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Biophysical assessment of the plant biodiversity of Northern Negros Natural Park, Negros Island, Philippines

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Abstract. *Jr Dechimo AA, Jr Buot IE. 2023. Biophysical assessment of the plant biodiversity of Northern Negros Natural Park, Negros Island, Philippines. Biodiversitas 24: 583-602.* Data sets on plant bioresources in Northern Negros Natural Park are critical in planning for conservation management and strategies. This study aimed to (i) conduct a survey of plant species in NNNP and determine their conservation status, (ii) assess the species diversity pattern and vegetation structures, (iii) establish altitudinal zones, and (iv) analyze the environmental factors affecting species distribution. Standard vegetation analysis and secondary data were utilized in the data collection process. Results showed 242 species, 72 families of 78 tree species, 90 shrubs and small trees, and 37 epiphytes. About 112 species are threatened, 35 of which are Philippine endemics. Two altitudinal zones were identified using the cluster analysis: Zone I (643 to 1,256 m asl.), dominated by *Crypteronia paniculata, Acer laurinum, Weinmannia hutchinsonii,* and *Syzygium* sp.; and Zone II (1421 to 1470 m asl.) dominated by *Dacrydium cf. beccarii*. Zone I was further subdivided into three clusters: Zone IA (643 to 985 m asl.), Zone IB (908 to 913 m asl.), and Zone IC (822 to 1,182 m asl.). Canonical correspondence analysis illustrated that environmental factors (N, Altitude, and human disturbance) influenced the zonation of vegetation or species abundance. These results are important in understanding the landscape and crafting strategic interventions and management plans for conservation.

Keywords: Biophysical assessment, elevational gradient, Northern Negros Natural Park, plant bioresource distribution, protected area

INTRODUCTION

The increasing human population threatens biodiversity (Williams 2013; Crist 2017; Cunningham and Beazley 2018). In fact, a 90% growth in global material extraction was recorded from 1980 to 2009 (Giljum et al. 2014). That highlights how renewable resources have been depleted beyond the capacity of the earth to restock and regenerate (Nature 2012). Forest resources, one of the frequently exploited resources that have provided ecosystem services, are affected by deforestation. The loss of forests has had a negative impact on biodiversity (Anyanwu et al. 2016). It is because of the strong interdependent relationship between the forest and biodiversity. It is demonstrated by the fact that forest conditions impact biodiversity and that changes in biodiversity impact forest production (Marín et al. 2021). The supply of a wide range of ecosystem services important to human well-being depends on forests, which are crucial habitats for biodiversity. Additionally, there is growing evidence that biodiversity plays an important role in the functioning of the forest ecosystem and the delivery of ecosystem services (Brockerhoff et al. 2017).

The ecosystem services of Northern Negros Natural Park (NNNP) of Negros Occidental in Negros Island, Philippines, are consumed directly or indirectly by the local and surrounding population. That, in turn, contributed to the forest degradation in the park. Presently, details on the vertical distribution and vegetation structure in NNNP have been given little attention. Nevertheless, NNNP, as one of the critical watersheds on the island, has interesting vegetation. It is home to 436 species of plants; seventy (16%) of these are Philippine endemics, 16 are introduced, and 65 are red-listed. Nineteen of the 65 red-listed species are critically endangered, and one is endangered (Foundation for the Philippine Environment 2021). NNNP is one of the last remaining wet tropical rainforest ecosystems in Western Visayas' biogeographic region (Hamann et al. 1999). It is also called the last intact watershed in the Negros Occidental that supports the Malogo, Imbang, Himugaan, and Bago rivers and is the source of water for 17 cities and municipalities (Foundation for the Philippine Environment 2021).

Several studies have been conducted on the plant biodiversity of protected areas. Chanthavong and Buot (2017) looked into the plant diversity of Dong Na Tard Provincial Protected Area; Villanueva et al. (2021) studied the biodiversity in forests over limestone in Paranas in Samar Island Natural Park; and Magcale-Macandog et al. (2022) on plant diversity of Mount Makiling Forest Reserve. Not much work has been done for NNNP.

The biodiversity assessment alongside its physical components is conducted either to characterize the study area (Rotter 1994; Peddle et al. 1999), to examine its relations to other factors like the patterns of diversity (Henkin 2013), distribution of community types (Henkin et al. 2015) or forest cover changes (Lonn et al. 2018); integrated to other fields to create a framework that influence policies (Bouman et al. 1999); or numerous other purposes anchored to the determination and description of biological, physical and geological characteristics of a forest ecosystem or landscape.

The detailed aerial and ground survey that established the altitudinal zonation of NNNP into 4,700 ha of mid-elevation old-growth forest and 5,200 ha of high-elevation mossy forest is still insufficient for the full characterization of NNNP since the work of Hamann (2002) focused on one portion of the park only. Obviously, there is a shortage of knowledge about the plant bioresources of the park. Therefore, this paper aims to assess plant biodiversity along the elevational gradient of NNNP. Specifically, it has the following objectives: (i) conduct a survey of plant species in NNNP and determine their conservation status, (ii) assess the species diversity pattern and vegetation structures in NNNP, (iii) establish altitudinal zones of NNNP, and (iv) analyze the environmental factors affecting species distribution along the altitudinal zones of NNNP.

MATERIALS AND METHODS

Study area

Northern Negros Natural Park (123º07' to 123º19'E and from 10º35' to 10º49'N) is situated in the northern portion of Negros Occidental, lying north of Mount Kanlaon and west of Bacolod City, the highly urbanized city in the province. It is the largest and the most intact remaining forest stand on the island of Negros, covering a span of 80,454.5 hectares bordering five municipalities (Toboso, Calatrava, E.B. Magalona, Murcia, and Don Salvador Benedicto) and six cities (San Carlos, Sagay, Cadiz, Victorias, Silay, and Talisay. Its forest is composed of primary and secondary growths. The altitudinal forest zones are lowland, lower, and upper montane forests. The two highest peaks of the park are Mt. Silay (1,510 m asl.) and Mt. Mandalagan (1885 m asl.), with old-growth forests in the higher (700-1,000 m asl.) and secondary forests in lower (400-700 m asl.) slopes (Figure 1).

Methods

The study was conducted along the two DENR-established transects in Patag, Silay City, and Gawahon, Victorias City (Figure 1). These were the only established transects utilized for biodiversity monitoring by the government and non-governmental organizations. Twenty-seven transects were established towards the ridge of Mount Silay in the area of Gawahon, Victorias City, and four along the transect going to Tinagong dagat, Silay City, all within NNNP from February to August 2021. The study utilized Species Level Assessment (SLA) and Ecosystem Level Assessment (ELA) for vegetation analysis.

Species Level Assessment (SLA)

Vegetation sampling and standard vegetation analysis were utilized in the species level assessment. The nested quadrat sampling (Mueller-Dombois and Ellenberg 1974) was done along each transect to collect flora inventory and done in data gathering procedure along the twenty-seven (27) sampling plots, each with 20 m x 20 m established quadrats. Each quadrat was further subdivided into three nested subplots to facilitate the recording of the ground cover (1 m x 1 m), intermediate (5 m x 5 m) plants having a diameter at breast height (DBH) of less than 10 cm; and the canopy plants with 10 cm or more diameter at breast height (DBH).

