Scientific Research Publishing

Open Journal of Ecology, 2022, 12, 407-433
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Population Structure and Spatial Pattern of Critically Endangered Dipterocarpaceae Tree Species in Mt. Malindang Range Natural Park, Mindanao, Philippines

Jersam C. Calago[1,2*], **Annie G. Diola**[2]

[1]Department of Biology, School of Arts & Sciences, University of San Carlos, Cebu City, Philippines
[2]Misamis University Community Extension Program (MUCEP), Misamis University, Mindanao, Philippines
Email: *jersam.h@gmail.com

How to cite this paper: Calago, J.C. and Diola, A.G. (2022) Population Structure and Spatial Pattern of Critically Endangered Dipterocarpaceae Tree Species in Mt. Malindang Range Natural Park, Mindanao, Philippines. *Open Journal of Ecology*, **12**, 407-433.
https://doi.org/10.4236/oje.2022.127024

Received: March 7, 2022
Accepted: July 11, 2022
Published: July 14, 2022

Abstract

Dipterocarps tree species are the key species in most tropical forests because of their economic and ecological value in nature. The present study was carried out to determine the population structure and spatial pattern distribution of critically endangered dipterocarps trees in Mt. Malindang. A total of 638 individuals belonging to 86 species among the 62 genera were recorded at all sites. The highest diversity index was recorded in the elevation range of 700 - 900 masl (3.53). Dipterocarpaceae family had the highest importance value (157.66) among the families recorded in this study. Seven dipterocarp tree species were recorded in this study. *Shorea negrosensis* Foxw, *Shorea polysperma* (Blanco) Merr., and *Shorea contorta* S.Vidal, *Shorea squamata* (Turcz.) Benth. & Hook.f. ex DC. are listed as critically endangered and *Dipterocarpus grandiflorus* (Blanco) Blanco as Vulnerable. Soil moisture has a great influence on *Anisoptera thurifera* (Blanco) Blume, whereas light is positively correlated with *Shorea polysperma* and negatively correlated with elevation. Diameter-class distribution of critically endangered dipterocarps tree species showed an interrupted growth pattern and because a fewer number of seedlings or saplings were found in each species, this suggested that regeneration is not good. However, threats and disturbances such as illegal poaching, slash and burn, roads, and land conversion to agricultural crops and settlements contribute to the declining population of critically endangered dipterocarps species. Thus, conservation, protection and prioritization management activities in Mt. Malindang are needed.

Keywords

Critically Endangered, Diameter-Class, Dipterocarps, Distribution,

Regeneration

1. Introduction

Dipterocarpaceae is the most well-known and dominant tree in the tropic regions [1] with economic and ecological importance. It particularly grows and is abundant in lowland within elevation ranges from 300 to 1200 masl and with an annual mean rainfall of 1000 mm to 2000 mm [2]. The dipterocarps are highly valuable timber products in Southeast Asian countries [3] [4]. They are also the source of minor forest products such as resins, camphor, dammars, and tannin [5], which most of the upland dwellers are dependent on for their survival [6]. Intense exploitation of dipterocarps trees caused their rapid decline and eventually became globally threatened.

The Philippine forest is rich in dipterocarps, especially in lowland forests. However, these areas experienced massive exploitation such as logging, land conversion and fragmentation that endangered local floral species. Philippine dipterocarps species are distributed to five habitat types namely: tropical lowland evergreen rain forest, tropical semi-evergreen rain forest, tropical lower montane rain forest, forest over limestone and peat swamp forest [7]. The philippines has around 50 species of dipterocarps in 6 genera, 21 are endemic to the country [2] [8], and 31 species are considered threatened [9] [10]. Furthermore, in 2011, an assessment conducted in Mt. Hamiguitan Range, Davao del Sur had identified 5 threatened endemic species of dipterocarps with high priority protection and conservation [11]. Furthermore, the preliminary assessment of threatened plants in the country assessed by [9] listed 686 taxa of vascular and mosses that are indigenous to the Philippines, which are considered threatened plants as well. Of the 686 taxa, 472 (69%) belonged to angiosperm of which the family Dipterocarpaceae is contributing 31 (6.5%) to the national list of threatened plants which 14 (45%) species are considered critically endangered.

Mt. Malidang Range Natural Park (MMRNP) is located in the Northern Part of Mindanao. On June 19, 1971, the area was proclaimed as Mount Malindang National Park by virtue of Republic Act 6266. Under the establishment of the National Integrated Protected Areas System (NIPAS) in 1992, the park was reclassified and was renamed Mount Malindang Range Natural Park on August 2, 2002, through Proclamation No. 228. It has an area of 53,262 hectares with 34,464 as Strict Protect Zone and 18,798 hectares as Multiple Use Zone [12]. It is part of the Key Biodiversity Areas (KBAs) and was declared an ASEAN Heritage Park in 2012 because of its immense value and high endemicity. The park was included in the list of one of the conservation priority areas in the country; however, the park is facing constant threats of illegal poaching, unsustainable farming practices, and weak law enforcement [13] [14]. Furthermore, in the 2013 Management Effectiveness and Capacity Assessment of the park, utilization of portions of the park for agricultural crops and logging and wood harvesting were considered as high threats to the park values [15].

The comprehensive study made during the Biodiversity Research Program (BRP) for Mindanao in the northern part of Mt. Malindang focused on tree diversity and abundance of which 85 species were recorded with 57% endemism [16]. In MMRNP, there were four (4) identified Dipterocarps species: *Shorea contorta*, *Shorea polysperma*, *Shorea squamata*, and *Shorea negrosensis*, which are listed as critically endangered in DAO-2007-01 and IUCN Red List [17]. However, the population structure and spatial tree pattern of the critically endangered dipterocarp trees have not yet been studied.

Given the large area of MMRNP, it is recommended that future studies be made on tree species richness and diversity for the rest of the park. There is also a need to assess the health status of the remaining forest cover in Mt. Malindang, especially the critically endangered species for propagation, conservation, protection, and policy development. Hence in order to address the following research objectives were provided: 1) describe tree composition, population structure and distribution patterns; 2) analyse the relationship of the spatial distribution of the critically endangered dipterocarp trees with Physico-chemical properties and topographic conditions; 3) identify sources of disturbances present in the area.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted in the northern part of Mount Malindang Range Natural Park (MMRNP), Misamis Occidental (**Figure 1**). It is within geographic coordinates 123˚31'45" to 123˚55'30" East longitudes and 8˚30'30" to 8˚45'55" North latitudes. MMRNP has a total area of 53,262 hectares with a Strict Protection Zone of 34,464 hectares and Multiple Use Zones of 18,798 hectares. It has an altitude range of 600 meters to 2404 m asl. It has 7 peaks namely: South Peak, Mt. Malindang peak itself, Mt. Labag, North Peak, Mt. Sumalarong, Mt. Ampiro, and Mt. Balabag [14] [18]. The climate of the MMRNP is wet and moist, slightly moderate dry season and has an average rainfall of about 2500 mm and above. Rainfall is fairly distributed throughout the area. The mean minimum monthly temperature is 27.7˚C with mean annual relative humidity is 82%. The soil is generally clay loam in the upland area with a pH value range of 4.6 - 6.0. The habitat types of the park includes: dipterocarp forest, grassland, lower montane forest, mossy forest and upland wetland. The northern portion Mount Malindang covers municipality of Concepcion, Calamba, Oroquieta, Lopez Jaena and parts of Don Victoriano.

2.2. Sampling Design and Vegetation Data Collection

Entry protocol made to the DENR- MMRNP Protected Area Office, Municipalities and Barangays covered in the study area, seeking their approval to penetrate the area for security reasons and presentation to the PAMB (Protected Area

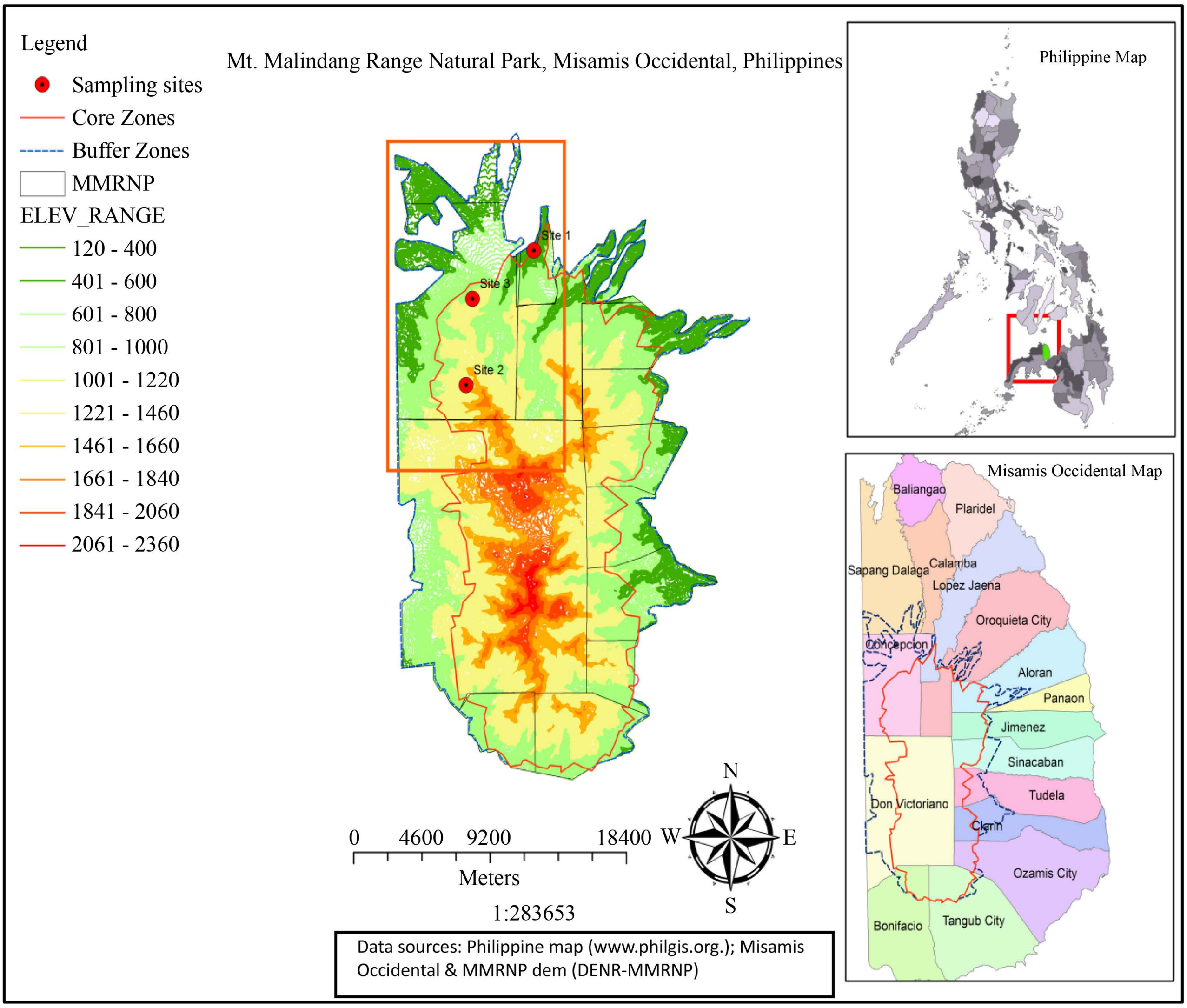

Figure 1. Location of the study area.

