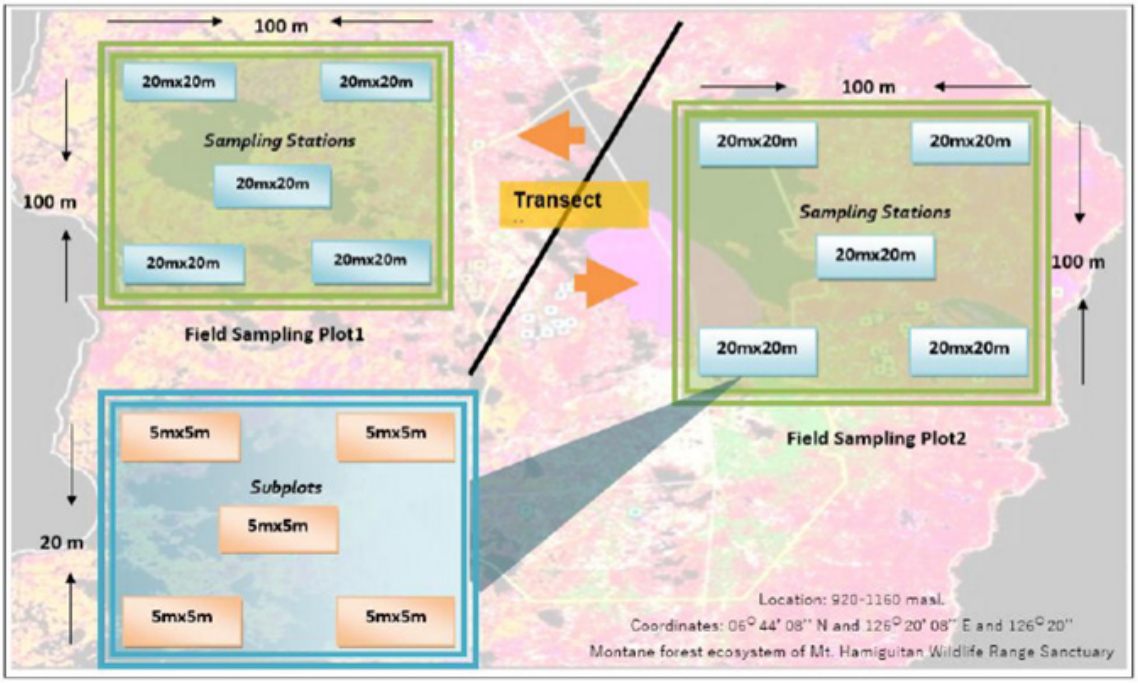


Figure 2. The field plots and sampling stations of the study established in the montane forest of Mt. Hamiguitan.

b) Sampling method

Mosses were collected using a knife and bolo. Moss specimens were placed in separate plastic bags and labeled with the following data: altitude, collection number, date of collection, and associated habitat or substrate. In each station (20 m × 20 m), representatives of soil samples were collected in every sub-station using a bolo by digging at 0- 20 cm depth. The samples collected were weighed to about 1 kilogram using the spring balance and were placed in a sealable container with a label.

c) Species identification

The collected moss specimens in the plastic bags were transferred and packaged in small paper envelopes for preservation. The specimens were labeled with the necessary data such as date and place found, sample number, and special habitat conditions. Moss samples were taken to the CMU (Central Mindanao University) museum for further identification and classification. Each species' representatives were identified morphologically based on gametophyte characteristics such as leaf arrangement, midrib, base, apex, margin, and shape, and sporophyte structure (size, texture of capsule, and seta). Pictures from different references were used.

d) Field observations of the vegetation

The montane forest ecosystem is one of the vegetation types of Mt. Hamiguitan Range Wildlife Sanctuary. This type of forest is characterized by the presence of various trees. The trees that were commonly found in sampling stations of the 2 plots were noted and identified locally, namely: Bitanghol, Almaciga, Kulipapa, Malagubat, Sagimsim, Tabanan, Lawaan,

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Pili-pili, Bansilan, Lumboy-lumboy, Badbad, Lako-lako, Bagtikan, Paguspos, Magsayutis, Tanguile, Yakal, Magbayabas, and Uwayan. Mosses and other bryophytes were observed to be epiphytic in that they are attached to the trunks, stems, and twigs. They can also be found on tree roots and bases of trunks. They also form mats in buttresses and decaying wood.

Soil parameters

Soil type and soil texture

A jar test technique was used for the characterization of different soil types wherein a soil sample was placed in a jar of about 2 inches and was filled 2/3 full with clean water (Figure 3). This technique took three to four days to obtain its result, and the settled soil layer was marked and measured carefully (Coates, 2009). Soil type and soil texture confirmation was based on the Department of Agriculture Regional Soils Laboratory interpretation of the soil samples sent.



Figure 3. Jar test technique for soil type characterization.