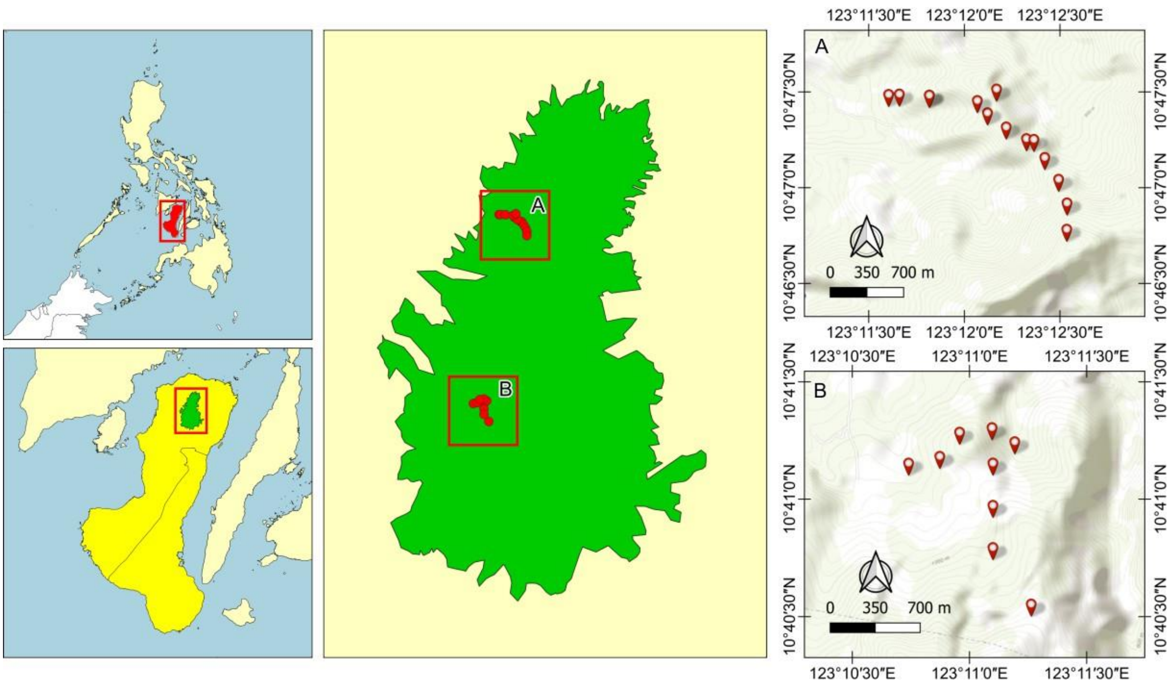


Figure 1. Location map of the 27 sampling sites inside Northern Negros Natural Park on the Negros Island, Philippines

The data recorded in the field were: (i) names of plants from the family to the species level, (ii) diameter at breast height, (iii) merchantable height, and (iv) total height. In addition, several individuals were collected for understory vegetation, and percent cover estimation was recorded for the ground cover species.

Plant specimens were identified by consulting experts using flora databases (International Plant Name Index 2016, Co's Digital Flora of the Philippines 2020), published books and field guides, and other literature were utilized for identifying plant species.

In the Species Level Assessment, each species' relative density, relative abundance, and relative frequency were gathered and computed to obtain their Importance Value (IV). That was done to characterize the floral composition of the study area. IV was also estimated to determine the rank relationships of species. In the case of canopy species or tree species, they were calculated separately. Importance values were calculated using the following formulae (Fernando 2008):

$$\text{Density} = \frac{\text{Number of individuals}}{\text{Area sampled}}$$

$$\text{Relative density} = \frac{\text{Density for a species}}{\text{Total density for all species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of plots where the species occurs}}{\text{Total Number of plots sampled}}$$

$$\text{Relative Frequency} = \frac{\text{Species frequency value}}{\text{Total frequency of all species}} \times 100$$

$$\text{Importance Value (IV)} = \frac{\text{Relative Density} + \text{Relative Basal Area} + \text{Relative Frequency}}{3} \times 100$$

Dominant species were determined using the dominance analysis of Ohsawa (1984):

$$d = \frac{1}{N}\left\{\sum_{i \in T}(x_i - \bar{x})^2 + \sum_{j \in U} x_j^2\right\}$$

Where: *d* is the deviation between the actual relative basal area values and the expected share of the corresponding co-dominant-number model, N is the total number of species, *x1* is the actual percent share (relative basal area) of the top species T, $\bar{x}$ is the ideal percent share based on the model, and *xj* is the percent share of the remaining species *U*. This equation assumed that 100% is the ideal dominance (the "expected share") of a single species, 50% if shared by two co-dominants, 33.3% for three sharing co-dominants and so on. The least deviation value showed the number of dominant species.

In the estimation of diversity indices (Shannon, Simpsons' and Evenness index) for each quadrat and transect, the equations of Magurran (1998) were employed, and the biodiversity software Paleontological Statistics (PAST) (Hammer and Harper 2006) was used.

Shannon Diversity Index (H') $= -\sum p_i(\mathrm{LN}p_i)$

Where: p_i is the proportion (n/N) of individuals of one particular species found (n), divided by the total number of individuals found (N)

Pielou's Evenness Index (E') = H'/ln(s)

Where: s: number of species

Simpson Diversity Index (D) = 1-(∑n(n-1)/N(N-1)

Where: n: the total number of organisms of a particular species; N: the total number of organisms of all species.

The conservation or ecological status of the different species was assessed to determine the ecological importance of the vegetation in NNNP to its local area. The endemicity and conservation status were based on the online database (Co's Digital Flora of the Philippines 2020), other published literature (e.g., Enumeration of Philippine Flowering Plants Vol. 1-4 by Merrill (1923-26) and Revised Lexicon of Philippine Trees by Rojo (1998)), The National List of Threatened Philippine Plants and their Categories (DENR Administrative Order No. 11-17, 2017) and the IUCN Red List (International Union for Conservation of Nature's Red List of Threatened Species 2019).

Ecosystem Level Assessment (ELA)

ELA was conducted simultaneously with the species level assessment along each 2 km transect. In this study, three transects were established (Figure 1). ELA was conducted every 50-meter interval along each transect, yielding 120 checked points by taking pictures of all cardinal directions (N, E, S, W). Twenty-three (23) out of twenty-seven (27) plots were situated within a tropical lower montane rainforest formation according to its elevation gradient. The other four (4) plots were found in the tropical upper montane rainforest formation. The forest formation, stand maturity, GPS coordinates of each nested plot, meters above sea level (m asl.) elevation, and degrees slope were recorded. Combined with the flora inventory for SLA, soil composite samples were collected for each of the 27 plots. An approximation of one kilogram (1kg) of soil samples was taken from nine (9) 1 x 1m plots (to a depth of about 10 to 30 cm) of each two-kilometer (2 km) transect line. The soil samples collected with the species inventory along the transects were tested for pH, N, P, and K using the soil test kit for 27 soil samples from 27 sampling plots. Next, using the capped tube from the kit, the soil sample was mixed with the powder from the capsule and was diluted to distilled water thoroughly mixed by shaking. The mixture was left to settle for at least a minute, and the resultant color of the mixture was compared to the pH chart attached to the capped tubes. The values' reading was based on their nearness to the color in the legend.

