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Distribution, Diversity and Spatial Analysis of Tree Species in a Long-Term Ecological Research Plot in Molawin-Dampalit Watershed, Mount Makiling Forest Reserve

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ABSTRACT

A two-hectare long-term ecological plot (LTERP) was established to generate data for biodiversity resource assessment, monitoring, and evaluation of Molawin-Dampalit watershed for adaptive management. The plot was subdivided into fifty 20mx20m subplots where identification of species, measurement of diameter at breast height (DBH) and total tree height and determination of geographic location of all trees were conducted. Growth parameters such as DBH and height were used to monitor and evaluate the area. The study recorded a total of 1,266 tree individuals comprising with 135 species distributed among 95 genera and 58 families. Of the 135 species recorded, 87 species are native or indigenous and 4 species are exotic or introduced in the area and 44 species are found to be endemic to the Philippines showing a 32% endemism profile for the whole study area. Three most dominant species include *Diplodiscus paniculatus* Turcz, *Celtis luzonica* Warb, and *Pinanga insignis* Becc based on Species Importance Value. A total of 29 threatened species were recorded in the area. The study revealed dominance of threatened species in the LTERP area. Out of 10 dominant species, 7 are threatened species and 3 of which are critically endangered species such as *Parashorea malaanonan* (Blanco) Merr and *Diospyros blancoi* A. DC. Tree diversity analysis showed a high species richness (135), evenness (0.71), Simpson diversity index (0.91) and Shannon Diversity Index (3.52) indicating a more diverse area, preserved and intact MMFR. Spatial analysis was correlated with the clustering of species using ordination method. Results showed species composition is affected by spatial distribution and each subplot may have different site requirements and unique floral characteristics.

Keywords: Biodiversity resource assessment, dominant species, critically endangered species, abundant and tree diversity

INTRODUCTION

The Mount Makiling Forest Reserve ASEAN Heritage Park (MMFR AHP) is a diverse biological resource area with more than 2,000 species of flowering plants (Pancho, 1983) and serves as a nearest carbon sink to Metro Manila. MMFR is the first forest reserve and national park established in the Philippines which aims primarily as a training laboratory for instruction, research, and extension. The University of the Philippines was mandated to protect and manage the MMFR by virtue of RA 6967 to ensure and maintain its diverse biological resources especially now with the changing climate.

Mount Makiling is an accredited site for Philippine LTER. Establishment of LTERP is an effective tool to monitor changes in the forest ecosystem. These monitoring plots will provide progressive data which will be the basis for conducting scientific research on temporal change for adaptive ecosystem management (Olpenda et al., 2013). As manager of MMFR, the LTERP will provide baseline data for crucial decisions and effective planning and management as a reserve and ASEAN Heritage Park. The paper presents assessment report on tree distribution, composition and diversity profile including its spatial analysis within the Molawin-Dampalit watershed, MMFR. The resource inventory was conducted in the 2-ha plot. However, the analysis was applied to Molawin-Dampalit watershed since the plot is a representation of the said watershed.

OBJECTIVES OF STUDY

Generally, the objective of the study was to generate data for biodiversity resource assessment, monitoring, and evaluation of Molawin-Dampalit watershed for adaptive management. Specifically, it aimed to do inventory and characterize the Molawin-Dampalit watershed in terms of tree species composition, dominance, diversity and analyze spatial distribution based on tree species clustering.

METHODOLOGY

The study was conducted in the Molawin-Dampalit watershed, Mount Makiling Forest Reserve and covers 22% (922 hectares) of the 4,244 total area of the MMFR and composed of Molawin, Maralas, Pili and Dampalit creeks (Castillo et al., 2015) (Figure 1). It is also found within the Dipterocarp mid-montane zone (300-900m asl) (Pancho, 1987; Gruezo, 1997). Molawin-Dampalit watershed is one of the four watersheds along with Sipit, Tigbi and Cambantoc of MMFR. It contains the highest number of vulnerable and critically endangered species among the 4 watersheds (Lapitan et al., 2012).

A 2-ha LTERP following the international protocol for establishment of permanent plots (Malabrigo et al., 2016) was established and oriented to the cardinal directions (North, West, East, and South) with100m N and 200m E. It was divided into fifty (50) 20x20m plot and within the plot, 10mx10m subplots and into 5mx5m subplots were also established (Figure 2 and Plate 1). Corners of subplots were marked with cemented PVCs: 2" Orange PVC (20m x 20m corners), 1" Orange PVC (10mx10m corners) and 1" Orange PVC w/ neon green sticker (5m x 5m corners). However, for this purpose, only tree vegetation data from the 20mx20m plots were presented.