Management Board) for seeking their approval for allowing the researcher to conduct and acquire permit gratuitous permit for the collection of voucher specimens of unidentified trees.

Three permanent 2-kilometer transect lines were established in different elevation ranges (300 masl to 700 masl, 701 masl to 900 masl, and 901 masl to 1500 masl) in the North-east portion of MMRNP following the method of the Biodiversity Monitoring System (BMS) of DENR in establishing a permanent plot for monitoring of a protected area [19] (**Figure 2**).

A total of 29 20 m × 20 m plots were laid down alternately in a 2-kilometer transect line at a regular distance of every 250 meters.

All trees with a diameter breast height (DBH) of at least 5 cm inside the quadrats were identified, measured, geo-tagged, and recorded. In addition, voucher specimens of each species were collected, photographed, labelled, pressed, and identified using different taxonomic keys from floras and monographs

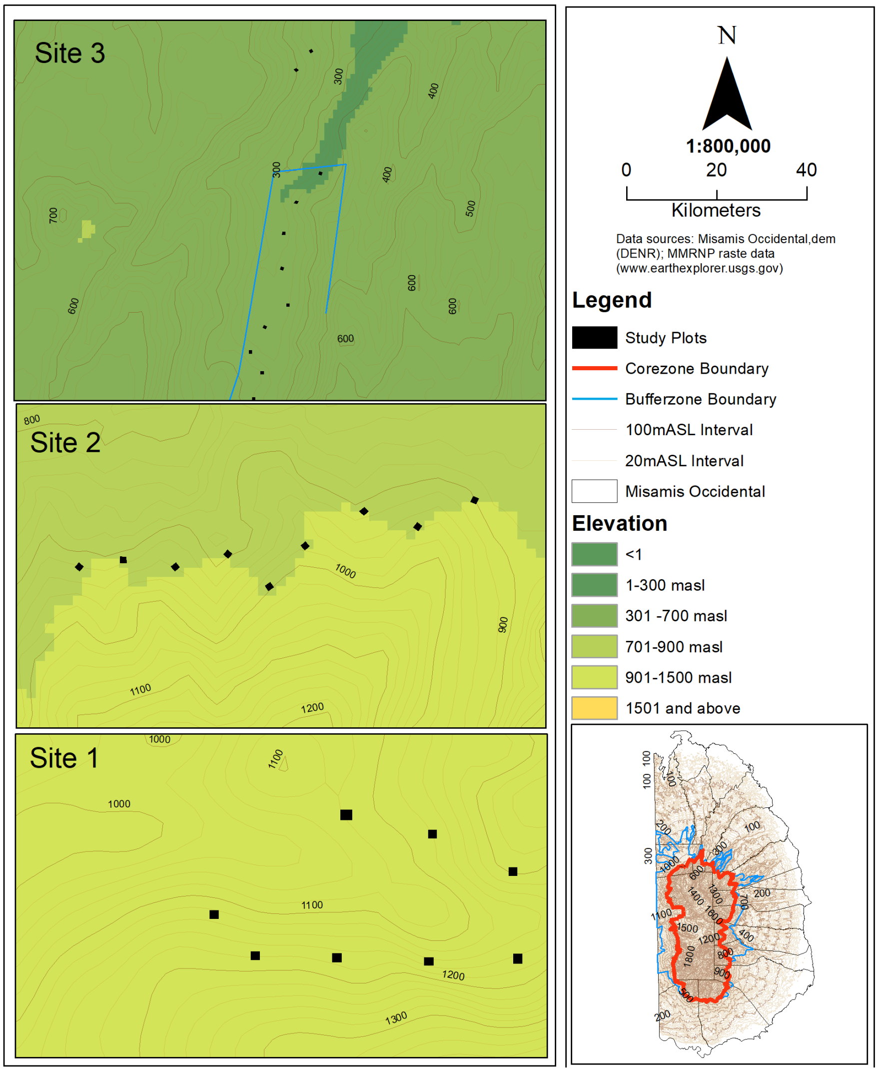

Figure 2. Topography of the three sites in the Northeastern part of Mt. Malindang Range.

of [20]-[25], Herbarium comparison, Co's Digital Flora in the Philippines [26], and sent to plant expert for further verification.

In each quadrat, threats and disturbances were recorded through direct observation in the study area. Threats determined were recorded as present and absent and identified the types of threats. Physico-chemical properties were recorded, such as soil moisture and pH in each quadrats using a Kelway Soil Tester, light intensity using the calibrated android App (Physics Toolbox v.1.8.9), a free app developed by Vieyra Software [27] installed in Samsung Galaxy J7 Prime mobile phone. The app was calibrated in LI-COR Model LI-250. The geographical locations of individual trees inside the quadrats were recorded using a Garmin e-Trex 30.

2.3. Data Analysis

Analysis of density, frequency and abundance followed the standard methods of [28] and [29].

Density = Total no. of individuals of a species/Total no. of quadrats studied;

Relative Density (%) = Number of individuals of species/Number of individuals of all species × 100;

Frequency = Number of sampling units species occur/Total no. of sampling units;

Rel. Frequency (%) = Frequency of a species/Frequency of all species × 100;

Rel. Basal Area (%) = Basal area of a species/Basal area of all species × 100.

The Basal Area of trees was calculated using this formula:

Basal Area = 0.7854 * d^2.

Where, d = diameter at breast height in meter.

Importance Value (IV) was used to measure to determine the productivity of species in a community. Species Importance Value Index (IVI) was calculated by summing the Relative Density, Relative Frequency, and Relative Basal Area following [30]. The abundance and Frequency ratio of each species were also calculated to determine the population dispersion pattern. The ranges of values in determining dispersion pattern were: regular (<0.025), random (0.025 - 0.05) and contiguous (>0.05) given by [31].

Tree diversity indices such as Shannon-Wiener Index, and Simpson's Diversity Index were calculated using PAST version 3.23 software package for education and data analysis [32]. The Shannon diversity index (H') is also known as the Shannon-Wiener index, Shannon-Weaver index and Shannon entropy. The H' value of the Shannon diversity index is a function of the number of species present in a plot and the degree of evenness of the total population that is distributed equally among species. Simpson's diversity index is used to measure diversity taking into account the common or dominant species. Moreover, the similarity of dipterocarps tree species along elevational gradient was calculated with the Bray-Curtis index of similarity.

The following formulae were used in calculating the different indices:

1) Shannon-Wiener Index (1963)

$$H = \sum \frac{ni}{N} \log\left(\frac{ni}{N}\right)$$

ni = Total number of individuals per species,

N = Total number of individuals per quadrat.

2) Simpson's Diversity Index (1949)

$$D = \sum \frac{ni(ni-1)}{N(N-1)}$$

For Simpson's index of diversity is the value of $1 - D$.

Shannon diversity index was used because it is more sensitive to small samples as compared to other indices while the Simpson diversity index was used for comparison. The classification of [33] was used for the interpretation of the Shannon diversity index (**Table 1**).

Demographic characterization of trees including the critically endangered dipterocarp trees, individuals were classified as seedlings (no measurable

Table 1. Diversity indices classification developed by [33].

Relative Values	Shannon (H') Index
Very High	3.5 and above
High	3.0 - 3.49
Moderate	2.5 - 2.99
Low	2.0 - 2.49
Very Low	1.9 and below

dbh 1.3 m); juveniles (with dbh < 20 cm); reproductive (with dbh > 20 cm) according to [34]. Dipterocarp trees that have measurable dbh of <10 cm were grouped into different size classes of 5cm of each group following by [35]. Basal area was calculated using the DENR formula: BA = $0.7854(D)^2$, where D is a diameter at breast height in meters.

The assessment of the conservation status of tree species was based on the national list of threatened Philippines plants [36] [37] [38] [39].

3. Results and Discussion

3.1. Tree Composition and Distribution Patterns

The present study recorded 638 individuals belonging to 86 species, 62 genera, and 54 families from the three (3) sampling sites (**Table 2**) in the North-western part of Mt. Malindang Range Natural Park. Out of these 27 families comprising 41 genera, 50 species and 215 individuals were recorded in Site 1; 28 families representing 35 genera, 58 species, and 300 individuals were recorded in Site 2. Site 3 contributed 123 individuals belonging to 43 species among 32 genera and 23 families. Site 1 is dominated by Moraceae (*Ficus* sp.), site 2 is dominated by Dipterocarpaceae (*Anisoptera thurifera*), and Melastomataceae and site 3 is also dominated by Dipterocarpaceae (*Shorea contorta*) in terms of basal density. Other relatively abundant families are Moraceae, Fagaceae, and Myrtaceae. The values of the Shannon-Weiner diversity index ranged from 3.30 to 3.54, with the value from Site 1 being the highest and site 3 as the lowest. On the other hand, Simpson's value ranged from 0.94 to 0.95 for all sites (**Table 2**). Using the classification scheme developed by [33], the diversity of the North-western part of Mt. Malindang in three study sites was considered high to very high. The result of this study is higher species diversity of [40] in the southern portion of the park and of [41] in upland farming communities of Nueva Viscaya, Benguet and Quezon. Furthermore, the values of Simpson's diversity index corresponded to the other reports on tropical forests [42] [43].

Understanding species composition and tree diversity are essential in determining forest community stability, tree population status, regeneration, and diversity [44] [45]. The previous study in the northern part of Mt. Malindang found 1284 species of plants belonging to 472 genera and 187 families [46], and southern part, there were 275 individuals belonging to 46 species and 28 families

Table 2. Floristic richness, number of individuals, and diversity indices for the three sites.

Variable	Site 1	Site 2	Site 3
No. of individuals	215	300	123
No. of species	50	58	43
No. of genera	41	35	32
No. of families	27	28	23
Density (plants/11,600m^2)	674.22	874.04	988.3
Basal area (cm^2)	6068	7866.70	10872
Shannon-Wiener Index	3.42	3.54	3.30
Simpson's Diversity Index	0.95	0.9518	0.94
Evenness	0.58	0.5645	0.63
Elevation	1000 - 1500 masl	700 - 900 masl	300 - 700 masl
Latitude	8˚23'17.64"N	8˚20'24.92"N	8˚24'54.49"N
Longitude	123˚35'50.89"E	123˚35'36.57"E	123˚38'6.32"E

[40]. The present findings account for 6.6% of the total species found in the comprehensive floral inventory in the Northern part of Mt. Malindang, and a higher number of tree species found in the southern portion of the park since the study in the southern part had only one (1) 2-kilometer transect in this study.