For the N, P, and K tests, one part of the soil sample was mixed with five parts distilled water and thoroughly mixed. The mixture was left to settle for at least ten minutes. The supernatant was taken without disturbing the sediments and poured into the capped tubes with powder from the capsule. N, P, and K tests capped tubes, and their capsules were color-coded to distinguish the value being tested. The tubes were mixed thoroughly by shaking and allowed to rest for 10 minutes until a color developed. Each resultant color was then compared to their respective plant food color charts. The color coding for N was violet, P was blue, and K was orange. There were five values corresponding to the color gradients in the legend, depleted being the lowest and surplus the highest.

The GPS device aided by Google earth pro was used to take the plot coordinates, elevation, and slopes for the ecosystems level assessment (ELA) and species level assessment (SLA). The coordinates were expressed in decimal degrees values, elevation by meter above sea level, and slopes by either negative or positive values, whether they gain or lose elevation.

A 30-year monthly average data for rainfall, humidity, and temperature were acquired from DOST PAGASA through the freedom of information website (https://www.foi.gov.ph/requests/aglzfmVmb2ktcGhyIAsSB0NvbnRlbnQiE1BBR0FTQS04MzE2MTU1NTU2MTgM). These data were processed and presented in the form of a climogram.

A canonical correspondence analysis (CCA) was employed to generate an ordination diagram that visualizes the pattern of community variation and species distribution along environmental variables (Ter Braak 1987). Environmental factors, including soil pH, soil NPK, altitude, slope, stand maturity, and proximity to human disturbances (distance between the community and forest edge), were analyzed to find out which influenced the species abundance data using Paleontological Statistics (PAST) software version 3.13 (Patent No. Palaeontol Electron 4 (1): 9 2001).

The Cluster analysis (classical similarity index) was done using the basal area data of the species along the altitudinal gradient of NNNP. The classical similarity index was also calculated using the PAST software. Finally, the Unweight Pair Group Method with Arithmetic means (UPGMA) hierarchical method was used to construct the dendrogram.

RESULTS AND DISCUSSION

Species Level Assessment: Floristic composition

The study recorded a total of 242 plant species representing 169 genera belonging to 72 families from 27 plots located in various elevational ranges in NNNP (Table 1). Among these species, 78 tree species, 90 shrubs, and 37 epiphytes were encountered along the altitudinal range of 643-1527 m asl. (Tables 1 and 2).

Agathis philippinensis, Podocarpus rumphii, and *Dacrydium cf. beccarii* were the only gymnosperms observed in the park (Figure 2). It was dominated by angiosperms comprising 59 plant families (82%) followed by pteridophytes with 11 families (15%) and the two gymnosperms (3%).

The species richness in NNNP is almost similar to the recorded data for Balbalasang-Balbalan National Park (Malabrigo 2013), Mount Calavite Wildlife Sanctuary (Malabrigo, Tobias and Boncodin 2018), Quezon Mountain Range (Gevaña et al. 2013) and other mountains in the Philippines (Table 3).

Endemism and conservation status

Out of 242 species recorded at the study site, 10 (4.13%) are classified as threatened (Table 4). Of the ten threatened species, one (1) is endangered, seven (7) are vulnerable, and three (3) are classified as "*other threatened species*," according to DENR DAO 2017-11. Remarkably, seven (7) threatened species were thriving in the lower montane rainforest. Thirty-five (35) species are found to be endemic to the Philippines. Thirty-one (31) endemic species were found along the tropical lower montane rain and four along the tropical upper montane rainforest.

Shorea contorta was considered the priority species for conservation in NNNP. Aside from being a Philippine endemic, it was also tagged as vulnerable and species of least concern by DENR DAO 2017-11 and the IUCN, respectively. *Etlingera pilosa* and *Saurauia panayensis* were two species identified as narrow endemics. *Etlingera pilosa*, which was recently found in Mindanao, Philippines (Naïve et al. 2021), is endemic to Negros Occidental and Oriental (Elmer 1919; Merrill 1923). *Saurauia panayensis* is endemic to Panay Island but is now seen in NNNP during the study. These include *Agathis philippinensis*, *Cyathea contaminans*, *Alocasia zebrine*, *Shorea almon*, *Shorea polysperma*, *Podocarpus rumphii*, and *Prunus grisea* are candidates for conservation in NNNP.

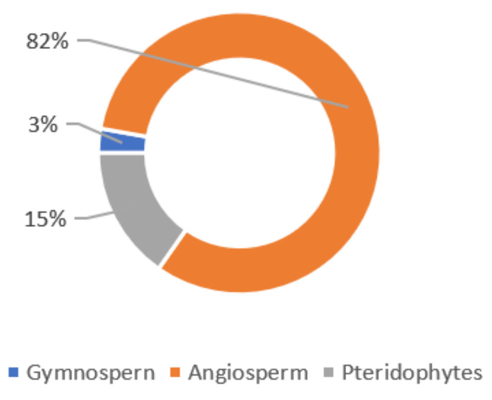


Figure 2. Chart showing proportions of Northern Negros Natural Park in Negros Island, Philippines

Table 1. Ecological characteristics of woody species in Northern Negros Natural Park, Negros Island, Philippines

Family scientific name	*Common name*	Alt. range (m asl.)	Forest formation	Freq.	Density (ind. per sq. m)	Basal Area
Aceraceae						
Acer laurinum	*Kulukatumbal / Bahai*	802-1527	Lower to Upper Montane	0.52	0.0483	219.03
Actinidiaceae						
Saurauia panayensis		802-1256	Lower Montane	0.04	0.0013	0.97
Adoxaceae						
Viburnum glaberrimum		802-1256	Lower Montane	0.26	0.0109	130.81
Anacardiaceae						
cf. Semecarpus cuneiformis	*Haras*	802-1256	Lower Montane	0.04	0.0001	0.81
Annonaceae						
Miliusa vidalii	*Takulau*	802-1256	Lower Montane	0.07	0.0009	3.23
Aquifoliaceae						
Ilex cf. crenata		802-1256	Lower Montane	0.04	0.0007	1.09
Araliaceae						
Polyscias aherniana		802-1256	Lower Montane	0.04	0.0037	1.21
Araucariaceae						
Agathis philippinensis	*Almaciga*	802-1256	Lower Montane	0.22	0.0040	89.04
Burseraceae						
Canarium asperum	*Pagsahingin*	802-1256	Lower Montane	0.26	0.0084	13.05
Canarium sp.		802-1256	Lower Montane	0.04	0.0016	1.03
Calophyllaceae						
Calophyllum sp.	*Hublas*	802-1256	Lower Montane	0.07	0.0014	30.49
Clethraceae						
Clethra sp.		643-1527	Lower to Upper Montane	0.41	0.0168	18.58
Cryteroniaceae						
Crypteronia paniculata	*Kape-kape*	643-1256	Lowland to Lower Montane	0.48	0.0313	140.26
Cunoniaceae						
Caldcluvia celebica	*Bulangkadyos*	802-1527	Lower to Upper Montane	0.30	0.0248	165.73
Caldcluvia sp.		802-1256	Lower Montane	0.07	0.0097	21.98
Weinmannia cf. lucida		802-1256	Lower Montane	0.04	0.0008	3.79
Weinmannia hutchinsonii	*Bunot-bunot*	643-1256	Lower Montane	0.41	0.0293	131.82
Cyatheaceae						
Cyathea sp.	*Kabo Negro*	1421-1527	Upper Montane	0.07	0.0130	220.74
Dipterocarpaceae						
Parashorea malaanonan	*Bagtikan*	802-1256	Lower Montane	0.04	0.0012	3.53
Shorea contorta	*White Lauan*	802-1256	Lower Montane	0.30	0.0120	77.37
Shorea polysperma	*Tanguile*	802-1256	Lower Montane	0.26	0.0075	42.95
Elaeocarpaceae						
Elaeocarpus calomala	*Bunsilak*	`	Lower to Upper Montane	0.19	0.0112	15.11
Ericaceae						
Vaccinium sp.		802-1256	Lower Montane	0.04	0.0027	1.34
Euphorbiaceae						
Cleidion ramosii	*Tisa-tisa*	802-1527	Lower to Upper Montane	0.26	0.0157	176.31
Homalanthus populneus	*Balanti*	643-1527	Lowland to Upper Montane	0.15	0.0063	26.24
Macaranga bicolor		802-1256	Lower Montane	0.04	0.0014	8.98
Macaranga hispida	*Hamindang*	802-1256	Lower Montane	0.07	0.0012	6.65
Macaranga sp.		802-1256	Lower Montane	0.04	0.0048	2.68
Macaranga stonei	*Hinlaumo*	802-1256	Lower Montane	0.22	0.0093	40.13
Fabaceae						
Pterocrpus indicus	*Narra*	802-1256	Lower Montane	0.07	0.0039	2.36
Gesneriaceae						
Cyrtandra cf. incisa		1421-1527	Upper Montane	0.07	0.0023	10.18
Lamiaceae						
Gmelina arborea		643-738	Lower Montane	0.07	0.0037	32.08
Lauraceae						
Cinnamomum mercadoi	*Kaningag*	643-1527	Lower to Upper Montane	0.26	0.0071	18.68
Listea sp. 2		802-1256	Lower Montane	0.04	0.0003	3.68
Litsea cordata	*Bakan*	643-1256	Lower Montane	0.07	0.0022	36.97
Litsea fulva	*Payong-payong*	1421-1527	Upper Montane		0.0005	40.72
Loganiaceae						
Willughbeia volubilis	*Kabal tree*	802-1256	Lower Montane	0.04	0.0013	4.13
Maratiaceae						
Angiopteris palmiformis	*Tree Fern*	643-1527	Lower to Upper Montane	0.41	0.0059	8.55