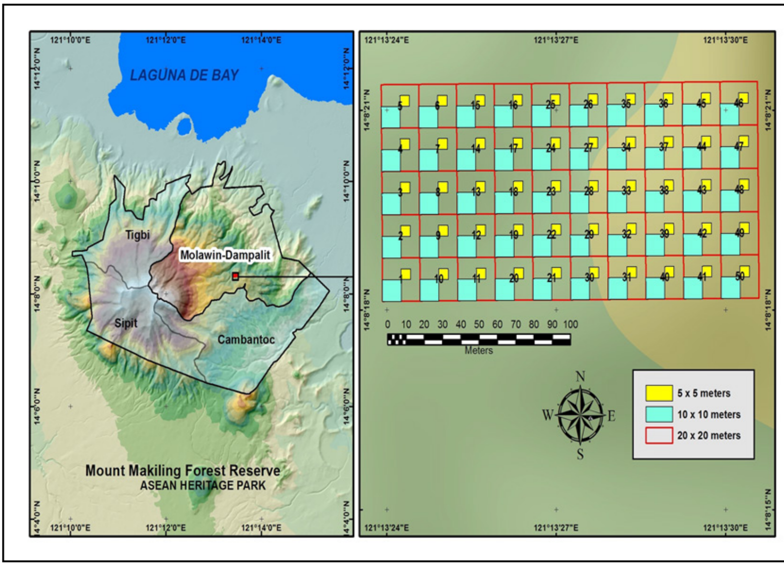

Figure 1.The two-hectare permanent biodiversity monitoring plot showing the 20mx20m

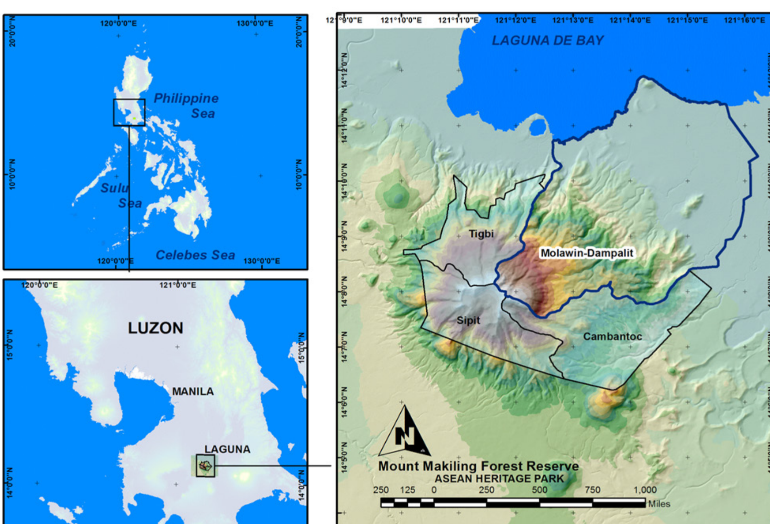

Figure 2. Location of study area

Plate 1. Site reconnaissance and establishment of Molawin-Dampalit Long-term Ecological Research Plot

Identification of species, measurement of diameter at breast height (DBH) and total tree height and determination of geographic location of all trees with ≥ 10.0cm DBH were conducted in each of the 20m x 20m subplot to monitor and evaluate the Molawin-Dampalit Watershed, parameters such as growth (DBH and height) and density (recruitment and mortality). The trees will be re-censused every 5 years to monitor these parameters. Also, whenever there is strong typhoon and caused essential damage to the plot, immediate assessment and evaluation will be conducted. Since trees are individually mapped, it is easily identified which trees have been damaged, fell or died. Likewise, it can easily be identified on the map which plot has the most damaged trees.

Multiple diversity indices were used to interpret and analyze the results. The study used R Studio to compute for the Species Richness, Evenness, Shannon Diversity Index, Simpson Diversity Index, Species-Accumulation Curve, Rank-Abundance Curve and Renyi Diversity Profile. The following were the formulas used to compute for the Species Importance Values and different diversity indices (Oksanen et al., 2016; Kindt et al., 2005; & Magurran, 2004):

Species Importance Value	SIV = Relative Density + Relative Frequency + Relative Dominance where: Relative Density = (Density of a species / total density of all species) x 100 Density = Number of a species / total area sampled Relative Frequency = (Frequency of a species / total frequency of all species) x 100 Frequency = Area of plots in which a species occurs / total area sampled Relative dominance = (Dominance of a species / total dominance of all species) x 100 Dominance = total basal area of a species / total area sampled
Evenness	E = H'/Hmax = H'/lnS where, H' is the Shannon-weiner index. The maximum diversity (Hmax) of a sample is found when all species are equally abundant. Hmax = ln S, where S is the total number of species.
Shannon Diversity Index	$H' = -\sum_{i=1}^{s} p_i(lnp_i)$ where, pi is the proportion of individuals found in the ith species and ln is the natural logarithm

Simpson diversity index

$$D_s = \sum_{i=1}^{s} \frac{(n_i(n_i - 1))}{(N(N-1))}$$

where, ni is the number of individuals in the ith species.

Renyi Diversity Profile

$$R(\alpha) = \frac{1}{1-\alpha} \ln \sum_{i=1}^{S} p_i^{\alpha}$$

RESULTS AND DISCUSSION

Floristic Composition and Dominance

The study recorded a total of 1,266 tree individuals comprising with 135 species distributed among 95 genera and 58 families. Table 1 shows the dominant species in percentile rank based on relative density, relative frequency and relative dominance. Accordingly, *Diplodiscus paniculatus* Turcz. is the most dominant species with an IV equals to 119.23, followed by *Celtis luzonica* Warb. and *Pinanga insignis* Becc. with 17.20 and 8.86, respectively. Abundance of *D. paniculatus* in this area is attributed to the fact that its fruits are eaten by birds and to lesser degree by humans plus the area is being designated before as Balobo Forest Zone because of the dominance of such species (Gruezo, 1997). Its seeds are widely and effectively distributed by these dispersal agents. *C. luzonica* and *D. paniculatus* are among the dominant species found in the Molawin-Dampalit watershed as reported by Malabrigo et al. (2016), Castillo et al. (2015), Lapitan et al. (2010) and Lee et al (2006).