The number of plant families in the three different elevation sites was 54 taxonomically well-represented families (**Table 3**). Moraceae and Myrtaceae had the most species-rich families (8 species each), followed by Dipterocarpaceae and Anacardiaceae (7 species each); Fagaceae (6 species each). Dipterocarpaceae had the maximum number of species (127 species each), followed by the family Moraceae (107 species each). Correspondingly, the most species-rich genera are *Ficus* & *Syzygium* (Moraceae and Myrtaceae (8 species), Lithocarpus Fagaceae (6 species), and *Shorea* (Dipterocarpaceae (5 species). Twelve (1.94%) undescribed tree species were collected because of the lacking of diagnostic features.

Dipterocarpaceae was analysed with the Importance Value Index (IVI = 50.98) in the present study as the ecologically most dominant and significant family. The other co-dominant families were Moraceae (IVI = 40.54), Rubiaceae (IVI = 20.87), Melastomataceae (IVI = 19.15), Myrtaceae (IVI = 18.81), and Fagaceae (IVI = 16.36) (**Table 3**). The greater importance value of dipterocarp trees in this study indicated that the dipterocarps are still dominated in Mt. Malindang, and this substantiated the forest types of the park and in other dipterocarp forests in tropical countries [47] [48].

There were seven (7) dipterocarps tree species recorded, representing three (3) genera, contributing 8.8% of total tree species diversity (86 species) of which one (1) species was identified up to genera level belonging to *Shorea* (**Table 3**). This accounts for (14 percent) of the total number of dipterocarps species in the

Table 3. Dominant families for the 3 sites based on number of individuals, species, genera, and family importance value index.

Series No.	Family Name	No. of individuals	No. of Species	No. of genera	FIVI
1	Dipterocarpaceae	127	7	3	50.98
2	Moraceae	106	9	1	40.54
3	Rubiaceae	45	3	3	20.87
4	Melastomataceae	48	2	2	19.15
5	Myrtaceae	42	11	3	18.81
6	Fagaceae	33	8	2	16.36
7	Anacardiaceae	21	7	7	11.66
8	Fabaceae	9	1	1	11.03
9	Urticaceae	21	2	2	10.8
10	Phyllanthaceae	9	3	2	7.3
11	Pentaphylacaceae	15	1	1	7.13
12	Lythraceae	9	1	1	7.09
13	Euphorbiaceae	12	5	5	6.39
14	Casuarinaceae	8	2	2	6.21
15	Lauraceae	9	4	3	6.21
16	Proteaceae	11	1	1	5.87
17	Clethraceae	8	1	1	5.33
18	Araliaceae	8	2	2	5.26
19	Meliaceae	8	3	3	5.23
20	Sapotaceae	9	2	1	5.14
21	Combretaceae	6	1	1	3.99
22	Cunnoniaceae	5	1	1	3.72
23	Rosaceae	6	1	1	3.54
24	Calophyllaceae	5	1	1	2.9
25	Lamiaceae	4	1	1	2.89
26	Olacaceae	3	1	1	2.5
27	Cannabaceae	3	1	1	2.48
28	Apocynaceae	2	1	1	1.67
29	Eleocarpaceae	2	1	1	1.52
30	Rutaceae	2	1	1	1.51
31	Sterculiaceae	1	1	1	0.89
32	Verbinaceae	1	1	1	0.82

Continued

33	Guttiferae	1	1	1	0.76
34	Aceraceae	1	1	1	0.72
35	Actinidiaceae	1	1	1	0.72
36	Myristicaceae	1	1	1	0.71
37	Sellaginellaceae	1	1	1	0.67
38	Clusiaceae	1	1	1	0.66

Note: 12 unidentified tree species.

Philippines [2] Seven (7) recorded dipterocarps species are *Anisoptera thurifera* (Blanco) Blume, *Dipterocarpus grandiflorus* (Blanco), *Shorea contort*a S Vidal, *Shorea negrosensis* Foxw., *Shorea polysperma* (Blanco) Merr, *Shorea squamata* (Turcz), and *Shorea* sp. This also corresponds to the findings of the previous study in the southern part of Mt. Malindang found 4 Shorea species: *Shorea polysperma*, *Shorea negrosensis*, *Shorea contorta*, and *Shorea squamata* [40]. *Shorea contorta*, *Shorea negrosensis*, and *Shorea polysperma* are listed as critically endangered listed in [49] and [36]. *Dipterocarpus grandiflorus* (Blanco) is listed in [36] as vulnerable and endangered in [49]. *Shorea squamata* syn. *Shorea palosapis* is listed in the [38] as critically endangered. *Anisoptera thurifera* is listed as vulnerable in [37].

The most important species across three sites were *A. thurifera* indicated with a value of 15.66 followed by *Astrocalyx calycina* (S.Vidal) M (11.27); *S. contorta* S. Vidal (9.32); *Neonauclea formicaria* (Elmer) Merr. (9.25) and *Ficus fistilulosa* Reinw.ex Blume (8.72). The other dipterocarps species, such as *S. polysperma* (Blanco) Merr. had 8.61 IVI, *S. squamata* (Turcz.) Benth. (4.49), *Dipterocarpus grandiflorus* (Blanco) (4.12), and *S. negrosensis* Foxw and *Shorea* sp. both had 1.08 SIV (**Table 4**). The present findings are unique to other studies conducted inside Mt. Malindang. In the previous study in the Southern part of the park, [40] reported *S. contorta* was abundant species of the Dipterocarpaceae family. This is because the Southern part is less disturbed than the Northern part, where the present study is.

Spatial patterns of Dipterocarps species across three sites are varied differently, *Anisoptera thurifera* (Blanco) Blume species distribution pattern is clumping in all sites, *Dipterocarpus grandiflorus* (Blanco) which is present only in Site 3 the distribution is also clumping, *Shorea contorta* S.Vidal is random in Site 2 and contiguous in site 3, *Shorea negrosensis*, present in site 2 only is regular in distribution pattern, *Shorea polysperma* (Blanco) Merr. Foxw is contiguous in site 1 and regular in both site 2 and 3. *Shorea s*p. is regular only in sites 3 and *Shorea squamata* (Turcz.) Benth. & Hook.f. ex DC is both regular in distribution pattern in sites 2 and 3 (**Table 5**).

Dipterocarp species in this study exhibit both clumping and uniform distribution pattern; this is similar to the study in the tropical evergreen forest of West

Table 4. Dominant species based on relative abundance, relative density, relative frequency, species importance value index and conservation status.

Scientific Name	Local Name/Common Name	Relative abundance (percent)	Relative Density (percent)	Relative Frequency (percent)	SIVI	Conservations Status	
						IUCN	DAO (2017-11 & 2007-1
Anisoptera thurifera (Blanco) Blume	Palosapis	9.06	3.48	3.12	15.66		OWS-OWS
Astrocalyx calycina (S.Vidal) Merr.	Tanghau	5.88	3.16	2.23	11.27		NL-NL
Shorea contorta S.Vidal	White Lauan	4.61	2.22	2.49	9.32	CR	VU
Neonauclea formicaria (Elmer) Merr.	Labalod	4.29	3.48	1.48	9.25		OWS-NL
Ficus fistulosa Reinw. ex Blume	Bosyong	4.13	2.85	1.74	8.72		OWS-NL
Shorea polysperma (Blanco) Merr	Tanguile	3.82	3.48	1.31	8.61	CR	VU
Ficus variegata Blume	Sigawan likpaw	3.97	2.22	2.15	8.34		OWS-NL
Ficus nota Merr.	Tibig	3.34	2.85	1.41	7.59		OWS-NL
Psydrax dicoccos Gaertn.	Malakape	2.70	2.85	1.14	6.69		OWS-NL
Ficus callosa Willd.	Hamindang	2.54	2.22	1.38	6.14		OWS-NL
Dendrocnide densiflora (C.B.Rob) Chew	Lingatong	2.38	2.22	1.29	5.89		NL
Eurya trichocarpa Korth. in Temminck	Ubod-ubod	2.38	1.90	1.51	5.79		NL
Ficus septica Burm. f.	Hawili	1.91	1.90	1.20	5.01		OWS-NL
Astronia sp.	Tungaw baye	1.75	2.22	0.95	4.91		
Helicia sp.	Dabo-dabo	1.75	2.22	0.95	4.91		
Pistacia chinensis Bunge	Iba-iba	1.59	2.22	0.86	4.67		NL
Shorea squamata (Turcz.) Benth. & Hook.f.ex DC.	Kalayaan	1.59	1.90	1.00	4.49	CR (2013)	OWS-NL
Syzygium sp.	Polayo	1.59	1.90	1.00	4.49		
Lithocarpus philippinensis (A.DC.) Rehder	Gulayan Puti	1.59	1.27	1.51	4.36		OWS-NL
Dipterocarpus grandiflorus (Blanco) Blanco	Apitong	0.79	0.32	3.01	4.12	En	Vu
Duabanga moluccana Blume	Laton	1.43	1.27	1.35	4.05		NL
Lithocarpus mindanaensis (Elmer) Rehder	Gulayan	1.43	1.27	1.35	4.05		OWS-NL
Clethra canescens var. novoguineensis (Kaneh. & Hatus.) Sleum	Sakam	1.27	1.90	0.80	3.97		NL
Falcataria moluccana (Miq.) Barneby & J. W. Grimes	Falcata	1.27	1.90	0.80	3.97		NL
Unidentified sp. 5	Bagaringan	1.27	0.95	1.61	3.83		