Soil temperature

A laboratory thermometer was used to determine the temperature of every sampling station. The air temperature was read and recorded at shoulder height. The temperature in the soil surface and ground surface was measured not directly by sunlight. Temperature readings were obtained at 2 inches, 6 inches, and 12 inches below the ground at the same site.

Soil moisture

A representative sample of approximately 25 grams of wet or moist soil from the composited sample was weighed and recorded using a spring balance. Soil samples were dried directly in sunlight for 5 days. After drying, the result of the weight before drying and the weight after drying were compared.

Soil pH

The result of soil pH was taken from the result determined by the soil analyst on the samples sent to the Department of Agriculture Regional Soils Laboratory located at Bangoy St., Agdao, Davao City.

Soil macronutrients (NPK)

For soil analysis, samples in each substation were air-dried for 3 weeks. After air-drying, samples collected in 5 substations that belong to one station were composited. The soils were pulverized, and a representative 1 kilogram from each station was sent to the Department of Agriculture Regional Soils Laboratory for the analysis of soil macronutrients (N, P, and K) and soil pH.

Data analysis

Diversity Indices

Shannon's index

Is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong.

Properties:

(1) H = 0 if and only if there is one species in the sample.

(2) H is the maximum only when all S species are represented by the same number of individuals, that is, when species are equally abundant. The usual maximum number is 6.

Formula:

$$H = \sum_{i=1}^{s} \left[\left[\frac{ni}{N} \right] in \left[\frac{ni}{N} \right] \right]$$

Where: ni = important values for species
N = total of importance value
P = importance probability for each species

Abundance

Pielou's Evenness Index, E

$$E = \frac{H}{\ln(S)}$$

Where: H= Shannon indexes
S= no. of species

When all species in a sample are equally abundant, the Evenness index should be maximum (1.0) and decrease towards zero as the relative abundance of the species diverges away from Evenness.

Formula of Simpson's Dominance Index, C

It gives the probability of any two individuals drawn at random from a large community belonging to different species. Values of C near 1.0 mean lower diversity, and values near 0 mean higher diversity.

$$C = -\sum_{i=1}^{S}\left[\frac{ni^2}{N^2}\right]$$

Where: ni = important value for each species
N = total important value

Pearson's correlation coefficient

Pearson's correlation coefficient is a method of measuring correlation. In Pearson's correlation coefficient, there should be a cause-and-effect relationship between the correlation variables. Probable error is used to determine the reliability of Pearson's correlation coefficient.

The following formula is used to determine the value of probable error.

$$P.E. = 0.6745\ \frac{1-r^2}{\sqrt{N}}$$

Where: P.E. = Probable error
r = Pearson's correlation coefficient
N = Number of observations

If the absolute value of Pearson's correlation coefficient is greater than 6 times the probable error, then Pearson's correlation coefficient is taken to be significant. If the absolute value of Pearson's correlation coefficient is less than 6 times the probable error, then the correlation coefficient will be insignificant.

The computed values were referred to the range of correlation given as follows;

1	100% (+) (-) Correlation	- 1
0.9 – 0.7	high (+) (-) Correlation	-0.9 – (0.7)
0.6 – 0.4	(+) (-) Correlation	-0.6 – (0.4)
0.3 – 0.1	Slight (+) (-) Correlation	-0.3 – (0.1)
0.09 – (-0-09)	No Correlation	

Results and Discussion

Moss species composition

The moss species composition of this study is the number of species that composed the total mosses found collected in the area and then taxonomically identified. Out of the moss specimens collected from the two plots, 28 moss species were identified. They all belong to 6 orders and 10 families which are shown in Table 1.

Table 1. The species composition of moss under Class Musci, occurrence, and their substrates in the 2 established plots in the montane forest of Mt. Hamiguitan.

ORDER (by rank)	FAMILY (with rank)	SPECIFIC NAMES	OCCURRENCE (x)		HABITAT
			Plot 1	Plot 2	
		Braunfelsia sp.	x	x	tree trunks