Melastomataceae						
Astronia cumingiana	*Badling*	802-1256	Lower Montane	0.07	0.0029	8.28
Astronia sp.		643-1256	Lower Montane	0.11	0.0016	4.48
Memecylon sp.		802-1256	Lower Montane	0.04	0.0002	3.68
Meliaceae						
Sandoricum koetjape		643-738	Lower Montane	0.04	0.0011	7.33
Swietenia macrophylla	*Big Leaf Mahogany*	802-1256	Lower Montane	0.04	0.0540	106.28
Artocarpus heterophyllus	*Nangka / Langka*	802-1256	Lower Montane	0.04	0.0023	1.15
Artocarpus odoratissimus		643-738	Lowland	0.04	0.0009	9.11
Ficus ampelas		802-1256	Lower Montane	0.07	0.0025	4.09
Ficus botryocarpa	*Basikong*	643-1256	Lower Montane	0.33	0.0074	8.12
Ficus magnoliifolia		802-1256	Lower Montane	0.04	0.0005	0.81
Ficus nota		802-1256	Lower Montane	0.04	0.0013	2.86
Ficus ruficaulis		802-1256	Lower Montane	0.04	0.0009	0.97
Ficus sp.		643-1256	Lower Montane	0.15	0.0059	156.94
Ficus ulmifolia	*Diri-diri / Is-is*	802-1256	Lower Montane	0.04	0.0033	9.16
Ficus variegata	*Burar-og*	643-1527	Lower to Upper Montane	0.26	0.0057	77.38
Myristicaceae						
Knema glomerata	*Tambalau*	802-1256	Lower Montane	0.04	0.0009	1.21
Myrtaceae						
Eugenia sp.		802-1256	Lower Montane	0.07	0.0024	3.79
Syzygium sp.	*Udling*	802-1527	Lower to Upper Montane	0.59	0.0227	94.49
Syzygium sp. 1		802-1256	Lower Montane	0.04	0.0003	3.14
Syzygium sp. 2		802-1256	Lower Montane	0.04	0.0008	7.22
Pentaphylacaceae						
Eurya chinensis		802-1256	Lower Montane	0.04	0.0017	3.26
Eurya sp.		802-1256	Lower Montane	0.07	0.0026	7.03
Podocarpaceae						
Dacrydium cf. beccarii	*Pine tree*	1421-1527	Upper Montane	0.11	0.0112	3321.50
Primulaceae						
Ardisia sp. 4		802-1256	Lower Montane	0.04	0.0001	1.61
Rhamnaceae						
Alphitonia excelsa		643-1256	Lower Montane	0.19	0.0061	35.95
Rosaceae						
Prunus grisea	*Lago*	802-1256	Lower Montane	0.04	0.0014	1.34
Rubiaceae						
Canthium sp.		802-1256	Lower Montane	0.04	0.0004	
Neonauclea sp.		802-1256	Lower Montane	0.04	0.0035	7.18
Rutaceae						
Melicope triphylla	*Amahit*	643-1527	Lower to Upper Montane	0.19	0.0048	142.37
Sapindaceae						
Guioa sp.	*Mala-mala*	802-1256	Lower Montane	0.07	0.0122	7.19
Sapotaceae						
Palaquium sp.		802-1256	Lower Montane	0.11	0.0042	20.17
Palaquium sp. 2		802-1256	Lower Montane	0.04	0.0022	4.97
Planchonella sp.		802-1256	Lower Montane	0.07	0.0012	6.31
Theaceae						
Polyspora luzonica		802-1256	Lower Montane	0.04	0.0007	5.89
Urticaceae						
Leucosyke capitellata	*Alagasi*	802-1256	Lower Montane	0.04	0.0014	12.99
Misc.8	*Bonsai*	1421-1527	Upper Montane	0.11	0.0059	85.86
Misc.3	*Dalakit**	802-1256	Lower Montane	0.04	0.0002	2.41
Fabaceae sp.		802-1256	Lower Montane	0.11	0.0027	13.58
Misc.4	*Lako-lako**	802-1256	Lower Montane	0.15	0.0057	23.31
Misc. 1	*Lako-lako**	802-1256	Lower Montane	0.04	0.0055	12.25

Table 2. Ecological characteristics of herbaceous species in Northern Negros Natural Park, Negros Island, Philippines