Continued

Lithocarpus celebicus (Miq.) Re	Salimbugaon	1.27	1.58	0.96	3.82	OWS-NL
Syzygium hutchinsonii (Merr. ex C. B. Rob.) Merr.	Polayo Tambison	1.11	0.95	1.41	3.47	OWS-NL
Swietenia macrophylla King	Mahogany	0.95	0.63	1.81	3.39	NL
Bischofia javanica Blume	Tuai	0.95	1.58	0.72	3.26	NL
Leucosyke capitellata Wedd.	Alagasi	0.95	1.27	0.90	3.12	OWS-NL
Palaquium philippense (Perr.) C. B. Rob.	Malak-malak	0.95	1.27	0.90	3.12	VU
Schefflera alvarezii Merr.	Tagima	0.95	1.27	0.90	3.12	OWS-
Terminalia foetidissima Griff.	Talisay gubat	0.95	1.27	0.90	3.12	OWS
Prunus sp.	Bakan sa Lasang	0.95	0.95	1.20	3.11	
Syzygium siderocola (Merr.) Merr.	Dabawak/ Sagimsim	0.95	0.95	1.20	3.11	OWS-NL
Spiraeopsis celebica (Blume) Miq.	Bakan sa Lasang	0.79	1.27	0.75	2.81	OWS-NL
Calophyllum blancoi Planch. & Triana	Bitanghol	0.79	0.95	1.00	2.75	NL
Casuarina equisetifolia L.	Agoho	0.79	0.95	1.00	2.75	NL
Decaspermum sp.	Polayo gagmay dahon	0.79	0.95	1.00	2.75	
Gymnostoma rumphianum (Jungh. Ex Vriese) L.A.S. Johnson	Maribuhok	0.48	0.32	1.81	2.60	NL
Lithocarpus sp.3	Gulayan dagko dahon	0.48	0.32	1.81	2.60	
Syzygium leucoxylon Korth.	Polayo puti	0.48	0.32	1.81	2.60	OWS-NL
Callicarpa erioclona Schauer in DC.	Neop	0.64	1.27	0.60	2.50	NL
Cinnamomum mercadoi S. Vidal	Kalingag	0.64	0.95	0.80	2.39	OTS-Vu
Semecarpus cuneiformis Blanco	Mahogany sa Lasang	0.64	0.95	0.80	2.39	OWS-NL
Ficus minahassae (Teijsm. & Vriese) Miq.	Hagimit	0.48	0.95	0.60	2.03	OWS-NL
Glochidion sp.	Bunot-bunot	0.48	0.95	0.60	2.03	
Palaquium luzoniense (Fern.-VilL.) S. Vidal	Nato	0.48	0.95	0.60	2.03	VU
Rhodomyrtus sp.	Tagubahi	0.48	0.95	0.60	2.03	
Strombosia sp.	Larak	0.48	0.95	0.60	2.03	
Bridelia insulana Hance	Balitadhan	0.48	0.63	0.90	2.01	NL
Buchanania sp.	Pale	0.48	0.63	0.90	2.01	
Hancea longistyla (Merr.) S. E. C. Sierra, Kulju & Welzen	Bukog-bukog	0.48	0.63	0.90	2.01	OWS-NL

Continued

Macaranga sinensis (Baill.) Müll. Arg. in DC.	Bunot-bunot	0.48	0.63	0.90	2.01	OWS-NL
Syzygium gigantifolium (Merr.) Merr.	Santol-santol	0.48	0.63	0.90	2.01	NL
Trema orientalis (L.) Blume	Hinagdong	0.48	0.63	0.90	2.01	OWS
Unidentified sp. 12	Pamasiton	0.48	0.63	0.90	2.01	
Decaspermum parviflorum (Lam.) Scott	Olingon	0.32	0.32	1.20	1.84	NL
Dracontomelon edule (Blanco) Skeels	Lamio	0.32	0.32	1.20	1.84	OWS-Vu
Ficus balete Merr.	Balete	0.32	0.32	1.20	1.84	OWS-NL
Koordersiodendron pinnatum (Blanco) Merr.	Amugis	0.32	0.32	1.20	1.84	OWS-NL
Unidentified sp. 10	Morag Hindang	0.32	0.32	1.20	1.84	
Unidentified sp. 11	Hambabalod gagmay dahon	0.32	0.32	1.20	1.84	
Alstonia macrophylla Wall. ex G. Don	Batino	0.32	0.63	0.60	1.55	OWS-OTS
Cinnamomum sp.	Kalingag	0.32	0.63	0.60	1.55	
Elaeocarpus calomala (Blanco) Merr.	Babati	0.32	0.63	0.60	1.55	NL
Endospermum peltatum Merr.	Bay-ang	0.32	0.63	0.60	1.55	NL
Eusideroxylon zwageri Teijsm. & Binn.	Tambulian	0.32	0.63	0.60	1.55	OTS-NL
Melicope latifolia (DC.) T. G. Ha	Bintuko	0.32	0.63	0.60	1.55	OWS-NL
Polyscias nodosa (Blume) Seem.	Binliw	0.32	0.63	0.60	1.55	NL
Unidentified sp. 1	Papait	0.32	0.63	0.60	1.55	
Acer laurinum Hassk. in Jungh. & Vriese	Philippine Maple	0.16	0.32	0.60	1.08	OWS-NL
Adenanthera intermedia Merr.	Tanglin	0.16	0.32	0.60	1.08	OTS-Vu
Aglaia edulis (Roxb.) Wall.	Malasaging	0.16	0.32	0.60	1.08	OTS-Vu
Artocarpus odoratissimus Blanco	Marang	0.16	0.32	0.60	1.08	NL-NL
Castanopsis sp.	Balangas	0.16	0.32	0.60	1.08	
Dysoxylum sp.	Tagiles	0.16	0.32	0.60	1.08	
Ficus botryocarpa Miq.	Tatanok	0.16	0.32	0.60	1.08	OWS-NL
Garcinia garciae Elmer	Kandiis	0.16	0.32	0.60	1.08	OWS-NL
Garcinia lateriflora Blume	Kandiis	0.16	0.32	0.60	1.08	OWS-NL
Glochidion album (Blanco) Boerl.	Dakonakon	0.16	0.32	0.60	1.08	OWS-NL
Gmelina arborea Roxb. ex Sm., in Rees	Gmelina	0.16	0.32	0.60	1.08	NL
Heritiera javanica (Blume) Kost	Lumbayao	0.16	0.32	0.60	1.08	OWS-NL

Continued

Lithocarpus sp. 1	Gulayan Baye	0.16	0.32	0.60	1.08		
Lithocarpus sp. 2	Gulayan laki	0.16	0.32	0.60	1.08		
Litsea philippinensis Merr.	Bakan	0.16	0.32	0.60	1.08		OWS-NL
Myristica philippensis Lam.	Duguan	0.16	0.32	0.60	1.08		OWS-NL
Nauclea orientalis (L.) L.	Bangkal	0.16	0.32	0.60	1.08		OWS-NL
Saurauia copelandii Elmer	Balangog	0.16	0.32	0.60	1.08		NL
Selaginella remotifolia Spring	Bangnay	0.16	0.32	0.60	1.08		OWS-NL
Shorea negrosensis Foxw	Red lauan	0.16	0.32	0.60	1.08	CR	VU
Shorea sp.	Lauan	0.16	0.32	0.60	1.08		
Syzygium sp. 1	Polayo Bagtikan	0.16	0.32	0.60	1.08		
Syzygium sp. 2	Polayo Bayabason	0.16	0.32	0.60	1.08		
Syzygium sp. 3	Polayo dagko dahon	0.16	0.32	0.60	1.08		
Unidentified sp. 2	Gurabo	0.16	0.32	0.60	1.08		
Unidentified sp. 3	Tagulamos	0.16	0.32	0.60	1.08		
Unidentified sp. 4	Tapok-tapok	0.16	0.32	0.60	1.08		
Unidentified sp. 6	Unknown 2	0.16	0.32	0.60	1.08		
Unidentified sp. 7	Nanagon	0.16	0.32	0.60	1.08		
Unidentified sp. 8	Bakhaw-bakhaw	0.16	0.32	0.60	1.08		
Unidentified sp. 9	Koreto	0.16	0.32	0.60	1.08		

Legend: SIVI-Species Importance Value Index; IUCN & DAO 2017-11 & -07 Criteria: CR (Critically Endangered), Vu (Vulnerable), En (Endangered), OTS (Other Threatened Species), OWS (Other Wildlife Species), NL (Not Listed).

Table 5. Distribution analysis of Dipterocapaceae tree species at three forest sites of Northern part of Mt. Malindang.

Species	Site 1				Site 2				Site 3			
	A	F	A/F	IVI	A	F	A/F	IVI	A	F	A/F	IVI
Anisoptera thurifera (Blanco) Blume	3.67	33.33	0.11	9.98	5.8	88.9	0.06	18.93	-	-	-	
Dipterocarpus grandiflorus (Blanco) Blanco	-	-	-		-	-	-		0.45	9.09	0.05	16.56
Shorea contorta S.Vidal	-	-	-		3.3	44.4	0.07	12.45	1.45	27.27	0.053	30.16
Shorea negrosensis Foxw	-	-	-		1	11.1	0.09	1.95	-	-	-	
Shorea polysperma (Blanco) Merr.	5	22.22	0.23	11.06	2.2	66.7	0.03	10.38	0.09	9.09	0.01	4.96
Shorea sp.	-	-	-		-	-	-		0.09	9.09	0.01	3.13
Shorea squamata (Turcz.) Benth. & Hook. f. ex DC.	-	-	-		1	33.3	0.03	5.05	0.64	27.27	0.023	16.85

India that dipterocarps species showed clumping or uniformed distribution patterns [50]. According to [51], a clumped distribution pattern is the most common in nature. In contrast, random distribution occurs in a homogeneous environment, and a regular pattern occurs when there is severe competition between individuals. It means that the secondary forest community of Mt. Malindang is highly patchy in nature. The clumping of individuals may be due to a lack of mode of seed dispersal in the area, or maybe after the logging, the removal of a mature tree creates a large gap in the forest, which encourages regeneration and growth of numerous seedlings as in the present studied dominated with a single stand of trees like the *Shorea contorta*.

3.2. Population Structure

Individual plants of dipterocarps species ranged in number from 1 (*Shorea negrosensis* Foxw and *Shorea* sp.) to 57 (*Anisopthera thurifera* (Blanco) Blume) (**Table 5**). The abundance of *S. negrosensis* Foxw and *Shorea* sp. are the lowest among the seven (7) species of dipterocarps found in three (3) study sites in a different elevation range. Abundance ranked in increasing order as *Shorea negrosesis* Foxw (1) = *Shorea* sp. (1) < *Dipterocarpus grandiflorus* (Blanco) Blanco (5) < *S. squamata* a (Turcz.) Benth. & Hook.f. ex DC. (7) < *S. polysperma* (Blanco) Merr. (24) < *Shorea contorta* S. Vidal (29) < *Anispothera thurifera* (Blanco) Blume (57). The total basal area of *Anisoptera thurifera* (Blanco) Blume was significantly larger than that of the other seven dipterocarp species, and the mean DBH and height of *S. polysperma* (Blanco) Merr. was notably largest than other Dipterocarpaceae species. Non-dipterocarps species mean dbh and height are lowest compared to dipterocarps species (**Table 6**).

Diameter-class distribution of dipterocarps species in all sites showed irregular population structure trends (**Figure 3**). Species like *Anisoptera thurifera* showed a distinct reverse J-shaped distribution and were represented mainly at lower-sized classes with higher density at juvenile and seedling stages (**Figure 4**). *A. thurifera* grows from >300 to 1200 masl with normal to slightly acidic, low relative light intensity, and high moisture environment. This means that *A. thurifera* recruitment is good and is regenerating even in both disturbed and undisturbed areas. However, with only one adult stage found and poaching present in the area, it indicates that the population is declining.