Table 1. List of top ten species based on Species Importance Value

TREE NAME	FAMILY	ABUNDANCE	RELATIVE DENSITY	RELATIVE FREQUENCY	RELATIVE DOMINANCE	IMPORTANCE VALUE
Diplodiscus paniculatus Turcz.	MALVACEAE	352	27.8041	7.0126	85.6496	120.466
Celtis luzonica Warb.	CANNABACEAE	102	8.0569	6.0309	3.8722	17.960
Pinanga insignis Becc.	ARECACEAE	62	4.8973	3.5063	0.8397	9.243
Parashorea malaanonan (Blanco) Merr	DIPTEROCARPACEAE	34	2.6856	3.3661	2.8266	8.878

Dillenia philippinensis Rolfe	DILLENIACEAE	41	3.2385	3.7868	1.2077	8.233
Diospyros blancoi A. DC.	EBENACEAE	33	2.6066	3.6466	0.6855	6.939
Strombosia philippinensis (Baill.) Rolfe	OLACACEAE	36	2.8436	3.0856	0.3998	6.329
Diospyros pyrrhocarpa Miq.	EBENACEAE	34	2.6856	2.5245	0.4484	5.659
Drypetes maquilingensis (Merr.) Pax & K. Hoffm.	PUTRANJIVACEAE	27	2.1327	2.9453	0.3634	5.441

Conservation Status and Endemicity

Of the 135 species recorded, 44 are endemics, 87 species are native or indigenous and 4 species are exotic or introduced in the area. Big-leaf Mahogany which is one of the introduced timber species has successfully grown wild in nearly pure stands in isolated spots within this area (Gruezo, 1997). Mahogany is one of the exotic species found in the area because the plot is nearby to Makiling Rainforest Park where many big mahongay mother trees are fruiting tremendously during fruiting season.

Further, the study shows a total of 29 threatened species based on IUCN Red List (2016-2), DAO 2007-01 and Fernando et al. (2008). Table 2 and Figure 4 show the list and distribution of threatened species in the area, respectively. It is notable that the critically endangered species such as *P. malaanonan* and *D. blancoi* and vulnerable species such as *D. paniculatus*, *C. luzonica* and *D. philippinensis* are abundant in Molawin-Dampalit watershed. This means that the integrity of the MMFR is preserved and that there seems to be no problem in conserving such species. Their abundance can also be accounted with the effective approaches and good management of the MMFR. Meanwhile, 44 species are found to be endemic to the Philippines giving a 32% endemism profile for the whole study area (Table 3).

Table 2. List of threatened species found inside the Molawin-Dampalit Permanent Biodiversity Monitoring Plot

NO.	SPECIES	Fernando et al (2008)	IUCN 2016-2	DAO 2007-01
1	*Aglaia edulis* (Roxb.) Wall.	VU A1cd		Category C. Vulnerable Species
2	*Aglaia oligophylla* Miq.			Category E. Other Wildlife Species
3	*Aphanamixis polystachya* (Wall.) R.N. Parker	VU A1c		
4	*Artocarpus blancoi* (Elmer) Merr.		VU A1d	
5	*Artocarpus rubrovenius* Warb.	VU A1c		Category C. Vulnerable Species
6	*Canarium luzonicum* (Blume) A. Gray	OTS LR/nt	VU A1cd	Category D. Other Threatened Species
7	*Celtis luzonica* Warb.		VU A1cd	
8	*Cinnamomum mercadoi* Vidal	VU A1c	VU A1d	Category C. Vulnerable Species
9	*Cryptocarya ampla* Merr.	VU A1c		Category C. Vulnerable Species
10	*Dillenia philippinensis* Rolfe	OWS LR/lc	VU A1d	Category E. Other Wildlife Species
11	*Diospyros blancoi* A. DC.	CR A1cd		Category A. Critically Endangered Species
12	*Diospyros ferrea* (Willd.) Bakh.		EN B1+2c	Category C. Vulnerable Species
13	*Diospyros pyrrhocarpa* Miq.	EN A1cd		Category B. Endangered Species
14	*Diplodiscus paniculatus* Turcz.		VU A1cd	
15	*Dracontomelon dao* (Blanco) Merr.	VU A1cd		Category C. Vulnerable Species
16	*Flacourtia rukam* Zoll & Moritzi	OWS LR/lc		Category E. Other Wildlife Species
17	*Guioa myriadenia* Radlk.	EN A1c/ B2c	EN A1c	Category B. Endangered Species
18	*Hopea acuminata* Merr.	CR A1cd, B1+2c	CR A1cd, B1+2c	Category A. Critically Endangered Species
19	*Litchi chinensis* Sonn. ssp. *philippinensis* (Radlk.) Leenh.			Category B. Endangered Species
20	*Macaranga grandifolia* (Blanco) Merr.		VU A1cd	
21	*Myristica philippensis* Lam.	OTS LR/nt		
22	*Palaquium philippensis* (Perr.) C.B. Rob.	VU A1cd		
23	*Parashorea malaanonan* (Blanco) Merr		CR A1cd	
24	*Pouteria villamilii* (Merr.) Baehni	VU A1cd		
25	*Pterocarpus indicus* Willd. forma *indicus*	CR A1cd	VU A1d	Category C. Vulnerable Species
26	*Shorea contorta* Vidal	VU A1cd	CR A1cd	Category C. Vulnerable Species
27	*Shorea guiso* (Blanco) Blume		CR A1cd	
28	*Syzygium nitidum* Benth.	CR A1cd		Category A. Critically Endangered Species
29	*Swietenia macrophylla* King		VU A1cd+2cd	