	DICRANACEAE (4sp.) (2nd rank)	*Dicranoloma blumii* (Nees) Par.	x	x	attached to stems
		Dicranoloma reflexum (C. Mull.) Ren	x	x	logs, root masses
		Leucoloma molle (C. Mull.) Mitt.	x	x	rotten log, barks
DICRANALES (1st rank)		*Leucobryum arfakianum* C. Mull. Ex. Geh.	x		
		Leucobryum bowringii Mitt.		x	tree bark, roots
	LEUCOBRYACEAE (5sp.) (1st rank)	*Leucobryum sanctura* (Brid.) Hampe		x	on stems, tree trunks
		Leucophanes angustifolium Ren & Carol in Ren	x		attached on barks
		Schistomitrium sp.	x		log, buttresses
		Ectropothecium sp.		x	
	HYPNACEAE (3sp.) (3rd rank)	*Ectropothecium falciforme* (Dozy & Molk.) Taeg	x		log, root stumps
		Vesicularia reticulata (Dozy & Molk. Broth)		x	on stem, barks
		Radulina elegantissima (Fleisch.) Buck & Tan	x		decaying log
HYPNALES (2nd rank)		*Radulina hamata* (Dozy & Molk) Buck & Tan	x	x	root stumps,
	SEMATOPHYLLACEAE (5sp.) (1st rank)	*Trismegistia calderensis* (Sull.) Broth	x	x	dead branch buttress
		Trismegistia panduriformis (C. Wright) Broth.		x	trees bases and trunks
		Trismegistia rigida (Mitt.) Broth	x	x	tree trunk
	HYPNODENDRACEAE (1sp.) (5th rank)	*Hypnodendron vitiense* Mitt. sp.	x	x	rock, roots
BRYALES (3rd rank)		*Pyrrhobryum spiniforme* (Hedw.) Mitt		x	rotten log
	RHIZOGONIACEAE (3sp.) (4th rank)	*Pyrrhobryum sp.*	x	x	tree trunk
		Rhizogonium sp.		x	stems, tree bases
	METEORIACEAE (1sp.) (5th rank)	*Barbella sp.*	x	x	tree barks
LEUCODONTALES (4th rank)		*Garovaglia angustifolia Mitt.*	x		tree trunk, logs
	PTEROBRYACEAE (2sp.) (4th rank)	*Garovaglia elegans* (Dozy & Molk) Hampe ex Bosch. & Loc		x	stem, fallen branches
		Macromitrium sp.	x		stem, tree trunks
ORTHOTRACHALES (5th rank)	ORTHOTRICACEAE	*Macromitrium semperi*	x	x	fallen log,

	(2sp.) (4th rank)	C. Mull.			decayed trunk
		Syrrhopodon confertus	x	x	tree bark, roots
POTTIALES	CALYMPERACEAE	Lac.			
(5th rank)	(2sp.) (4th rank)	*Syrrhopodon tristichus*		x	tree trunks
		Nees ex Schwaegr			
TOTAL: 6	**10**	**28 sp.**	**21**	**20**	

Legend: x = moss species are present in the plot.

The highest number of species included as members of the 6 orders are: **Dicranales** in 2 families and 9 species, were first in rank; **Hypnales** in 2 families and 8 species, were second; **Bryales,** with 2 families and 3 species, were third; **Leucodontales**, with 2 families and 3 species, were fourth; **Pottiales** and **Orthotrichales**, wherein 1family and 1 species were found in each order, respectively, were the fifth rank. On the other hand, in terms of the highest number of species found, the families **Leucobryaceae** and **Sematophyllaceae,** which both have 5 species, were the first rank. The family Leucobryaceae has 5 species and 3 genera, namely: **Leucobryum, Leucophanes,** and **Schistomitrium,** and the species are **L. arfakianium, L. bowringii, L. sanctura, Leucophanes aungustifolium, and Schistomitrium sp.** For the family ***Sematophyllaceae,*** the five species are under 2 genera, **Genus Radulina and Trismegistia.** Individually by species, these are **R. elegantissima, R. hamata, T. calderensis, T. panduriformis, and T. rigida.**

Family **Dicranaceae** comes second with 4 species, which are under 3 genera, namely: **Braunfelsia, Dicranoloma,** and **Leucoloma.** Individually by species, these are **Braunfelsia sp., D. reflexum, D. blumii, and Leucoloma molle.**

Families **Hypnaceae** and **Rhizogoniaceae** come third, both with 3 species under 2 genera. For the family **Hypnaceae, Ectropothecium** and **Vesicularia** are the genera. One species was unidentified until now, the **Ectropothecium** *sp*., and the 2 species identified were identified as **E. falciforme** and **Vesicularia reticulata.** Genera under the family **Rhizogoniaceae** are **Pyrrhobryum** and **Rhizogonium**, and only one species is identified: **Pyrrhobryum spiniforme**.Families **Calymperaceae, Orthotrichaceae***,* and **Pterobryaceae***,* all with 2 species, come fourth and each has 1 genus. For *Calymperaceae*, they are identified as **Syrrhopodon confertus** and **S. tristichus**. For **Orthotrichaceae***,* they are **Macromitrium semperi** and one species not yet identified. For family **Pterobryaceae,** they are **Garovaglia aungustifolia** and **G. elegans.** Families **Hypnodendraceae** and **Meteoriaceae** come last and are the least diverse, with only 1 species and 1 genus. For **Hypnodendraceae, t**he only species identified is **H. vitiense,** while in **Meteoriaceae,** the species under the **genus Barbella** was not yet identified to its specific level. Conversely, epiphytic mosses are most commonly observed in the area rather than on the soil, which is roofed by a dense layer of dead leaves (Gradstein & Heike Culmsee, 2010). These mosses inhabit or are commonly found at the bases of trees, on trunks, attached to bark, covering stems and roots, and on rotten and fallen logs, branches, and twigs. Aside from the mosses, there were 27 specimens of liverworts, and 3 fern allies were included among the gathered specimens but their species were not identified taxonomically. Towards higher elevations of montane forests, species richness of liverworts increases while moss richness decreases (Gradstein & Heike Culmsee, 2010).