The rest of the dipterocarps species, *i.e.*, *Shorea contorta*, *Shorea polysperma*, and *Shorea squamata*, were represented by an irregular trend in size class distribution with high density at the mature stage except for *Shorea polysperma* which has a higher density at the juvenile stage. *Dipterocarpus grandiflorus* showed uniform but uneven distribution in the size class. *Shorea negrosensis* and *Shorea* sp. both species are in the juvenile stage with single species. Dipterocarps species found in this study were mostly in the reproductive stage. The declining population is evident in both types of the structure since the seedlings of critically endangered dipterocarps are in short supply. There would be an inadequate number of seedlings or saplings to maintain their population in the

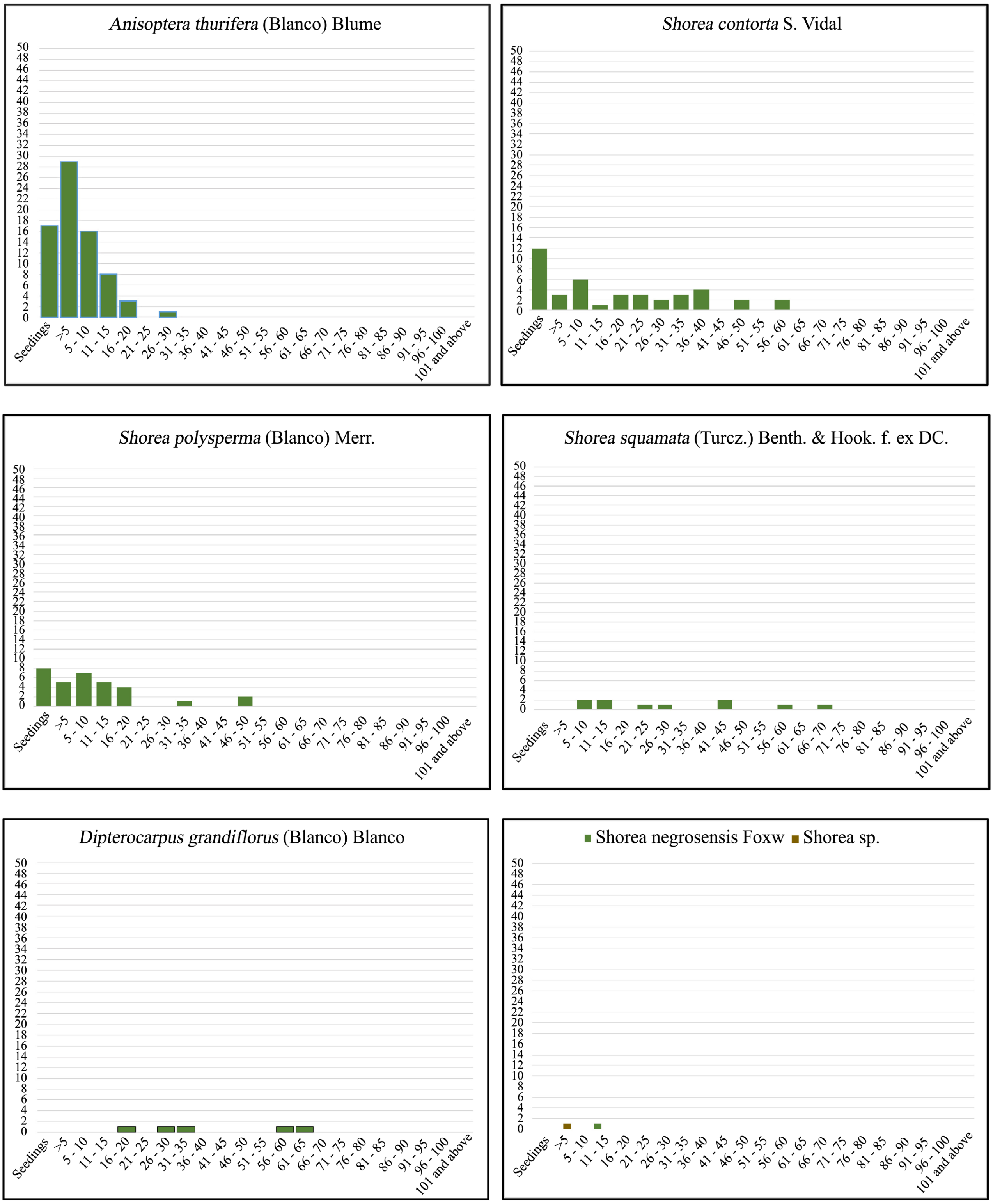

Figure 3. Diameter-class distribution of dipterocarps and non-dipterocarps species by density.

future. Furthermore, according to [52], a species is on the verge of extinction if its population is represented by a high size class diameter. Anthropogenic activities observed in the area like poaching, slash and burn, land conversion can

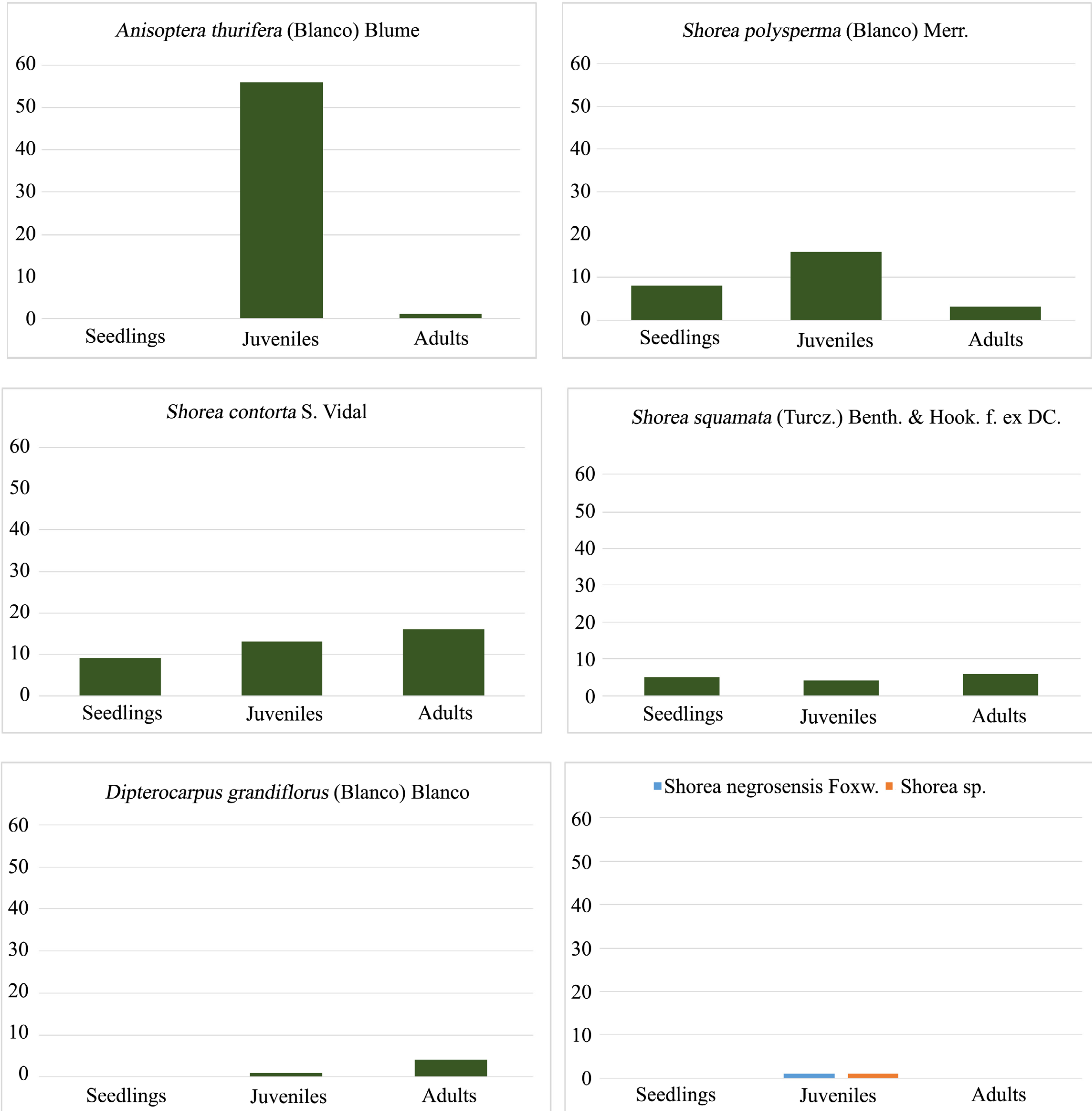

Figure 4. Dipterocarps species with their seedlings, saplings, and mature tree abundance pattern by [34].

greatly influence the recruitment of dipterocarps in the area. The larger stem of *Shorea contorta* is still present in Site 3 and thus is susceptible to high disturbance.

The overall population of critically endangered dipterocarps species in Mt. Malindang Park (e.g., *S. contorta*, *S. polysperma*, *S. squamata*, *Dipterocarpus grandiflorus*, *S. negrosensis* are decreasing and at high risk of local extinction. Thus, conservation and protection priority in the park need to be strengthened and strictly imposed.

Plant structure and diversity in any site are subjective by their abundance pattern, species distribution, topography, soil, geographical location, and climate

Table 6. Population structure of seven (7) Dipterocarpaceae and non-Dipterocarps tree species in three different elevation range in the north-east portion of Mt. Malindang.

Species	Elevation (masl)	Abundance	No. of Seedlings	Basal Area (plants/m^2)	Mean DBH (cm)	Mean Height (m)
Anisoptera thurifera	300 - 700					
	701 - 900	46	45	244.78	6.77	6.83
	901 - 1500	11		77.49	8.97	6.55
Dipterocarpus grandiflorus (Blanco) Blanco	300 - 700	5		159.44	40.6	21.6
	701 - 900					
	901 - 1500					
S. contorta S. Vidal	300 - 700	13		202.63	19.85	13.85
	701 - 900	16	3	350.29	27.88	17.81
	901 - 1500					
Shorea negrosensis Foxw.	300 - 700					
	701 - 900	1		8.64	11	12
	901 - 1500					
S. *polysperma* (Blanco) Merr.	300 - 700	1	3	38.48	49	25
	701 - 900	13	5	134.57	13.18	9.77
	901 - 1500	10		86.92	11.07	8.1
Shorea squamata (Turcz) Benth. & Hook. f. ex DC.	300 - 700	7	5	170.43	31	14.71
	701 - 900	3		65.71	27.89	14
	901 - 1500					
Shorea sp.	300 - 700	1		3.14	4	5
	701 - 900					
	901 - 1500					
Non-Dipterocarps	300 - 700	123	74	1804.33	9.66	10.88
	701 - 900	300	126	3096.33	13.14	8.97
	901 - 1500	251	136	2371.38	14.04	8.58

[53] [54]. In this study *Anisoptera thurifera* structure in all sites showed good regeneration from the management perspective, thus in the future, its population will maintain.