Table 3. List of endemic species found thriving in the area

No.	Species Name	Terrestrial-biozones.net (2010)	Rojo (1999)	Guezo (2012)
1	*Macaranga grandifolia* (Blanco) Merr.		Cagayan, Benguet, Nueva Vizcaya, La Union, Pangasinan, Bataan, Quezon, Rizal, Laguna, Batangas, Mindoro	Philippine Endemic
2	*Canarium luzonicum* (Blume) A. Gray	Philippine Endemic	Northern Luzon to Alabart, Mindoro, Tico, Masbate, Bohol	Philippine Endemic
3	*Antidesma pleuricum* Tul.			Philippine Endemic
4	*Semecarpus longifolius* Blume			Philippine Endemic
5	*Dendrocnide luzonensis* (Wedd.) Chew var. *luzonensis*		Luzon, Mindanao	Luzon to Mindoro
6	*Trigonostemon philippinensi*s Stapf.			Luzon to the Visayan islands
7	*Astronia cumingiana* Vidal		Luzon, Mindoro, Negros, Mindanao	Mt. Makiling
8	*Syzygium bordenii* (Merr.) Merr.			Philippines: Batanes Islands to Northern Mindanao
9	*Diplodiscus paniculatus* Turcz.			Throughout Philippines
10	*Drypetes maquilingensis* (Merr.) Pax & K. Hoffm.			Throughout Philippines
11	*Planchonia spectabilis* Merr.		Luzon and vicinities	Throughout the Philippines
12	*Myristica elliptica* Wall. Ex. Hook.f. & Thoms. ssp. *simiarum* (A.DC.) Sincl.		Samay, Leyte, Davao	Northern and Central Luzon, southwards to Surigao and Agusan, endemic
13	*Dillenia philippinensis* Rolfe	Philippine Endemic	Babuyan, Sulu, Palawan,	Philippine endemic
14	*Palaquium merrillii* Dub.		Cagayan, Isabela, Rizal, Quezon, Laguna, Mindoro, Camarines, Sorsogon, Guimaras, Davao	Philippine Endemic
15	*Myristica philippinensis* Lam.		Mindoro, many Luzon provinces Samar, Leyte, Mindanao, Basilan	Philippine endemic
16	*Artocarpus ovatus* Blanco		Northern Luzon to Palawan, Mindanao	Philippine endemic
17	*Linociera philippinensis* Merr.			Philippine Endemic
18	*Parashorea malaanonan* (Blanco) Merr			Philippine endemic
19	*Bambusa merrilliana* (Elmer) Rojo & Roxas		Abra, Ilocos Sur, Pangasinan, Bulacan, Rizal, Zambales, Cebu, Bohol, Leyte, Lanao,	Philippines endemic
20	*Neonauclea media* (Havil.) Merr.		Cagayan, Bataan, Rizal, Quezon, Laguna, Batangas, Mindoro, Sorsogon, Panay, Guimaras	Philippines endemic

21	*Caryota cumingii* Lodd.			Philippines endemic
22	*Caryota rumphiana* Mart. var. *philippinensis* Becc.			Philippines endemic
23	*Pinanga insignis* Becc.			Philippines endemic
24	*Palaquium foxworthyi* Merr.		Zambales, Bataan, Quezon, Laguna	Zambales, Bataan, Quezon, Laguna
25	*Knema glomerata* (Blanco) Merr.		Babuyan Island to Mindanao	
26	*Hopea acuminata* Merr.	Philippine Endemic	Babuyan Islands, Cagayan, Sorsogon, Mindoro, Samar, Leyte, Davao, Misamis, Cotabato, Zamboanga	
27	*Leea philippinensis* Merr.	Philippine Endemic	Batan Island, Cagayan, Apayao, Pangasinan, Nueva Ecija, Zambales, Bataan, Rizal, Quezon, Laguna, Mindoro	
28	*Artocarpus blancoi* (Elmer) Merr.		Batan Island, Northern Luzon to Negros, Mindoro, Palawan, Cebu, Mindanao	
29	*Guioa myriadenia* Radlk.	Philippine Endemic	Bontoc, Benguet	
30	*Gomphandra luzoniensis* (Merr.) Merr.	Philippine Endemic	Cagayan, Ilocos Norte, Ilocos Sur, La Union, Nueva Ecija, Bataan, Rizal, Laguna, Cavite, Batangas, Mindoro, Marinduque, Palawan	
31	*Palaquium philippinense* (Perr.) C.B. Rob.		Cagayan Sorsogon Mindoro Panay Negros Mindanao	
32	*Neotrewia cumingii* (Muell.-Arg.) Pax & K. Hoffm		Cagayan to Sorsogon, Mindoro, Palawan, Masbate, Panay, Cebu, Samar, Leyte, Mindanao	
33	*Dipterocarpus caudatus* Foxw.		Camarines, Albay, Mindanao	
34	*Meliosma pinnata* (Roxb.) Maxim. ssp. *macrophylla* (Merr.) v. Beuss.		Lepanto Benguet	
35	*Ficus odorata* (Blanco) Merr.		Luzon, Batan Island, Panay, Negros, Bohol, Samar, Leyte, Mindanao	
36	*Celtis luzonica* Warb.	Philippine Endemic	Luzon, Mindanao	
37	*Artocarpus rubrovenius* Warb.		Mt. Pinatubo, Bataan, Quezon, Aurora, Laguna, Batangas, Camarines, Albay	
38	*Trichadenia philippinensi*s Merr.		Pangasinan, Nueva Ecija, Rizal, Quezon, Laguna, Sibuyan, Camarines, Panay, Negros, Davao, Lanao	