Family, species name	Common name	Alt. range (m asl.)	Forest formation	Count	Frequency	Density (ind. /sq.m)
Apocynaceae						
Hoya sp.		802-1256	Lower Montane	12	0.04	0.0013
Araceae						
Aglaonema philippinense		802-1256	Lower Montane	5	0.04	0.0005
Alocasia macrorrhiza	*Badiang*				0.04	
Alocasia micholitziana		1421-1527	Upper Montane	3	0.04	0.0003
Alocasia sp.		802-1256	Lower Montane	4	0.04	0.0004
Alocasia zebrina	*Tigre-tigre*			1	0.04	0.0001
Homalomena philippinensis	*Gabi-gabi*	802-1256	Lower Montane	24	0.11	0.0026
Arecaceae						
Calamus cf. siphonospathus		802-1256	Lower Montane	7	0.15	0.0008
Calamus siphonospathus		802-1256	Lower Montane	19	0.15	0.0021
Calamus sp.		643-1527	Lower to Upper Montane	76	0.37	0.0083
Heterospathe negrosensis		802-1256	Lower Montane	9	0.07	0.0010
Aspleniaceae						
Abrodictyum obscurum		802-1256	Lower Montane	6	0.04	0.0007
Asplenium musifolium	*Bakwitan*	802-1256	Lower Montane	5	0.04	0.0005
Asplenium nidus		802-1256	Lower Montane	1	0.04	0.0001
Asplenium tenerum		802-1256	Lower Montane	13	0.04	0.0014
Elephantopus mollis		802-1256	Lower Montane	7	0.04	0.0008
Elephantopus sp.		802-1256	Lower Montane	8	0.04	0.0009
Athyriaceae						
Diplazium cordifolium		802-1256	Lower Montane	9	0.07	0.0010
Diplazium esculentum	*Pako-pako / pako*	802-1527	Lower to Upper Montane	22	0.19	0.0024
Fern		802-1256	Lower Montane	54	0.30	0.0059
Fern 1		802-1256	Lower Montane	9	0.04	0.0010
Fern 2		802-1256	Lower Montane	10	0.04	0.0011
Begoniaceae						
Begonia cf. lagunensis		802-1256	Lower Montane	1	0.04	0.0001
Begonia sp.		802-1256	Lower Montane	8	0.04	0.0009
Boraceae						
Boraceae sp.		802-1256	Lower Montane	4	0.04	0.0004
Chloranthaceae						
Chloranthus erectus		802-1256	Lower Montane	5	0.04	0.0005
Commelinaceae						
Commelina benghalensis L.		802-1256	Lower Montane	1	0.04	0.0001
Commelina diffusa		802-1256	Lower Montane	1	0.04	0.0001
Hewittia sp.		802-1256	Lower Montane	7	0.04	0.0008
Costaceae						
Hellenia speciosa	*Costus*	802-1256	Lower Montane	8	0.04	0.0009
Cyperaceae						
Cyperus sp.		802-1256	Lower Montane	17	0.07	0.0018
Davillaceae						
Davilla cf. pubescens		802-1256	Lower Montane	8	0.04	0.0009
Gesneriaceae						
Cyrtandra sp.		802-1256	Lower Montane	5	0.04	0.0005
Gleicheniaceae						
Dicranopteris linearis	*Agsam*	802-1256	Lower Montane	33	0.22	0.0036
Hymenophyllaceae						
cf. Abrodictyum obscurum		802-1256	Lower Montane	4	0.04	0.0004
Hypoxidaceae						
Curculigo sp.		802-1256	Lower Montane	7	0.04	0.0008
Lomariopsidaceae						
Cyclopeltis crenata		802-1256	Lower Montane	17	0.07	0.0018
Lycopodiaceae						
Huperzia squarossa	*Salindugok*	1421-1527	Upper Montane	2	0.04	0.0002
Meliaceae						
Aglaia sp.		802-1256	Lower Montane	12	0.04	0.0013
*Bagosantol**	*Bagosantol**	802-1256	Lower Montane	21	0.04	0.0023
Menispermaceae						
cf. Menispemaceae--if climbing		802-1256	Lower Montane	5	0.04	0.0005
Moraceae						
Ficus balete	*Lonok*	802-1256	Lower Montane	23	0.04	0.0025

Orchidaceae						
Agrostophyllum sp.		802-1256	Lower Montane	2	0.04	0.0002
cf. Appendicula sp.		802-1256	Lower Montane	10	0.04	0.0011
cf. Cylindrolobus sp.					0.04	
Crepidium sp.		802-1256	Lower Montane	8	0.04	0.0009
Dendrobium sp. (2)		802-1256	Lower Montane	6	0.04	0.0007
Phyllanthaceae						
cf. Aporosa sp.		802-1256	Lower Montane	5	0.04	0.0005
cf. Cleistanthus sp.		802-1256	Lower Montane	3	0.04	0.0003
Glochidion sp.		802-1256	Lower Montane	6	0.04	0.0007
Poaceae						
Axonopus compressus		643-738	Lower	2	0.04	0.0002
Cynodon dactylno		802-1527	Lower to Upper Montane	9	0.04	0.0010
Eleusine indica		802-1527	Lower to Upper Montane	5	0.11	0.0005
Pteridaceae						
cf. Adiantum sp.	*Dun-is*	802-1256	Lower Montane	6	0.04	0.0007
Pteridophytes						
Amphineuron terminals		802-1256	Lower Montane	2	0.04	0.0002
cf. Asplenium monanthes		1421-1527	Upper Montane	5	0.04	0.0005
Dicranopteris cf. linearis		802-1256	Lower Montane	9	0.04	0.0010
Histiopteris incisa		643-1256	Lowland to Lower Montane	3	0.04	0.0003
Sapindaceae						
Harpulia cf. cupanoides	*Bonsilak (male)*	802-1256	Lower Montane	18	0.07	0.0020
Sapotaceae						
cf. Palaquium sp.		802-1256	Lower Montane	6	0.04	0.0007
Symplocaceae						
cf. Symplocos sp.		802-1256	Lower Montane	1	0.04	0.0001
Thelypteridaceae						
Chingia ferox		802-1527	Lower to Upper Montane	19	0.22	0.0021
Urticaceae						
Dendrocnide meyeniana	*Alingatong*	802-1256	Lower Montane	3	0.04	0.0003
Elatostema sp		802-1527	Lower to Upper Montane	2	0.04	0.0002
Elatostema sp. 1		802-1256	Lower Montane	4	0.04	0.0004
Elatostema sp. 2		802-1256	Lower Montane	2	0.04	0.0002
Vitaceae						
Ampelocissus sp.		802-1256	Lower Montane	9	0.04	0.0010
Leea guineensis		802-1256	Lower Montane	4	0.07	0.0004
Leea sp.	*Mali-mali*	802-1256	Lower Montane	12	0.11	0.0013
Zingiberaceae						
Alpinia sp.		802-1527	Lower to Upper Montane	36	0.15	0.0039
Amomum sp.	*Malatugis*	802-1256	Lower Montane	14	0.04	0.0015
cf. Alpinia sp.		802-1256	Lower Montane	1	0.04	0.0001
Etlingera pilosa		802-1256	Lower Montane	1	0.04	0.0001

Species diversity

Table 5 shows the characteristics of the 27 plots along the altitudinal gradients in NNNP. Each plot is described by elevation (m asl.), coordinates, slope, forest formation, and distance to human settlements. The average species diversity along the altitudinal gradients of NNNP is moderate at H'=2.88 (Figure 3). The highest diversity is found in plot 10 with H'=3.4, and the lowest value complimented it for dominance (D= 0.0351) compared to the rest of the plots. *Dacrydium cf. beccarii*, the dominant species in plot 25, influenced the lowest reading for species diversity (H'= 2.256). The observed high diversity in some plots is not representative of a pristine ecosystem in NNNP but an early stage of succession after disturbance (Swanson et al. 2011). The average value for species evenness is at 0.84, showing the varying relative abundance across the species in the gradient.