Order: **DICRANALES**
Family: **LEUCOBRYACEAE**



Figure 4. *Leucobryum arfakianum*



Figure 5. *Leucobryum bowringii*



Figure 6. *Leucobryum sanctura*



Figure 7. *Schistomitrium* sp.



Figure 8. *Leucophanes aungustifolium*

The family Leucobryaceae comprises plants characterized by thick, whitish leaves, mostly with an expanded costa and a narrow basal lamina. The stems are erect; however, the branching of the central strand is poorly developed. They are abundant on roots, stems, rocks, and buttresses (Leucobryum, 2000). The genus Leucobryum is universal, named white mosses, consisting of 74 species in all. They are found on tree roots, in woods, and on the borders of swamps, forming conspicuous greenish-white cushions. The leaves are lance-shaped with an awl-like apex and a vein occupying the width of the leaf except for a few rows of cells on each side. The spore cases are exerted on a long pedicle; they are erect or have the summit

somewhat inclined, and the base is more or less swollen on one side (Leucobryum, 2000). The genus *Leucophanes* consists of 25 species in the world, mainly with tropical distributions. These plants are soft and slender, with their color grayish green to yellow or glucose green, in loose to dense tufts. The stems are erect, orange-brown to dark red in color, and sparsely branched. Leaves are erect to be more or less compressed when dry (Leucobryum, 2000).

Order: **DICRANALES**
Family: **DICRANACEAE**



Figure 9. *Braunfelsia sp.*



Figure 10. *Dicranoloma blumii*



Figure 11. *Dicranoloma reflexum*



Figure 12. *Leucoloma molle*

The family Dicranaceae comprises approximately 50 genera and more than 1000 species. These are moss species having costate leaves and long-stalked capsules with a cleft peristome. They preferably inhabit higher elevations in upper and subalpine montane regions. Most species are characterized by acidic substrates and are commonly found on open soil, rotten wood, peat, and rocks (Frahm, 2000). The genus Dicranoloma is common on stems and branches in moist habitats at 1800 and 3200m altitude. A genus with more than 100 species distributed in the Southern Hemisphere, mainly in Australasia, on humus or soil in the montane ecosystem. They are distinguished by the absence of a central strand, the presence of a narrow costa, and a narrow border of elongated hyaline cells along the leaf margin (Frahm, 2000). Genus *Leucoloma* is epiphytic, also pendant from branches in montane forests 800-2100m. The genus is related to *Dicranoloma*, with which it shares the border of hyaline cells along the leaf margin, but is distinguished by the short, pluripappilose upper laminal cells (Frahm, 2000).

Order: **HYPNALES**
Family: **SEMATOPHYLLACEAE**



Figure 13. *Radulina elegantissima*



Figure 14. *Radulina hamata*



Figure 15. *Trismegistia calderensis*



Figure 16. *Trismegistia panduriformis*



Figure 17. *Trismegistia rigida*

The order Hypnales is often known as feather moss, having 14 families and some 135 genera, primarily put together because they share a hypnoid peristome. These mosses generally have a creeping habit, frequently with pinnate or sub-pinnate branching; they are the so-called pleuricarpous mosses; archegonia are not at the apex rather it is situated at the tip of short special branches or buds. The peristome is usually double with an inner set of teeth alternating

with the outer ones. This order is extremely variable both in vegetative characteristics and habitats. Family Sematophyllaceae are characterized as cespitose, often moustrous, creeping to ascending, irregularly branched; pleuriseriate, costa double, very short, one row of basal cells inflated; with free inner peristome, high basal membrane; antheridial clusters gemmiform (Henderson, nd.).

Order: **HYPNALES**
Family: **HYPNACEAE**



Figure 18. *Ectropothecium sp.*



Figure 19. *Ectropothecium falciforme*



Figure 20. *Vesicularia reticulata*

Mosses from Family Hypnaceae are cespitose with irregularly pinnate branches, often quite regularly pinnate. They are distinguished by having plurisrate scales, unistratose, erect-spreading or squarrose to imbricated, and mostly hyaline; with elongated seta, usually, the sporangium is arcuate, inclined to horizontal, double peristome, teeth are usually confluent at the obtuse to acute or short-rostrate (Henderson, undated).

Order: **BRYALES**
Family: **RHIZOGONIACEAE**



Figure 21. *Pyrrhobryum spiniform*



Figure 22. *Pyrrhobryum* sp.