39	*Shorea contorta* Vidal	Philippine Endemic	Philippines	
40	*Calophyllum inophyllum* L.		Philippines	
41	*Ficus botryocarpa* Miq.		Quezon, Laguna, Samar, Camarines, Sorsogon	
42	*Homolanthus rotundifolius* Merr.		Samar, Leyte, Siargao, Surigao	
43	*Semecarpus cuneiformis* Blanco	Philippine Endemic		
44	*Strombosia philippinensis* (Baill.) Rolfe	Philippine Endemic		

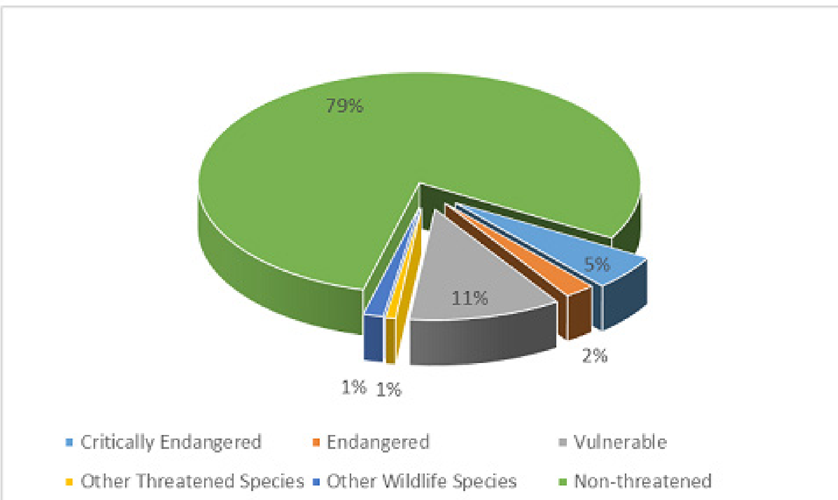

Figure 3. Distribution of threatened species in Molawin-Dampalit watershed

Figure 4 shows the spatial distribution of the tree individuals highlighting the threatened species (critically endangered, endangered, vulnerable, other threatened species and other wildlife species). The map also gives particular to endemic and at the same threatened species especially critically endangered such as *H. acuminata* and *P. malaanonan*. The plots containing endemic and endangered species will be prioritized for conservation and will be declared a priority conservation area.

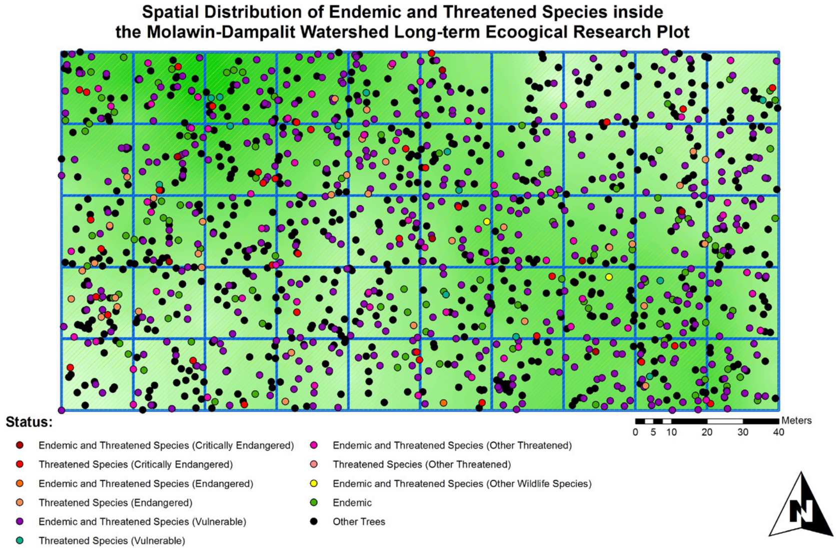

Figure 4. Relative location trees highlighting threatened and endemic species

Tree Diversity Analysis and Profile

Evenness and Species Richness

The study reveals an evenness of 0.72 with a species richness equals to 135. The evenness value is directly related to the distribution of tree species inside the plot. The value indicates some dominance and about 72% of the species are distributed among the tree individuals showing a relatively high evenness. The remaining 28% is attributed to *D. paniculatus* which is the most common species in the area. The value translates heterogeneity of the area and making it more resistant against diseases and infestation and other disturbances.

Rank Abundance Curve

The rank abundance curve shows abundance among the species. *D. paniculatus* dominates about 28% of the area while *C. luzonica* and *P. insignis* are 8% and 5% respectively. The curve does not show only the abundant species but more importantly the rarity of the species. Conservation biologists are concerned with relative abundance because rare species are more vulnerable to extinction. In this case, the study showed a rare species like *Hopea acuminata* Merr. which is endemic (Fernando et al., 2009) and critically endangered (Fernando et al., 2008; IUCN, 2016). The species is more frequent in forests over limestone (Fernando et al., 2009). The rank abundance curve gives the opportunity to prioritize conservation areas in terms of relative abundance of the species.