3.3. Spatial Pattern

Figure 5 and **Figure 6** show the spatial distribution of the individual tree species highlighting the dipterocarps species. The map also gives a particular location and elevation distribution of dipterocarps species, especially the critically

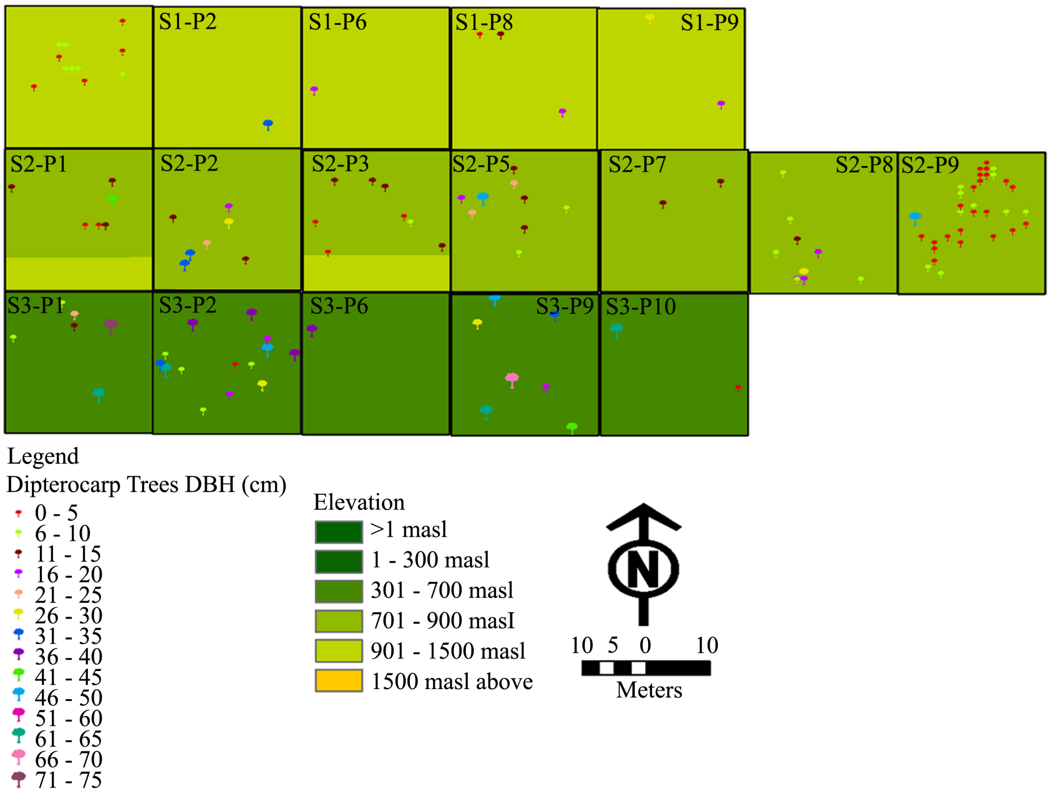

Figure 5. Spatial distribution pattern of dipterocarps species in relation to the topography of the study sites.

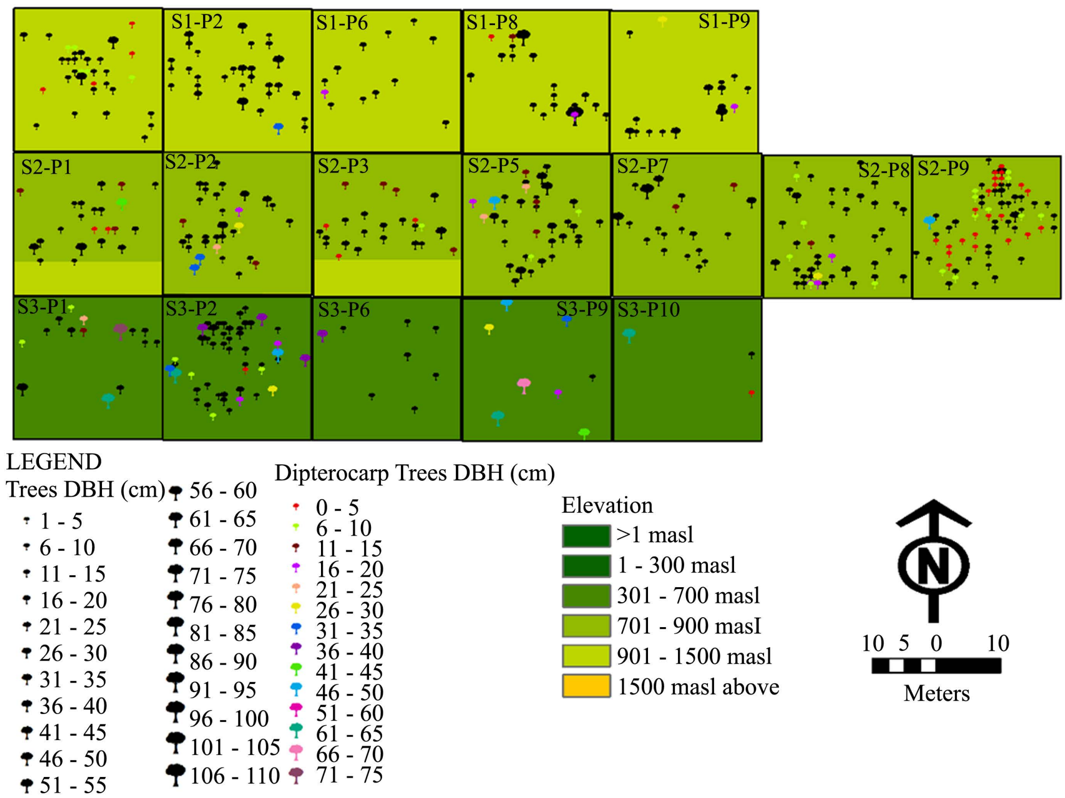

Figure 6. Distribution pattern of dipterocarps and non-dipterocarps.

endangered species such as *Shorea contorta* S. Vidal, *Shorea negrosensis* Foxw. and *Shorea polysperma* (Blanco) Merr. and other associated tree species. The plots containing the critically endangered or threatened dipterocarps species should be prioritized for conservation and protection. However, areas located outside the strict protection zone with dipterocarps species should be declared priority conservation areas for reforestation programs DENR or become local conservation areas of LGUs or barangays where the critically endangered dipterocarps are located and become a seed source area for ex-situ and in-situ conservation.

The distribution of *Anisoptera turifera* in some plots in different elevation ranges is aggregated; however, it is also observed that it has a regular pattern because of disturbances. *Dipterocarpus grandifluros* has a regular pattern in an elevation ranging from 300 - 700 masl. *Shorea contorta* is aggregated in an elevation ranging from 300 to 900 masl. *Shorea polysperma* is randomly distributed in an elevation of 701 - 900 masl and regular distribution in the lower elevation (300 to 700 masl). Moreover, *Shorea squamata*, *Shorea negrosensis*, *Shorea* sp. are regularly distributed in the elevation range of 700 to 900 masl; this may be influenced by the disturbance present in those areas. The different patterns observed in this study, such as random, regular, and aggregated, tend towards regularity patterns among the adult trees found in [55] and randomness in [56] study Xuan Nha Nature Reserve, Vietnam.

Cluster analysis was carried out using the Bray-Curtis similarity index between dipterocarps tree species and elevation gradients. The dendrogram showed the similarity between elevation gradients and dipterocarps tree species forming 3 clusters. *D. grandifluros*, *Shorea* sp. and *S. squama*ta was found in the lower elevation and mid-elevation (300 - 900 masl), *S. polysperma*, *A. thurifera* and *S. contorta* can grow from lower to high elevations (300 - 1200 masl) whereas *S. negrosensis* formed a unique cluster among the dipterocarps and was found the middle elevation (700 - 900 masl) with one singles species recorded, but *S. negrosensis* is preferably growing up to 1000 masl (**Figure 7**).

3.4. Physicochemical Properties

Limited or uniformed environmental homogeneity leads to a regular pattern of individual organisms [57]. However, different environmental factors and seed dispersal mechanisms lead to aggregated individual organisms [58]. Soil moisture, pH, light, nutrient availability, herbivory, and pathogen pressure lead to variations in species diversity [59]. Details of the soil of the three study site's physicochemical properties are given in (**Table 7**). Actual soil moisture content was highest in Site 1 (65.91) and lowest in Site 3 (58.0), while a maximum pH value was at Site 1 (6.8) and minimum pH at Site 2 and 3 (6.7). Relative light was highest in Site 3 (7.91) and was lowest in Site 2 with 0.71.

To understand the relationship between environmental factors and the critically endangered dipterocarps species correlation test was carried out (**Table 8**). The basal area of four (4) dipterocarps species is affected by environmental

Table 7. Physicochemical properties of the three sites in north western portion of Mt. Malindang.

Parameters	Site 1	Site 2	Site 3
pH	6.8 [0.20]	6.7 [0.19]	6.7 [0.19]
Soil moisture	65.91 [8.75]	63.34 [7.17	58.0 [6.55]
Relative Light Intensity (percent)	0.72 [0.48]	0.71 [0.45]	7.91 [10.19]
Elevation (masl)	1143 [31.2]	891 [5.7]	359 [50.7]
No. of Plots	9	9	11
No. of individual dipterocarps	21	76	30
No. of plot w/dipterocarps	5	7	5

Note: Values in parentheses show standard error.

Table 8. Pearson correlation coefficients between Dipterocarpaceae trees basal area and height and physico-chemical and topographic variables.

Species	pH		Light Intensity		soil moisture		Elevation	
	Basal	Height	Basal	Height	Basal	Height	Basal	Height
A. thurifera	0.21	−0.04	−0.37	−0.10	0.52***	0.36	0.2	−0.01
S. contorta	0.09	0.17	0.036	−0.00	0.1	0.03	−0.27	−0.22
S. polysperma	−0.23	−0.20	0.64***	0.66**	−0.01	0.13	−0.44*	−0.54**
S. squamata	−0.37	0.10	0.16	0.31	−0.22	−0.14	−0.08	−0.06

Legend: value with (*) indicates significant value of p = 0.05: (*) – p = 0.5, (**) – p = 0.03, (***) – p = 0.000 to p = 0.001.