The Family Rhizogoniaceae consists of 8 genera and some 40 species with a pan-tropical distribution, with two genera and 3 species in Africa. The distinguishing feature of the Rhizogoniaceae is that sporophytes occur laterally near the base, midway along the erect stems (but terminal liptotheca). Pyrrhobryum is one of the genera in the family Rhizogoniaceae, which is characterized by an elongated stem, leaves that are distal and spirally arranged, broadly to narrowly lanceolate or linear-lanceolate, doubly toothed, bistratose leaf margins, and a costa distally positioned somewhat midway along the stem or near the base. They usually grow on tree trunks, logs, and soil or humus, leaf litter-covered banks, and silty rocks in streams. *Pyrrhobryum spiniforme* is a species having an unbranched stem or branched below, a seta arising from the base, and leaves that are 4-8 cm long, linear-lanceolate, and crisped when dry (O'Shea, 2000). This species is also commonly known as Bonsai moss, usually found on damp, slanting to vertical cliff faces and also on decayed logs and large boulders (Singapore Red Data Book, 2008).

Order: **BRYALES**
Family: **HYPNODENDRACEAE**



Figure 23. *Hypnodendron vitiense*

Order: **LEUCODONTALES**
Family: **PTEROBRYACEAE**



Figure 24. *Garovaglia elegans*



Figure 25. *Garovaglia angustifolia*

Family *Pterobryaceae* size ranges from 0.2-3.0 (-6.0) cm, with creeping stolons becoming erect, inclined, or horizontal to form simple or pinnately branched leafy stems. Often with a basal stripe region, and frequently it has flagellate branches. Its color is dark or yellowish green (Newton, 2001).

Order: **LEUCODONTALES**
Family: **METEORIACEAE**



Figure 26. *Barbella sp.*

Order: **ORTHOTRICHALES**
Family: **ORTHOTRICACEAE**



Figure 27. *Macromitrium semperi*

Order: **POTTIALES**
Family: **CALYMPERACEAE**



Figure 28. *Syrrhopodon confertus*



Figure 29. *Syrrhopodon tristichus*

Moss Diversity

There are 73 moss specimens collected in plot 1, where the taxonomic identification resulted in 21 moss species found; in plot 2, there are 20 moss species identified out of 55 specimens collected. A total of 28 species were found in the two established plots of the montane forest of Mt. Hamiguitan (Table 2). The results showed that the calculated mean diversity of mosses in plot 1 was 1.9602, a value that results in a mid-high diversity, similar to plot 2, having the value of 1.3919. The species evenness has a mean value of 0.5883 in plot 1 and 0.5378 in plot 2. These values describe the equitability or evenness of the distribution of moss species among the stations of the area. The dominance average was 0.8214 in plot 1 and 0.8416 in plot 2 since the values were nearer to 0; the value reveals that there is no dominant species in the study site.

Diversity was measured using the Shannon-Weaver Index (H') as shown in Table 2. Moss diversity is defined by the number of mosses that occur in the study site as well as the commonness of species. Given a very large sample size, with more than 5 species, the values (H) of the S-W index can range from 0 to ~4.6 using the natural log (ln). A value near 0 is an indication that every species in the sample is the same. A value near 4.6 would indicate that the numbers of individuals were evenly distributed between all the species. Values in the middle are ambiguous or uncertain which is an obvious flaw of this index (SHANNON-WIENER DIVERSITY INDEX, 2010).

Stations in PLOT 1	**No. of species (S)**	**No.of samples**	**Shannon index (*H'*) (diversity index)**	**Evenness (e)**	**McIntosh(D) dominance (C)**
S1	9	15	2.0838	0.6253	0.8477
S2	9	17	2.1193	0.636	0.8478
S3	9	13	1.9513	0.5856	0.8305
S4	10	14	2.1762	0.6531	0.8641
S5	4	14	1.4708	0.4414	0.7168
Average		**73**	**1.9602**	**0.5883**	**0.8214**

PLOT 2	**No. of species (S)**	**No.of samples**	**Shannon index (*H'*)**	**Evenness (e)**	**Dominance (C)**
S1	6	13	1.9073	0.5724	0.8563
S2	9	13	1.9915	0.5977	0.8516

S3	6	8	1.5596	0.468	0.8234
S4	4	8	1.5498	0.4651	0.8307
S5	3	13	1.9513	0.5856	0.8307
Average		**55**	**1.3919**	**0.5378**	**0.8416**

Relative abundance of moss species

Bryophytes are widely distributed throughout the area. The figure below shows the abundance of moss species per family found in 2 plots. Among the moss species being collected and identified at the site, the family Sematophyllaceae has the highest number of genera (30.37), followed by the family Dicranaceae (27.05). These families include Trismegistia calderensis which was the most abundant in plot 1, Braunfelsia sp, most abundant in plot 2, Radulina hamata and Radulina elegantissima were the second highest abundant in plot 1 and Pyrrhobryum sp. of family Rhizogoniaceae in plot 2. Families Pterobryaceae and Orthotrichaceae had the lowest in number of abundance (0.72).