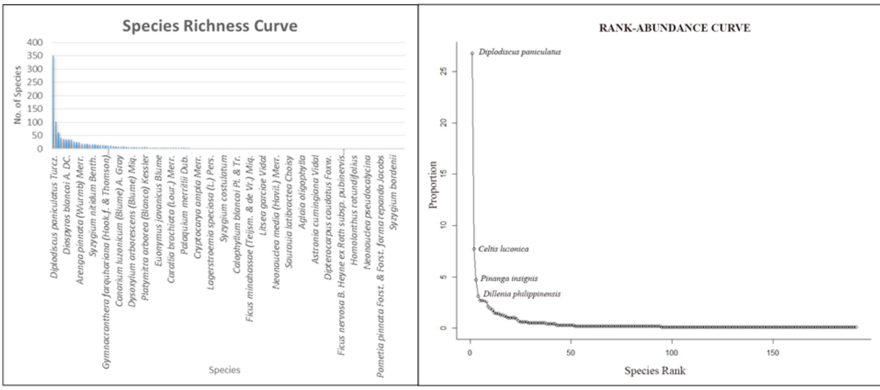

Figure 5. Rank of abundant species in Molawin-Dampalit permanent biodiversity monitoring plot

Species Accumulation Curve

The species accumulation curve shows that greater sampling increases the diversity usually showing a diminishing return because the same species are coming along. The study revealed a usual accumulation curve where additional species are recorded and which only confirms diversity of the area.

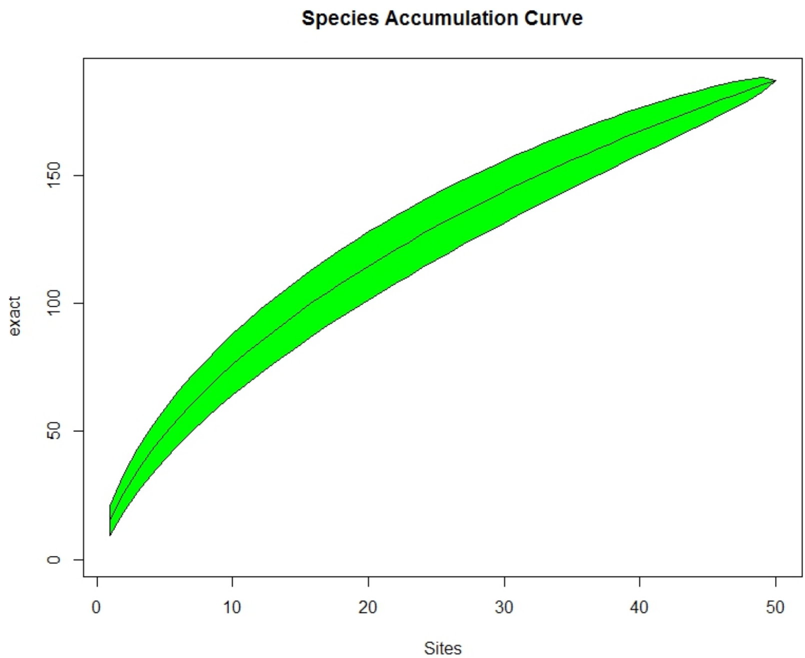

Figure 6. Species accumulation curve showing increasing species along the way

Shannon Diversity Index (H')

The H' for the whole 2-ha plot is 3.52 indicating a very high diversity index following interpretation proposed by Fernando 2008 as cited by Gevania (2013). The computed diversity index is supported by the individual diversity indices inside the plot. Figure 7 shows a moderate to high diversity level among the 20m x 20m subplots where one of the subplots contains 27 different species. Minimum H' is 1.55 while maximum H' is 2.967 and Mean H' is 2.403. This is almost similar with the study conducted by Bantayan et al. (2008) in Greater Sipit Watershed of MMFR with H' values ranging from 1.55-3.28.

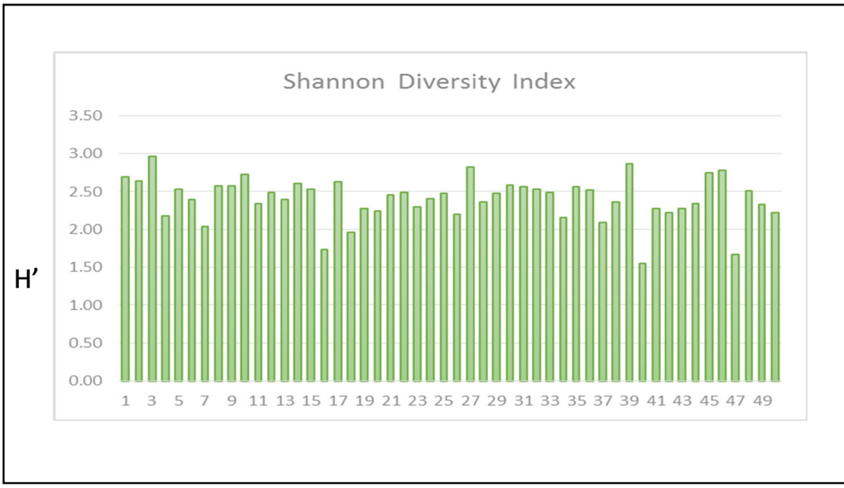

Figure 7. The graph shows the diversity indices for every 20m x 20m subplot inside the 2 ha permanent plot

The 3.52 high diversity index value from the study confirms the Shannon Diversity Index of 3.94 obtained in Mount Makiling dipterocarp mid-montane forest zone as reported by Gruezo in 1997. This value is much higher with the findings of Abraham et al. (2010) which revealed an H'=3.19 in the crater of Mount Makiling. The values do not only show the comparison of high diversity value but more importantly, the values attest for the good management of Mount Makiling as a forest reserve and now an ASEAN Heritage Park. Fluctuation in the graph is attributed in the variations of density among the plots.