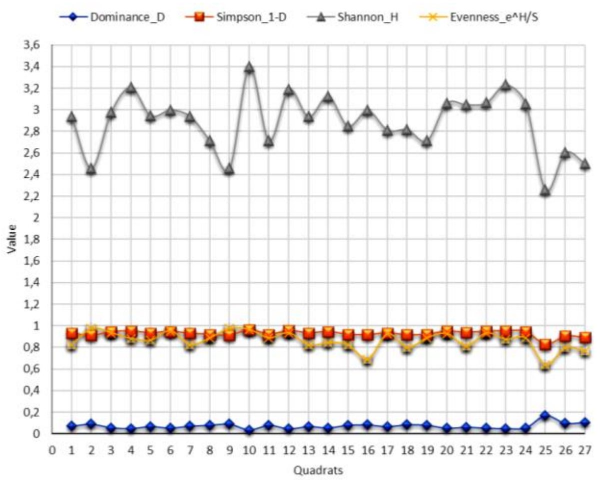


Figure 3. Diversity Indices of the different forest formations according across 27 quadrats in Northern Negros Natural Park in Negros Island, Philippines

Table 3. Comparison of species richness in Northern Negros Natural Park with other mountains in the Philippines

Mountain	No. of taxon		
	Species	Genera	Family
Northern Negros Natural Park	242	169	72
Mt. Tago Range, Mindanao	121	85	54
Balbalasang-Balbalan National Park, Kalinga Province	319	206	84
Mt. Calavite Wildlife Sanctuary, Mindoro Island	181		67
Quezon Mountain Range, Southern Mindanao	202	158	107

Table 4. Endemic and threatened species along the altitudinal gradient in Northern Negros Natural Park, Negros Island, Philippines

Family	Species	Conservation status		
		DENR 2017 (DAO 2017-11)	IUCN Red list	Endemicity Pelser et al. (2011 onwards)
Actinidiaceae	*Saurauia panayensis*	-	-	PE
Adoxaceae	*Viburnum glaberrimum*	-	-	PE
Annonaceae	*Miliusa vidalii*	-	-	PE
Araceae	*Alocasia zebrina*	VU	-	-
Araucariaceae	*Agathis philippinensis*	VU	VU	-
Arecaceae	*Caryota cf cumingii*	-	-	PE
	Pinanga insignis	-	-	PE
	Pinanga philippinensis	-	-	PE
Begoniaceae	*Begonia lagunensis*	-	-	PE
Cunoniaceae	*Weinmannia cf. lucida*	-	-	PE
	Weinmannia hutchinsonii	-	-	PE
Cyatheaceae	*Cyathea contaminans*	EN	LC	-
Dilleniaceae	*Dillenia philippinensis*	-	-	PE
Dipterocarpaceae	*Parashorea malaanonan*	-	-	PE
	Shorea almon	VU	NT	-
	Shorea contorta	VU	LC	PE
	Shorea polysperma	VU	LC	-
Elaeocarpaceae	*Elaeocarpus calomala*	-	-	PE
Escalloniaceae	*Cleidion ramosii*	-	-	PE
Euphorbiaceae	*Macaranga bicolor*	-	-	PE
	Macaranga hispida	-	-	PE
	Macaranga stonei	-	-	PE
Lauraceae	*Cinnamomum mercadoi*	OTS	LC	PE
Loganiaceae	*Willughbeia volubilis*	-	-	PE
Marattiaceae	*Angiopteris palmiformis*	OTS	-	-
Melastomataceae	*Astronia cumingiana*	-	-	PE
Moraceae	*Artocarpus odoratissimus*	-	-	PE
	Ficus balete	-	-	PE
	Ficus ulmifolia	-	-	PE
Pandanaceae	*Freycinetia cf. cumingiana*	-	-	PE
	Freycinetia cf. ensifolia	-	-	PE
	Freycinetia cf. monocephala	-	-	PE
	Freycinetia multiflora	-	-	PE
Podocarpaceae	*Podocarpus rumphii*	VU	NT	-
Rosaceae	*Prunus grisea*	VU	LC	-
Theaceae	*Polyspora luzonica*	-	-	PE
Urticaceae	*Oreocnide trinervis*	-	-	PE
Vitaceae	*Tetrastigma loheri*	-	-	PE
Zingiberaceae	*Etlingera pilosa*	-	-	PE

Notes: VU: Vulnerable; NT: Near Threatened; LC: Least Concern OTS: Other Threatened Species; PE: Philippine Endemic

Environmental factors influencing species diversity

The biophysical factors examined for their influence on the plant bioresources in NNNP are the soil surface pH, N, P, K, elevation, slope, and stand maturity. Observing the result of soil acidity (Figure 4), NNNP has a mean value of 6 in its pH level with a standard deviation of 0.35, indicating a closer clustering to the mean of all other pH recordings throughout 27 points.

Among nitrogen (N), phosphorus (P), and potassium (K), the soil analysis yielded the lowest value for N, with a mean of 1.19. It has registered as either deficient or depleted throughout the sampling points with a standard deviation of 0.4. Phosphorus was observed to be adequate, with a high value recorded in 27 sampling sites, a mean value of 3.3 and a standard deviation of 1.11, and a significant positive correlation with elevation. Potassium is recorded as deficient with a mean of 2.22 at 0.80 standard deviations and has a significant negative correlation with elevation. All these soil surface characteristics showed no significant correlation with the species diversity along the plots established in the gradients of NNNP.

The socioeconomic factor is the sample plot's proximity to human disturbance. Species diversity has been observed to be negatively correlated with altitude ($r=-0.03$), similar to the observations in elevation gradients in three climatic zones in Yunnan, southern China (Song et al. 2021). They calculated species diversity indices and the composition of mature trees and seedlings to investigate how tree species and their seedlings respond to elevational gradients.

The climatic regime for NNNP falls under the type III climate, where seasons are not very pronounced. It is relatively dry from November to April and wet during the rest of the year. The mean annual temperature has been at 26.05ºC for the past 30 years (1991-2020). The mean annual rainfall recorded was 106.63 inches, and the mean relative humidity was 80.59%, taken from Dumaguete Radar Station (PAGASA 2020) (Figure 5).

Ecosystems Level Assessment: Vegetation structure

The altitudinal distribution of vegetation based on habit is shown in Figure 6. The individual samples were classified into four groups: (i) ground cover vegetation; (ii) understory vegetation; (iii) upper canopy vegetation; and (iv) epiphytic vegetation. The majority of the plots (79%) harbor all four groups. There were no recorded epiphytes in the eight plots located at the lower elevation.

Environmental factors influencing vegetation structure

The species abundance of the ground cover vegetation (Figure 6) was affected by the soil potassium (K). The positive influence on species abundance of potassium was also observed in the grassland legumes (Tognetti et al. 2021). The ground cover vegetation species abundance was also observed to have a negative correlation with proximity to human disturbance, conforming to the findings of Murphy and Romanuk (2014). The abundance of upper canopy vegetation was negatively correlated with the slope and soil potassium.