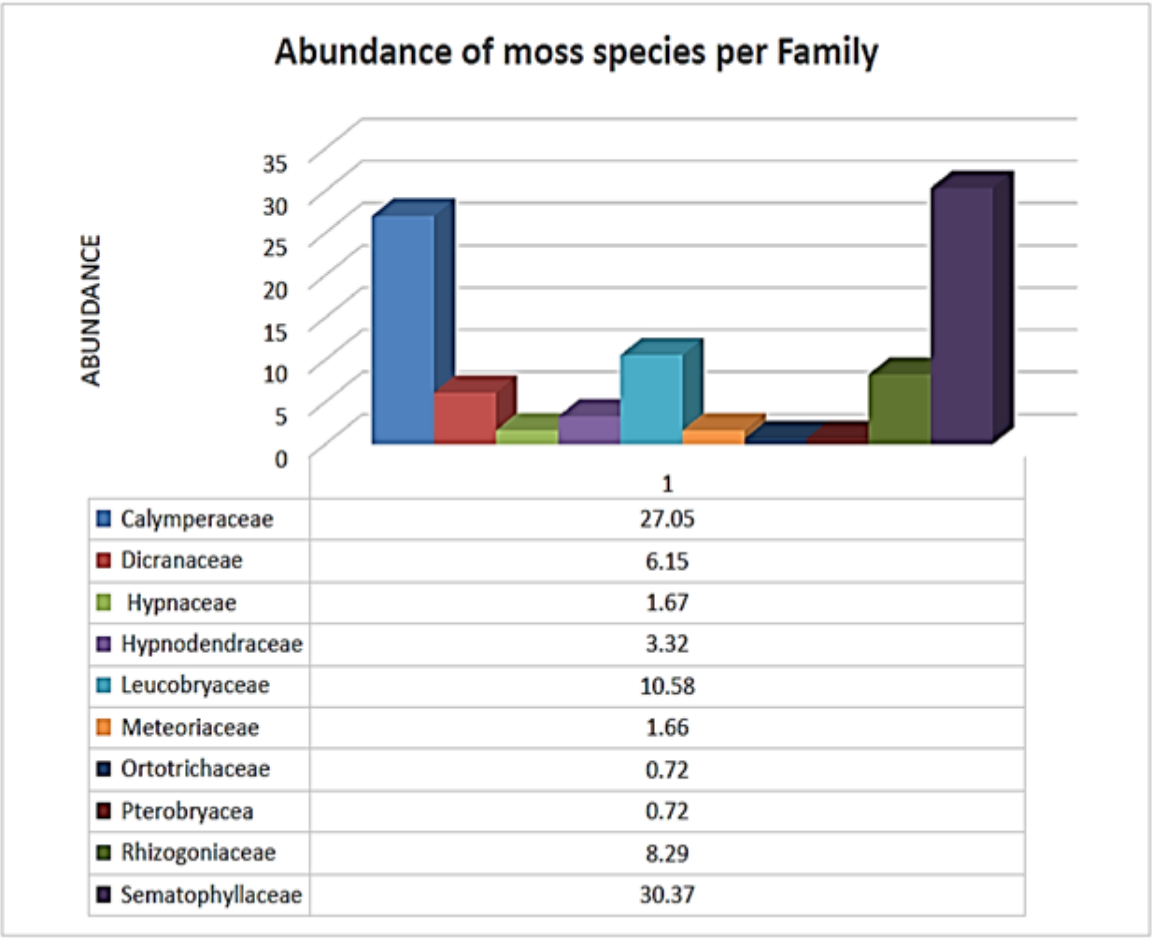


Figure 30. The abundance of moss species identified in the established plots.

Soil Parameters

A. Physical Properties of Soil

Soil Type

The texture of soil samples in all sampling stations of the montane forest was characterized as a clay loam type of soil. This soil is a mixture of loam and clay; however, it contains more particles of clay that are very small. A loam soil that contains a vast amount of clay

soil is considered heavy since it is so dense (Schreiber, 2003). A clay loam type of soil has a firm structure because they strongly bind together (Soil, 2011). This soil is formed from the basalt parent material (Red gradational soil), wherein the topsoil has a loam-loam clay texture. The soil appeared to be dark reddish brown in color (Soil, 2011).

Temperature

A low soil temperature was observed in the established plots of the montane area, where it ranges from 19°C-21.5°C (Table 3). This implies that the soil has a high water-holding capacity due to its compactness, which also results in poor drainage. The air temperature also ranges from 19-21°C, which denotes that the site has high humidity since it is a shaded area. The low temperature is associated with the altitude of the area. As the elevation increases the humidity and the lower the temperature it gets.

Moisture content

The available soil moisture from the established plots ranges from 1.05- 1.07in/ ft. wherein the soil has a high retention of water. Because of its compactness, it lessens the porosity, and the soil is saturated with water. The high humidity of the area also influences the moisture of the soil. The area receives less penetration of sunlight due to the compactness of trees. In coarse-textured soils (clay loam and loamy sand), the increment was between 1 mg kg' and 6 mg kg1, a result of the influence of soil moisture and temperature.