The biodiversity value of MMFR is much higher as compared with the Tropical Montane Forest in Balbalasang-Balbalan National Park, Kalinga Province, Northern Luzon, with an average diversity index of 2.76 (Malabrigo, 2013) and Quezon Mountain Range in Southern Mindanao also with an average diversity of 1.66 (Gevaña, 2013). Comparing the value with other ASEAN Heritage Park, the diversity index of MMFR from the plot is much higher than Mt. Malindang Range Natural Park, Mindanao with an average diversity index of 2.5 for its Mixed Lowland, Mixed dipterocarp, Dipterocarp lowland and Dipterocarp submontane (Amoroso et al., 2013). Mt. Malindang Natural Park and MMFR are both rich in biodiversity and contain important resources for both in situ and ex situ conservation. This comparison shows that Mount Makiling is still one of the most diverse areas in the Philippines.

Simpson Diversity Index (D)

D is a measure of biodiversity that shows the number of species present and the relative abundance of each species. As species richness and evenness increase, diversity increases. The study showed a very high 0.91 Simpson's Diversity Index which conforms with the Shannon Diversity Index. It translates that Molawin-Dampalit watershed has a diverse habitat, rich species and able to withstand some environmental impacts. High diversity is attributed to the future stability of a forest ecosystem which means the higher the diversity, the more stable the ecosystem will be in the succeeding generations. This also ensures a healthy ecosystem being resistant and resilient to different disturbances such as pest infestation, strong typhoon, etc.

Simpson Diversity focuses on the dominant species of the area. The dominant species influences the overall measure of the index. On the other hand, H' incorporates the species richness and distribution and the evenness of the plot. The difference between the diversity value of each subplot is the number of species within the subplot and its distribution among the total number of species including evenness of the plot.

Multiple Renyi Profile

This Multiple Renyi Profile curves show the individual subplot's diversity profile. The vertical line indicates the diversity index and the horizontal line is the scale parameter for evenness ranging from zero to infinity. The first dot in the dotted curve indicates the diversity index while the curves behavior tell the evenness inside the subplot. The more horizontally inclined the curve is, the higher the evenness which means the species are more equally distributed within the plot.

There are four curves consisting a Renyi diversity profile, (a) the upper line which represents the highest diversity index in all the subplot; (b) the lowest line which represents the lowest diversity index in all subplot; (c) the median between the highest and the lowest curves and (d) the dotted line which contains the diversity information about the subplot.

The Multiple Renyi Profile reveals that subplot 35 is the best ideal plot showing a horizontal curve. This means a high diversity and complete evenness (Figure 8). Subplot 35 contains 11 species and 11 number of individuals. Some sample subplots showing a high evenness or more or less equal distribution of species (the curve is leading a horizontal line and above the median line) are Plot 32 (14 species, 21 individuals), Plot 1 (16 species, 21 individuals) and Plot 39 (19 species, 28 individuals). Meanwhile, some of the subplots showing low evenness which means there are species dominating the area (the curve is in downward direction and below the median line) are Plot 16 (12 species, 28 individuals), Plot 40 (11 species, 26 individuals) and plot 47 (10 species, 24 individuals).

Renyi Diversity Profile

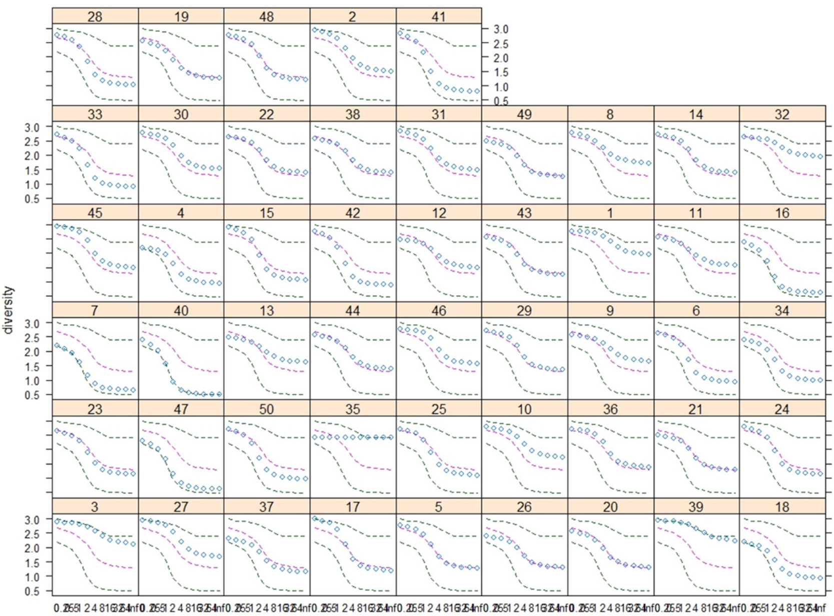

Figure 8. The generated diversity profile from Multiple Renyi

The Multiple Renyi Profile simply tells the diversity profile of each subplot which is critical in prioritizing areas for conservation and development. Those plots with high diversity and high evenness (i.e. subplot 35) should be conserved and protected while those plots with low evenness (e.g. sublots 16, 20 and 47) should be prioritized for rehabilitation.