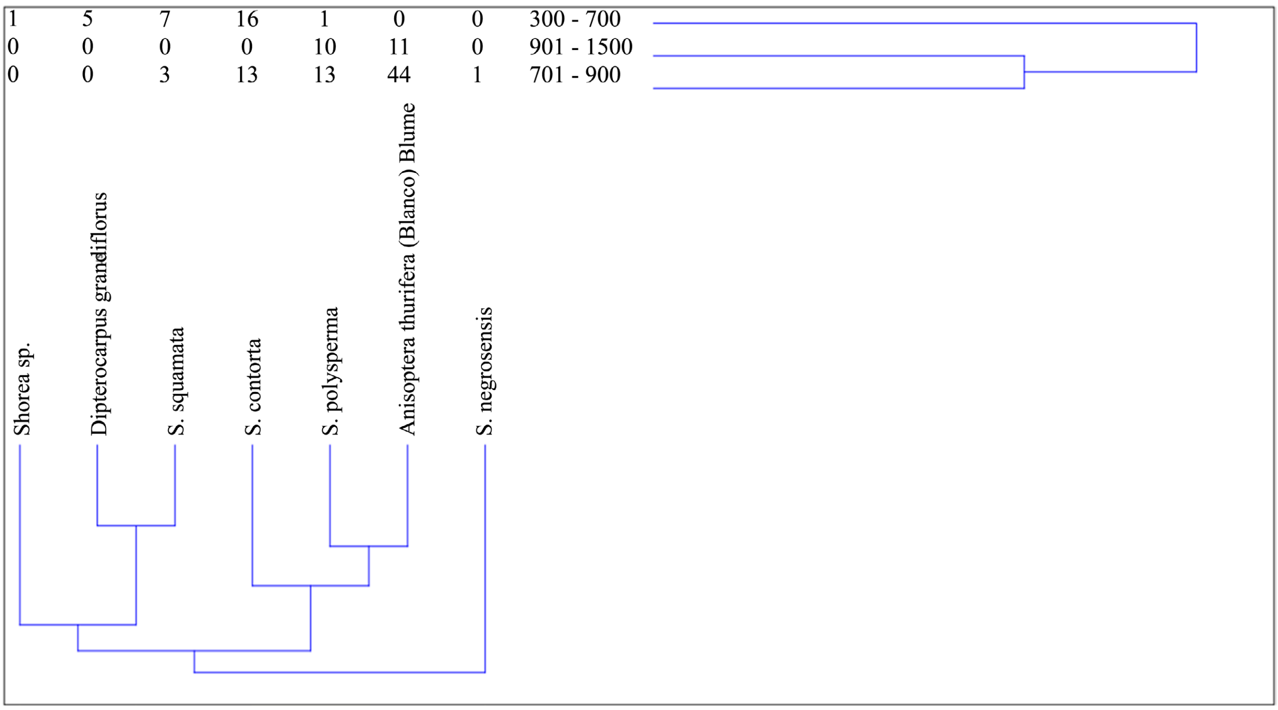

Figure 7. Dendrogram of dipterocarps tree species between elevations generated through UPGMA using bray-curtis similarity index. Bootstrapping was done n = 0; correlation = 0.8578.

factors such as light intensity, soil moisture, and elevation. The basal area of *A. thurifera* was significantly correlated with soil moisture and inversely correlated with light in both basal and height. *S. polysperma* is significantly correlated with light intensity and elevation. *D. grandiflorus* and *S. negrosensis* cannot be correlated to environmental factors in this study because of the single species found in one plot. In this study, dipterocarps species showed different responses to light. Plants are influenced by light in terms of their growth; however, it introduces stresses and vulnerabilities when there is high light exposure; though it allows rapid growth, it increases water and nutrient demand in soil.

3.5. Threats and Disturbances

Despite being classified as a protected area, the study area is still vulnerable to both natural and human disturbances that could threaten the vegetation of Mt. Malindang. The three study sites are in secondary forests belonging to the lowland dipterocarp and montane forest classification of Mt. Malindang (**Figure 8**). Anthropogenic activities were noticeable in Site 1 and very widespread in Sites 2 and 3. Timber poaching, particularly to *Anisoptera thurifera* species in Site 2, is extensive. The sampling sites were previously selectively logged areas in the year 1960s [60]. Poaching and kaingin were present in Site 2. In contrast, in Site 3,

Figure 8. Sample picture of different disturbance observe in sampling sites.

the disturbance is mainly caused by agricultural conversion since it is located within the park's buffer zone where human activities are allowed. Site 1 is free from human disturbance at present; however, it was a logged area. The presence of a logging road near the sampling plots was observed during the field sampling. Evidence of grazing was also apparent in all plots of Site 2, which may be affecting the dipterocarp trees' growth, especially during the seedling stage. Based on the interviews of some residents living at the foot of Site 3, there had been no cutting allowed since 2000 because of the strict enforcement and regular patrolling of DENR in the area. Another threat found in the study area is the presence of non-native plants *Gmelina arborea*, *Falcataria mollucana* and *Sweitennia macrophylla*, however, their effects on the population of dipterocarp species are not yet established.

4. Conclusions and Recommendations

A recent study recorded 638 individual trees recorded belonging to 86 species, 54 families, and 64 genera. The distribution of tree species is contiguous in less disturbed and regular distribution patterns in disturbed areas. There were seven dipterocarps species registered in this study, namely: *Anisoptera thurifera*, *Dipterocarpus grandiflorus* (Blanco), *Shorea negrosensis*, *Shorea polysperma* (Blanco) Merr. Foxw, *Shorea squamata* (Turcz.) Benth. & Hook. f. ex DC, and *Shorea* sp. Four are listed as critically endangered, and one is vulnerable in IUCN and DAO 2017-11.

The population of dipterocarps species in MMRNP is declining. These results imply that even though Mt. Malindang is a protected area, tree species with economic value are degraded over time due to threats and disturbances in the area because of poaching, slash and burn, settlements, agricultural activities, roads, and infrastructure, especially in the park's low elevation.

Among the environmental variables (soil pH, moisture, light, and elevation), light and elevation are the major factors that influences the growth of dipterocarps species in the area.

The present study has provided valuable information on the structure and spatial pattern of critically endangered dipterocarps species in Mt. Malindang Range Natural Park that would be used as an input for effective conservation and protection of the area.

Acknowledgements

The authors are very thankful to the United States Agency for International Development (USAID)—DAI, through its Protect Wildlife Project, the Commission on Higher Education (CHED), for the financial assistance. To Mt. Malindang Range Natural Park—Protected Area Management Board (PAMB), Protected Area Management Office (PAMO), Armed Forces of the Philippines (AFP)-10th Infantry Battalion, National Commission on Indigenous People (NCIP), the Local Government of Municipality of Calamba and Concepcion for allowing the authors to conduct her study in Mt. Malindang. To Misamis University through Misamis University Community Extension Program (MUCEP) headed by EnP. Grace V. Villanueva for their moral support and encouragement.

Conflicts of Interest

The authors declare no conflicts of interest the publications of this paper.

References

[1] Appanah, S. and Turnbull, J.W. (1998) A Review of Dipterocarps: Taxonomy, Ecology and Silviculture. Center for International Forestry Research, Bogor. https://doi.org/10.17528/cifor/000463

[2] Ashton. P.S. (1982) Dipterocarpaceae. In: Steenis, Ed., *Malesiana Series I*, Vol. 9. Part 2, National Herbarium of the Netherlands, Netherlands, 237-552.

[3] Poore, D. (1989) No Timber without Trees. Sustainability in the Tropical Forest. Earthscan Publications, London.

[4] Maury-Lechon, G. (1991) Comparative Dynamics of Tropical Rain Forest Regeneration in French Guyana. In: Gomez Pompa, A., Whitmore, T.C. and Hadley, M., Eds., *Rain Forest Regeneration and Management*, Man and the Biosphere Series, Vol. 6, UNESCO (United Nations Educational, Scientific and Cultural Organization) and Parthenon, Paris, 285-293.

[5] Shiva, M.P. and Jantan, I. (1998) Non-Timber Forest Products from Dipterocarps. In: Appanah, S. and Turnbull, J.M., Eds., *A Review of Dipterocarps: Taxonomy, Ecology and Silviculture*, Center for International Forestry Research, Bogor, 191-200.

[6] Panayotou, T. and Ashton, P.S. (1992) Not by Timber alone: Economics and Ecology for Sustaining Tropical Forests. Island Press, Washington DC, 282.

[7] Fernando, E.S., Suh, M.H., Lee, J. and Lee, D.K. (2009) Forest Formations of the Philippine. ASEAN Korea Environmental Cooperation Unit, Seoul National University, Seoul, 240.

[8] Rojo, J.P. (1979) Updated Enumeration of Philippine Dipterocarps. *Sylvatrop*, **4**, 123-146.

[9] Fernando, E.S., Gruezo, W.S. and Barcelona, J.F. (2008) Threatened Plants of the Philippines: A Preliminary Assessment. *Asia Life Sciences,* No. S3, 1-52.

[10] Rojo, J.P. (2000) Species Diversity and Conservation Status of Philippine Dipterocarps. Forest Products Research and Development Institute, Laguna.

[11] Amoroso, V.B. and Aspiras, R.A. (2011) Hamiguitan Range: A Sanctuary for Native Flora. *Saudi Journal of Biological Sciences*, **18**, 7-15. https://doi.org/10.1016/j.sjbs.2010.07.003

[12] Department of Environment and Natural Resources [DENR] (2017) MMRNP General Management Plan, 3rd Edition. Department of Environment and Natural Resources, Quezon City.

[13] Amoroso, V.B., Arances, J.B., Gorne, N.D., Ruba, R.P., Comilap, R., Montimar, B., Rufila L.V., Opiso, G.S., Demetillo, M.T., Noval, K.G., van de Berg, A., Storetelder, A., Kessler, P.J.A., Gruezo, W.Sm., Lagunzad, D.A., Tan, C.B., Co, L.L., Aranico, E.C., Roscom, B.A. and Alaba, C.G. (2002) Plant Diversity in the Northern Landscape of Mt. Malindang Range and Environs, Misamis Occidental, Philippines.

SEAMCO SEARCA. College Laguna. PDM Press, Quezon City.

[14] Department of Environment and Natural Resources [DENR] (2009) MMRNP General Management Plan. 2nd Edition, Department of Environment and Natural Resources, Quezon City.

[15] Camat, R.E., Beltran, O., Villanueva, M.S., Jasma, A.D. and Camat, C. (2013) Mt. Malindang Range Natural Park: Management Effectiveness and Capacity Assessment Report. Department of Environment and Natural Resources—Protected Areas and Wildlife. Bureua and Deustche Gessellschaft fur Internationale Zusammenarbeit (GIZ) GmbH, Quezon City.

[16] Arances, J.B., Amoroso, V.B., Nuñeza, O.M. and Kessler, P.A. (2002) Participatory biodiversity assessment in Malindang Range, Philippines. Society, Development and Environment. The Mt. Malindang Experience. SEAMCO SEARCA, College Laguna, PDM Press, Quezon City, 25-26.

[17] Department of Environment and Natural Resources [DENR] (2018) BAMS for 2.0 Hectares Permanent Plot Monitoring Report. Department of Environment and Natural Resources, Quezon City.