Soil pH

The pH of the soil can be characterized as neutral, acidic, or basic. From the first plot, it varies from 5.1 to 5.8, and the soil is moderately acidic, while in the second plot, it varies from 4.9 to 5.7 and tends to be strongly acidic. The range of pH affects the uptake of nutrients, the availability of essential elements, and the physical condition of the soil (Harris, 2005). A pH below 5.6 is considered too low for most plants; moreover, the removal of natural bases such as potassium and magnesium helps to acidify the soil (Watkins, 2011).

B. Soil macronutrients

The PK values were far below the required/average standard levels for plant soils, such that low < 10 ppm based on East of Cascades (Olsen test) for P level, and low <150 ppm for K levels. For N interpretation, <10 is considered low, medium 10–20, high 20–30, and>30 are excessive based on the Soil Interpretation Guide (Marx, Hart, and Stevens, 1999).

Nitrogen

In each plot, there was a composite of 5 samples was obtained to test the soil macronutrient. From the results of the laboratory investigation, the amount of nitrogen in the samples from stations 1, 2, 3, and 5 of plot 1 was adequate based on Wilde's Organic Matter (OM) Method, while station 4 showed a very high amount of organic matter (14.0%). In plot 2, samples from stations 1, 3, 4, and 5 were revealed to have an adequate amount of OM, while station 2 has a medium content (3.0%) (Appendix 5). There is stimulation of root growth as well as plant development of plants when there is a sufficient amount of nitrogen in the soil (Brady & Weil, 1999). It is stored as organic matter if there is a large amount or presence of nitrogen reserves and is found in the upper layer of the horizon of the soil. This organic matter makes the soil stickier. Climatic conditions also influenced the increasing level of OM. More precipitation at cooler temperatures thus increases nitrogen and soil moisture (Cathcart, 2003).

Phosphorus (ppm)

From the results, it was found that the amount of phosphorus in all stations of the two plots was very low. Only station 2 of plot 2 has resulted to 4ppm, and the rest has 6ppm, as measured using the H_2SO_4 Ext's (Table 4). Phosphorus is needed for the growth and development of the roots and strength of stems (Plant Nutrition, 2011). The plant's uptake of phosphorus is about one-tenth that of nitrogen and one-twentieth that of potassium. The deficiency of phosphorus and other nutrients in plants is generally not easy to recognize. A plant is often short, thin-stemmed, and spindly, and its foliage is often dark. As a result, the plants are shorter than usual, yet, phosphorus-plant deficient frequently seem to be normal in appearance (Brady & Weil, 1999). Phosphorus tends to become deficient after the occurrence of clearing in an area (Harris, 2005).

Potassium (K)

Potassium is a macronutrient that is significant in maintaining water balance as well as in metabolic pathways of plants such as photosynthesis. The potassium level in the soil in the established plots was deficient where in plot 1 ranges from 25ppm-45ppm while in plot 2, 35ppm-48ppm (Appendix 5). Availability of potassium in the clay loam type of soil is very low, and this comprises 1 to 10% of the total soil K. It is released slowly to the plants because it is held tightly between clay minerals (Borysowich, 1998). On the heavy texture of soils, there is little movement of potassium (Kilmer, V.J. et al., nd.). In clay soils, Potassium is available in soil minerals; however, when it is in the soil solution or soil water, it becomes slowly unavailable (Soil Potassium, nd).

Table 3. The Soil Test data in Plot 1 and Plot 2 in the montane forest of Mt. Hamiguitan.

PLOT 1 Stations	Soil pH	Soil Temp.	Soil moisture (in/ft)	Soil type	Soil macronutrients OM%	P	K
S1	5.8	21°C	1.05	Clay loam	3.1%	6 ppm	25 ppm
S2	5.6	21°C	1.06	Clay loam	3.8%	6 ppm	45 ppm
S3	5.5	21.5 °C	1.07	Clay loam	5.6%	6 ppm	40 ppm
S4	5.1	21 °C	1.05	Clay loam	14.0%	6 ppm	45 ppm
S5	5.3	21 °C	1.05	Clay loam	3.2%	6 ppm	30 ppm
PLOT 2							
S1	5.7	20 °C	1.05	Clay loam	3.3%	4 ppm	35 ppm
S2	5.4	20 °C	1.0	Clay loam	3.0%	6 ppm	35 ppm
S3	5.6	20 °C	1.0	Clay loam	3.8%	6 ppm	45 ppm
S4	4.9	19.5 °C	1.05	Clay loam	6.0%	6 ppm	48 ppm
S5	5.0	19 °C	1.05	Clay loam	3.7%	6 ppm	40 ppm

Correlation coefficient test

The soil parameters such as temperature, moisture, pH value, and N, P, and K macronutrients were computed using the correlation coefficient test as shown in Tables 4 & 5. The r measures the strength of the relationship between two variables. Positive correlation implies that when the cause variable increases, the effect variables will increase. A negative correlation indicates that when the value of the cause variable increases, it would result in a decrease in the effect variable (Borysowich, 1998).