Table 5. Plot characteristics of 27 sites inside Northern Negros Natural Park in Negros Island, Philippines

Quadrat	Elevation (m asl.)	Latitude	Longitude	Slope (degrees)	Forest formation (Frenando et al. 2008)	Proximity to human disturbances (m)
1	643	10.790350°	123.193400°	11.2	Tropical lower montane rainforest	380
2	674	10.790383°	123.194333°	15.1	Tropical lower montane rainforest	616
3	738	10.790283°	123.196950°	3.6	Tropical lower montane rainforest	783
4	802	10.790283°	123.196950°	-54	Tropical lower montane rainforest	1050
5	822	10.685000°	123.185000°	36.2	Tropical lower montane rainforest	1024
6	825	10.686516°	123.186552°	-1	Tropical lower montane rainforest	1047
7	828	10.685000°	123.179000°	2	Tropical lower montane rainforest	1106
8	881	10.788750°	123.202017°	22.9	Tropical lower montane rainforest	1265
9	884	10.685478°	123.181219°	13.8	Tropical lower montane rainforest	1782
10	907	10.786500°	123.205417°	33.0%	Tropical lower montane rainforest	1254
11	907	10.786438°	123.206065°	30.4%	Tropical lower montane rainforest	1340
12	908	10.687515°	123.184937°	21.2%	Tropical lower montane rainforest	1630
13	913	10.784863°	123.207013°	16%	Tropical lower montane rainforest	1899
14	918	10.787517°	123.203650°	36%	Tropical lower montane rainforest	2086
15	935	10.789817°	123.201133°	-22%	Tropical lower montane rainforest	2256
16	937	10.790815°	123.202807°	-13%	Tropical lower montane rainforest	2207
17	941	10.687191°	123.182629°	10%	Tropical lower montane rainforest	2414
18	985	10.782966°	123.208222°	1%	Tropical lower montane rainforest	2612
19	993	10.682000°	123.185000°	-11.15%	Tropical lower montane rainforest	2680
20	1023	10.679000°	123.185000°	22.00%	Tropical lower montane rainforest	2840
21	1131	10.780904°	123.208954°	38.30%	Tropical lower montane rainforest	3039
22	1182	10.674988°	123.187725°	44.60%	Tropical lower montane rainforest	3206
23	1256	10.778617°	123.208931°	25.90%	Tropical lower montane rainforest	3317
24	1421	10.665594°	123.184317°	-29.90%	Tropical upper montane rainforest	2426
25	1465	10.658164°	123.18105°	-14.50%	Tropical upper montane rainforest	2657
26	1470	10.655778°	123.169569°	25.30%	Tropical upper montane rainforest	3353
27	1517	10.662794°	123.182981°	-90.00%	Tropical upper montane rainforest	3117

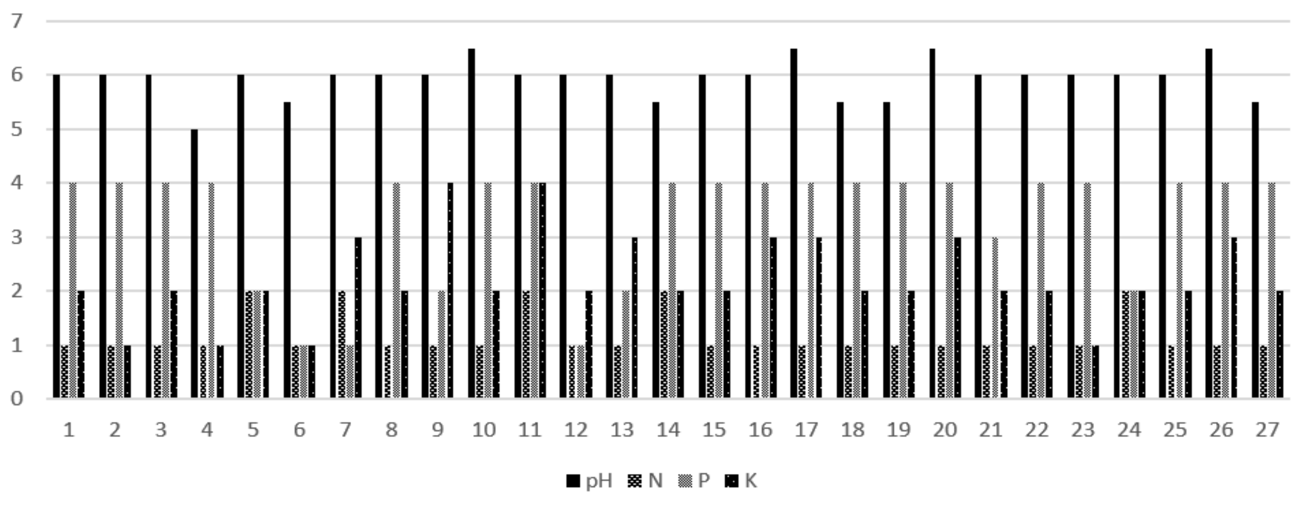


Figure 4. Soil NPK Graph of 27 sampling plots in Northern Negros Natural Park, Negros Occidental, Philippines

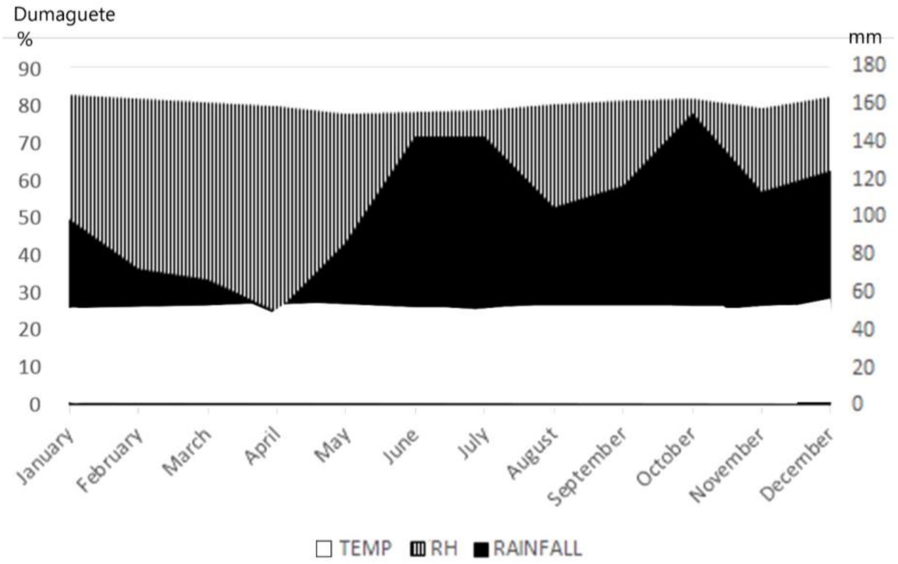


Figure 5. Climogram for Dumaguete Radar Station, the nearest weather station to Northern Negros Natural Park, for 30 years (1990-2020)

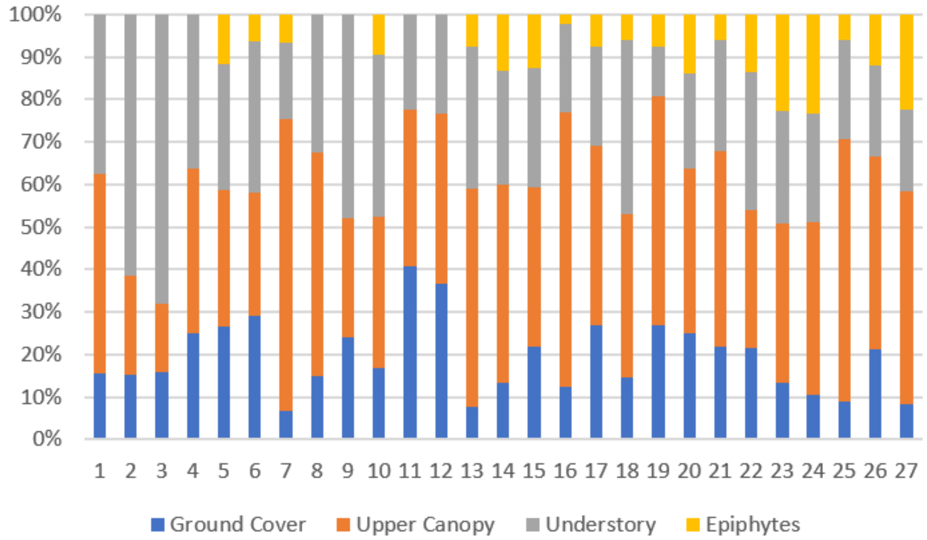


Figure 6. The proportion of individuals with different habits in Northern Negros Natural Park in Negros Island, Philippines