Spatial Analysis

The spatial behavior was correlated based on the clustering of species using the ordination method (Figure 9). This ordination method groups the subplot into clusters according to the similarities between the subplots' species composition. Based on ordination method, study reveals that subplots 47, 1, 45 and 27 form part at the North direction while subplot 40 and 7 at the South direction. Subplot

4 was found at the west most part while subplot 46 at the east most part and the rest of the plot are simply scattered within the area.

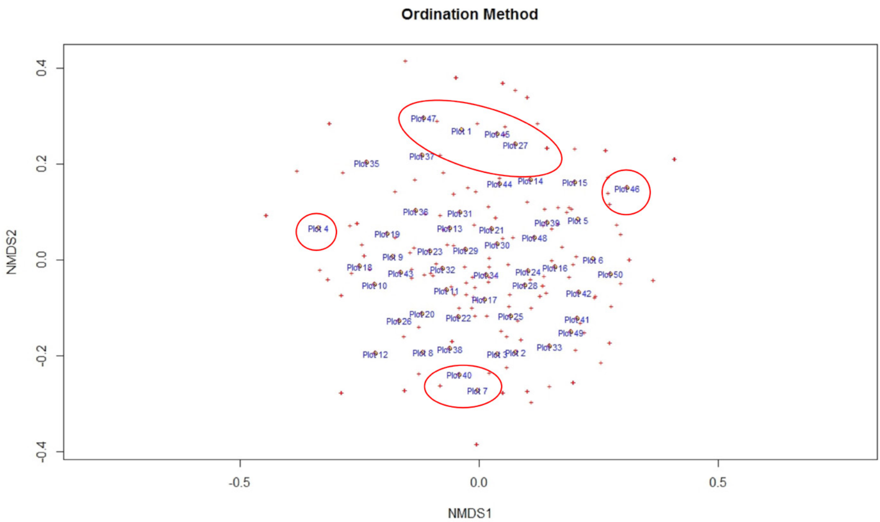

Figure 9. Spatial analysis using ordination method

Subplots 47, 1, 45 and 27 share similar species composition since the plots are spatially aligned downwards from the ridge with subplot 27 being at the top (ridge). Seed dispersal would be limited along the spatially distributed trees from subplot 27 down to subplot 45 and thus explains the similar species composition. Subplots 40 and 7 are both located on high elevation. Subplot 4 is located at the ridge with very steep slope and contains very few species (second to the lowest number of individuals) and less diverse since the plot location limits entry of other species. Subplot 6 is located at the lower portion of the ridge and receives limited sunlight and therefore fewer species may survive.

The results imply that those plots that are grouped together (i.e. North part group) share common characteristics and qualifications which may be in terms of species composition, environmental requirements and biotic and abiotic factors. Those plots which are scattered far from the group have different site requirements and unique floral characteristics and thus very much different from the other quadrats.

Like the Mutiple Renyi Profile, these information will be of great help in the protection and management of biodiversity in the area. Those grids that share the same environmental behavior will have the same program and project strategies.

In the same manner, those grids with unique characteristics will have a different management approaches.

Monitoring Plots

To facilitate the monitoring process of LTERP, a simple monitoring map was generated reflecting the initial frequency and diameter class per subplot (Figure 10). With this, changes in morphological or structural properties of individual trees can be documented regularly. All the data that will be collected will form the database which will perform a crucial role for subsequent updating.

Monitoring of changes is every five years. Parameters such as growth (DBH and height) and density (recruitment and mortality) where trees will be re-censused every 5 years to monitor these parameters. Plots with less number of trees will be prioritized for restoration and rehabilitation. The growth increment in terms of DBH and total height will be measured regularly to monitor changes in response to climate change and other major environmental disturbances.

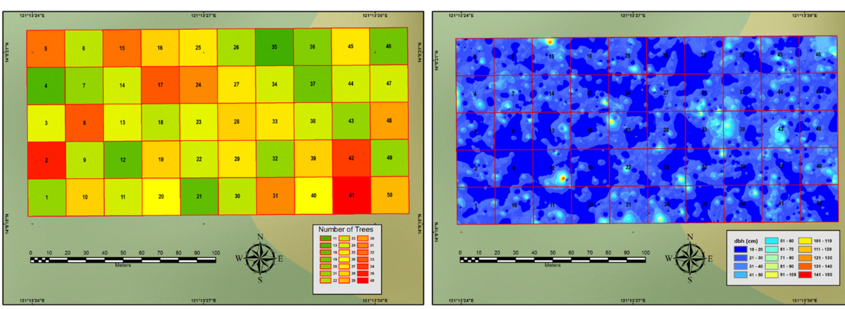

Figure 10. Number of trees (left) and mean diameter of trees (right) per plot in LTERP

CONCLUSION

The study revealed abundance of threatened species in the LTERP at the Molawin-Watershed area. Out of ten dominant species based on IV, 7 are threatened species and 3 of which are critically endangered species. Futher, the study also recorded a relatively high endemism. Presence of both threatened and endemic species makes the LTERP a priority biodiversity conservation area. Monitoring and evaluation of the LTERP to monitor changes in tree individuals and the area as well will be conducted every year. Parameters such growth, recruitment and mortality shall be documented during monitoring and evaluation.

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