Table 4. Correlation Coefficient Test between the moss diversity index and soil parameters such as temperature, moisture, pH, and the soil macronutrients of Plot 1 in the montane area.

Soil parameters	Regression (r-value)	Remarks
Temperature	-0.0176	No correlation
Moisture	-0.2372	Slight negative correlation
Soil pH	0.2087	Slight positive correlation
Wilde's OM%	0.4535	Positive correlation
Potassium	0.4734	Positive correlation
Phosphorus	-	No correlation

Table 5. Correlation Coefficient Test between the moss diversity index and soil parameters such as temperature, moisture, pH, and the soil macronutrients of Plot 2 in the montane area.

Soil parameters	Regression (r-value)	Remarks
Temperature	-0.0981	No correlation
Moisture	-0.0683	No correlation
Soil pH	0.1459	Slight positive correlation
Wilde's OM%	-0.7395	High negative correlation
Potassium	-0.2951	Slight negative correlation
Phosphorus	-0.9126	High negative correlation

The results revealed that the correlation between moss diversity and soil temperature showed no correlation in both study sites having a value of r=0.0176. This indicates that whether low or high diversity of moss species does not affect the temperature of the area. Moss diversity showed a slightly negative correlation with soil moisture in plot 1, having the value of (r=-0.2372), but in plot 2, moisture does not correlate at all, with a value of (r= -0.0981). Soil pH correlative values have a slight positive correlation to the diversity of mosses in both plots, with values of r=0.2087 and r = 0.1459, respectively. This would simply mean that soil pH has a weak influence on the diversity of moss species. However, it was observed by Todd (2001) that pH shows that few plants will grow in very acidic soil or very alkaline soil.

In Plot 1, the regression value between the diversity of species and the environmental parameters of the soil, such as soil pH, %OM, and the presence of potassium, was positively correlated. Consequently, mosses are considered one of the biotic factors of the soil nature in the montane forest, and the result implies that the greater the diversity of moss, the higher the importance of moss to soil fertility in terms of organic matter. The correlation with soil moisture is slightly negative, correlation having a value of -0.2372, while temperature does not correlate (-0.0176). This indicates that the increase and decrease in species diversity has no effect on temperature, but temperature has a significant relationship with moss diversity. Potassium does not have an r value since all stations in Plot 1 did not show any variation; rather, it has a uniform potassium content of 6 ppm.

In Plot 2, the correlation shows that the values of soil temperature and soil moisture do not correlate with the values of species diversity of mosses. The macronutrients present showed a slight and high negative correlation. There is a slight positive correlation between the values of the diversity of moss and the soil pH, with an average value of 0.1459.

Conclusion

The hypothesis that the diversity of mosses can define the character or the natural state of

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the soils was anchored to Dailey's (2007) statement that the soil requires micro- and macro-organisms that include, particularly, the mosses to drain the necessary macronutrients as well. This was supported to a certain extent by the findings of the study. Hence, the following general conclusions were drawn.

1. The species composition of mosses in the established plots of the montane forest of Mt. Hamiguitan attained an intermediate-high level with a species diversity index of 1.68 and a dominance value of 0.83. It is composed of twenty-eight (28) species of mosses belonging to 6 orders and 10 families. The family Sematophyllaceae ranked first by relative abundance, which included five (5) species, namely: *Trismegistia calderensis, Trismegistia rigida, Trismegistia panduriformis, Radulina elegantissima,* and *Radulina hamata.* This family and the rest, however, were mostly attached to tree trunks or barks, on tree bases, buttress roots, and rotten logs. Only very few species were ground mosses.

2. The soil nature was characterized by a clay loam soil type with a temperature range of 19.5- 21.5 °C and 1.05-1.07 % soil moisture content. The soil was slightly to strongly acidic, with a pH value of 4.9 – 5.8. The soil fertility by NPK macronutrient content levels were 3.0 % - 14.0%, 6 ppm level of P, and 25-48 ppm, respectively. The PK values were far below the required/average standard levels for plant soils, such that low if < 10 ppm based on East of Cascades (Olsen test) for P level, and low if <150 ppm for K levels. For N interpretation, <10 is considered low, medium 10–20, high 20–30, and excessive if >30 by the Soil Interpretation Guide (Marx, Hart, and Stevens, 1999). This just suggests that the soil was naturally ultramafic or serpentine.

3. The degrees of correlation of the index value of moss diversity to the different soil parameters came out differently and were found only in soil moisture, soil pH, and soil fertility by NPK macronutrients. Correlation coefficients indicated that moss diversity had no to slightly positive effects on soil moisture, a slight positive effect on soil pH, and a high to slightly negative to positive effect on soil N and K, but a zero to high negative effect on P macronutrient supply.

4. There was no correlation between the index value of moss diversity to one of the soil Parameters which has the soil temperature. This could be because only very few moss species were found growing in direct contact with the soil on the forest floor or ground.

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