[18] Department of Environment and Natural Resources [DENR] (2017) Department Administrative Order 2017-11 Updated National List of Threatened Philippine Plants and Their Categories. Department of Environment and Natural Resources, Quezon City.

[19] Department of Environment and Natural Resources [DENR], Biodiversity Management Bureau [BMB] (2016) Guidelines on Biodiversity Assessment and Monitoring System for Terrestrial Ecosystems. Technical Bulletin No. 2016-05, Department of Environment and Natural Resources, Quezon City.

[20] Rojo, J.P. (1999) Revised Lexicon of Philippine Trees. Forest Products Research and Development Institute. Department of Science and Technology, Laguna.

[21] Merril, E.D. (1926) An Enumeration of Philippines Flowering Plants. Vol. I-IV, Bureau of Printing, Manila.

[22] Madulid, D. (1995) Plant Diversity in the Philippines. In: Peng, C.I. and Chou, C.H., Eds., *Biodiversity and Terrestrial Ecosystems*, Academia Sinica Monograph Series No. 14, Institute of Botany, Taipei, 102-105.

[23] Salvosa, F.M. (1963) Lexicon of Philippine Trees to Botanical Collectors of All Nationalities. Forest Products Research Institute, College.

[24] Zamora, P. and Co, L. (1986) Guide to Philippine Flora and Fauna. Vol. IV, Goodwill, Quezon City.

[25] Tan, B., Fernando, E.A. and Rojo, J.P. (1986) An Updated List of Endangered Philippine Plants. *Yushania*, **3**, 1-5.

[26] Pelser, P.B., Barcelona, J.F. and Nickrent, D.L. (Eds.) (2011) Onwards. Co's Digital Flora of the Philippines. http://www.philippineplants.org

[27] Veiyra,R. and Vieyra, C. (2019) Physics Toolbox Suit. http://www.vieyrasotware.net

[28] Mueller-Dombois, D. and Ellenberg, H. (1974) Aims and Methods of Vegetation Ecology. Wiley, New York, 547.

[29] Curtis, J.T. and McIntosh, R.P. (1950). The Interrelations of Certain Analytic and Synthetic Phytosociological Characters. *Ecology*, **31**, 434-455. https://doi.org/10.2307/1931497

[30] Curtis, J.T. (1959) The Vegetation of Wisconsis: An Ordination of Plant Communities. University of Wisconsin Press, Madison.

[31] Cottam, G. and Curtis, J.T. (1956) The Use of Distance Measures in Phytosociological Sampling. *Ecology*, **37**, 451-460. https://doi.org/10.2307/1930167

[32] Hammer, O. and Harper, D.A.T. (2006) Paleontological Data Analysis. Blackwell Publishing, Oxford. https://doi.org/10.1002/9780470750711

[33] Fernando, E.S. (1998) Forest Formations and Flora of the Philippines: Handout in FBS 21. UPLB, Philippines. (Unpublished).

[34] Endris, A., Seid, A. and Asefa, A. (2017) Structure and Regeneration Status of Woody Plants in the Hallideghie Wildlife Reserve, North East Ethiopia. *International Journal of Biodiversity and Conservation*, **9**, 200-211. https://doi.org/10.5897/IJBC2017.1085

[35] Orozumbekov, A., Cantarello, E. and Newton, A.C. (2015) Status, Distribution and Use of Threatened Tree Species in the Walnut-Fruit Forests of Kyrgyzstan. *Forests, Tress and Livelihoods*, **24**, 1-17. https://doi.org/10.1080/14728028.2014.928604

[36] Department of Environment and Natural Resources [DENR] (2017) DAO 2017-11. https://www.philippineplants.org/dao-2017-11.pdf

[37] International Union for Conservation Nature [IUCN] (2017) The IUCN Redlist of Threatened Species. https://www.iucnredlist.org

[38] International Union for Conservation Nature [IUCN] (2011) IUCN Red List of Threatened Species. Version 2011.2.

[39] Fern, K (2019). *Shorea palosapis* (Blanco) Merr. Useful Tropical Plants Database. http://tropical.theferns.info/viewtropical.php?id=Shorea%20palosapis

[40] Pito, E.C., Villantes-Labajo, Y., Alaman, B.B., Villanueva, G.V., Jumuad, P.D., Garrido Jr., A.F. and Restauro, G.P. (2020) Species Richness Importance and Conservation Status of Trees of Natural Forest in Southern Part of Mt. Malindang, Philippines. *AES BioFlux*, **12**, 160-169.

[41] Baliton, R.S., Landicho, L.D., Cabahug, R.E.D., Paelmo, R.F., Laruan, K.A., Rodriguez, R.S., Visco, R.G. and Castillo, A.K.A. (2020) Ecological Services of Agroforestry Systems in Selected Upland Farming Communities in the Philippines. *Biodiversitas*, **21**, 707-717. https://doi.org/10.13057/biodiv/d210237

[42] Sahu, S.C., Dhal, N.K., Reddy, C.S., Pattanaik, C. and Brahmam, M. (2007) Phytosociological Study of dry deciduous Forest of Boudh District, Orissa, India. *Research Journal of Forestry*, **1**, 66-72. https://doi.org/10.3923/rjf.2007.66.72

[43] Khaine, I., Woo, S.Y., Kang, H., Kwak, M., Je, S.M., You, H., Lee, T., Jang, J., Lee, H.K., Lee, E., Yang, L., Kim, H., Lee, J.K. and Kim, J. (2017) Species Diversity, Stand Structure, and Species Distribution across a Precipitation Gradient in Tropical Forests in Myanmar. *Forests*, **8**, Article No. 282. https://doi.org/10.3390/f8080282

[44] Manna, S.S. and Mishra, S.P. (2017) Diversity, Population Structure and Regeneration of Tree Species in Lalgarh Forest Range of West Bengla, India. *International Journal of Botany Studies*, **2**, 191-195.

[45] Singh, S., Malik, Z.A. and Sharma, C.M. (2016) Tree Species Richness, Diversity, and Regeneration Status in Different Oak (*Quercus* spp.) Dominated Forests of Garhwal Himalaya, India. *Journal of Asia-Pacific Biodiversity*, **9**, 293-300. https://doi.org/10.1016/j.japb.2016.06.002

[46] Amoroso, V.B., Arances, J.B., Gorne, N.D., Ruba,R.P., Comilap, R., Montimar, B., Rufila, L.V., Opiso, G.S., Demetillo, M.T., Noval, K.G., Opiso, G.S., van den Berg, A., Storetelder, A., Kessler, P.J.A., Gurezo, W.S., Lagunzad, D.D., Tan, B.C., Aranico, E.C., Roscom, B. and Alava, C. (2004) Participatory Inventory and Assessment of Plants in Malindang Range Natural Park, Mindanao Island, Philippines. Biodiver-

sity Research Programme for Development in Mindanao: Focus on Mt. Malindang and Environs. SEAMCO SEARCA, College Laguna, PDM Press, Quezon City.

[47] Manokaran, N. and La Frankie, J.V. (1990) Stand Structure of Pasoh Forest Reserve, a Lowland Rain Forest in Peninsula Malaysia. *Journal of Tropical Forest Science*, **3**, 14-24.

[48] Devi Prasad, A.G. and Nageeb, A.A. (2012) Floristic Diversity of Regenerated Tree Species in Dipterocarp Forests in Western Ghats of Karnataka, India. *Journal of Environmental Biology*, **33**, 791-797.

[49] International Union for Conservation Nature [IUCN] (2019) The IUCN Redlist of Threatened Species. https://www.iucnredlist.org

[50] Ayyappan, N. and Parthasaranthy, N. (2001) Composition, Population Structure and Distribution of Dipterocarps in a Tropical Evergreen Forest at Varagalaiar, Anamalais, Western Ghats, South India. *Journal of Tropical Forest Science*, **13**, 311-321.

[51] Odum, E.P. (1971) Fundamentals of Ecology. 3rd Edition, W.B. Saunders Company, Philadelphia.

[52] Kennedy, D.N. and Swaine, M.D. (1991) Germination and Growth of Colonizing Species in Artificial Gaps of Different Sizes in Dipterocarp Rain Forest. *Philosophical Transaction of the Royal Society Biological Sciences*, **335**, 357-367. https://doi.org/10.1098/rstb.1992.0027

[53] Kaine, I., Woo, S.Y., Kwak, M., Lee, S.H., Je, S.M., You, H., Lee,T., Jang, J., Lee, H.K., Cheng, H.C., Park, J.H., Lee, E., Li, Y., Kim, H., Lee, J.K. and Kim, J. (2018) Factors Affecting Natural Regeneration of Tropical Forest across Precipitation Gradient in Myanmar, *Forests*, **9**, Article No. 143. https://doi.org/10.3390/f9030143

[54] Das, S.C., Alam, M.S. and Hossain, M.A. (2018) Diversity and Structural Composition of Species in Dipterocarps Forests: A Study from Fasiakhali Wildlife Sanctuary, Bangladesh. *Journal of Forest Research*, **29**, 1241-1249. https://doi.org/10.1007/s11676-017-0548-7

[55] Pelissier, R. (1998) Tree Spatial Patterns in Three Contrasting Plots of a Southern Indian Tropical Moist Evergreen Forest. *Journal of Tropical Ecology*, **14**, 1-16. https://doi.org/10.1017/S0266467498000017

[56] Le, D.T.N., Thinh, N.G., Dung, N.T. and Mitlohner, R. (2016) Effect of Disturbance Regimes on Spatial Patterns of Three Species in Three Sites in a Tropical Evergreen Forest in Vietnam. *International Journal of Forestry Research*, **2016**, Article ID: 4903749. https://doi.org/10.1155/2016/4903749

[57] Gill, D.E. (1975) Spatial Patterning of Pies and Oaks in the New Jersey Pine Barrens. *Journal of Ecology*, **63**, 291-298. https://doi.org/10.2307/2258855

[58] Pielou, E.C. (1960) A Single Mechanism to Account for Regular, Random and Aggregated Populations. *Journal of Ecology*, **48**, 575-584. https://doi.org/10.2307/2257334

[59] Engelbrecht, B.M.J., Comita, L.S., Condit, R.S., Kursar, T.A., Tyree, M.T., Turner, B.L. and Hubbell, S.P. (2007) Drought Sensitivity Shapes Species Distribution Patterns in Tropical Forests. *Nature*, **447**, 80-82. https://doi.org/10.1038/nature05747

[60] Bugayong, E.L. (2006) Effectiveness of Logging Ban Policies in Protecting the Remaining Forests of the Philippines. *Paper Presented at Berlin Conference at* 2006 *on Human Dimension of Global Environmental Change-Resource Policies: Effectiveness, Efficiency, and Equity*, Berlin, 17-18 November 2006, 13.