Table 6. Vegetation of different Ecosystems along the altitudinal gradient in Northern Negros Natural Park, Negros Island, Philippines (modified from Geollegue 2011)

Ecosystem	Elevation	Vegetation
Upper montane forest	Up-1850	Dense mossy forest, dominated by shrubby growth of *Rhododendron, Vaccinium, Isachne vulcanica*, etc.
Lower montane forest	600-1300	Start of the mossy growth on trees dominated by *Crypteronia paniculata, Acer laurinum, Weinmannia hutchinsonii, Syzygium* sp., *Viburnum glaberrimum, Alphitonia excelsa, Shorea contorta, Ficus* sp., *Melicope triphylla*
Lowland tropical rainforest/wooded grasslands	0-600	Sparse Residuals of Dipterocarp species and remnants of primary lowland forest, tree plantations, kaingin, pioneer tree species
Upland farms and Idle or open grasslands	600-1000	Cogon, shrubs, successional vegetation (pioneer trees), upland rice, kaingin farms, rice in terraces, etc.
Cultivated croplands	0-800	Sugarcane, rice, corn, orchards, perennial crops, plantation forest, orchards
Settlements/ Built-up areas	0-500	Urban trees and ornamentals, fruit trees, tree plantations, orchards

Table 7. Basal area and frequency of trees across diameter and height classes per forest habitat type

Forest habitat	Average basal area (m^2/ha)	Frequency							
		%Diameter classes (cm)				%Height classes (m)			
		10-49	50-99	100-149	150-500	1-10	11-20	21-30	31-40
Tropical lower montane rainforest	0.55	91%	7%	1%	0%	53%	37%	3%	8%
Tropical upper montane rainforest	6.12	39%	50%	0%	11%	50%	0%	3%	47%

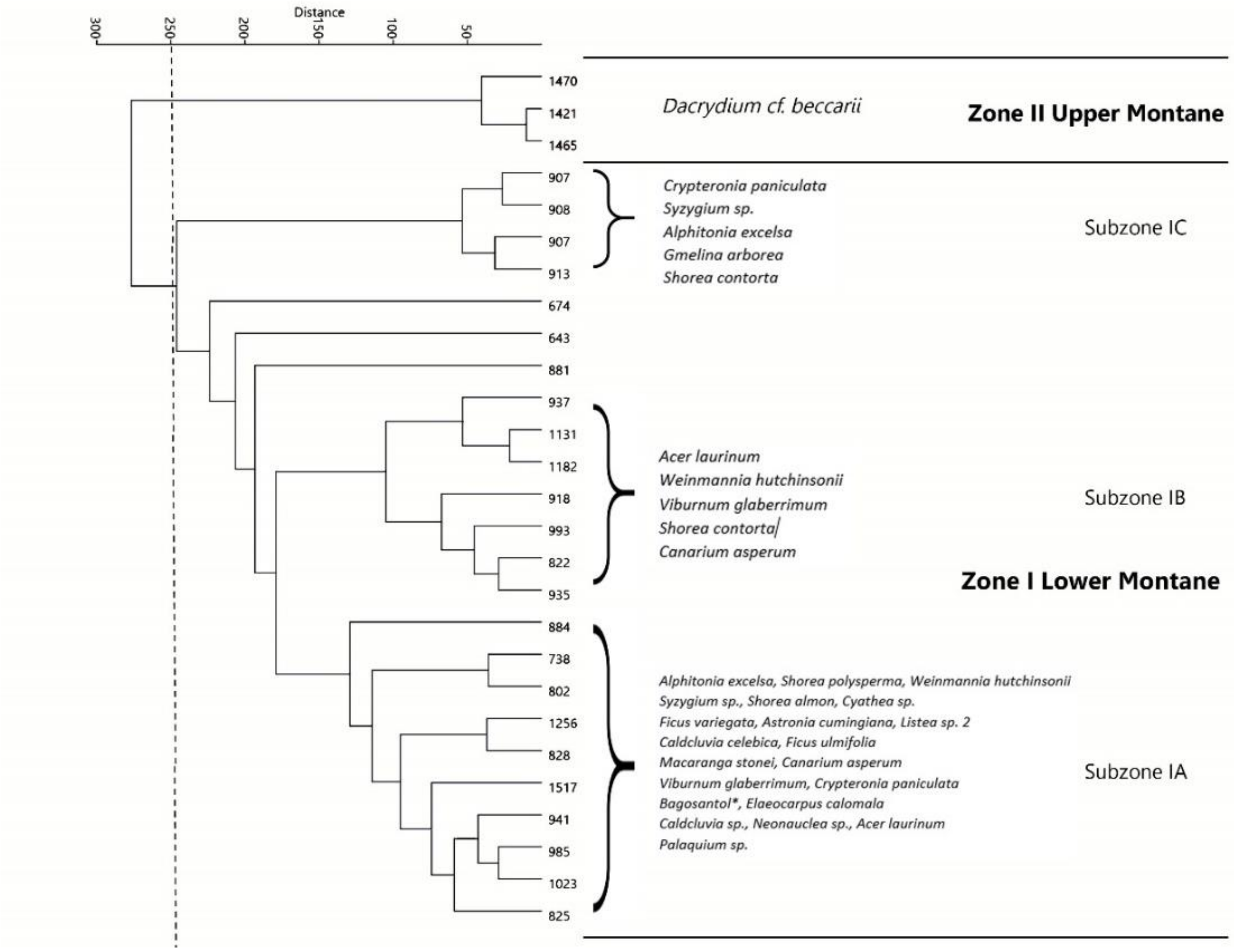


Figure 7. Dendrogram of 27 sampling quadrats on the altitudinal zones of Northern Negros Natural Park obtained by the nearest classical method using the Ward algorithm. Two altitudinal vegetation zones were identified from 643 to 1,256 m asl.: Zone I) *Crypteronia paniculata, Acer laurinum, Weinmannia hutchinsonii, Syzygium sp., Viburnum glaberrimum, Alphitonia excelsa, Shorea contorta,* and *Ficus sp.;* and Zone II) *Dacrydium cf. beccarii* at 1,421 to 1,470 m asl.

Altitudinal zones

The RBA of each species was subjected to cluster analysis using the classical similarity index in PAST software. Two forest zones were identified and named according to the respective dominant species. Incidentally, this corresponded with the tropical forest formations according to altitudinal gradient. Zone I for plots within 643 to 1,256 m asl. corresponded with the tropical lower montane rainforest within 600 to 1,300 m asl., and Zone II for plots along 1,421 to 1,470 m asl. corresponded with tropical upper montane rainforest (1,300 to 1,850 m asl.) (Figure 7, Tables 8, 9, 10, 11).

Table 6 shows the different ecosystems along the different elevations in NNNP according to BWFR Management Framework Plan, which was used as the base to determine the forest formations along the altitudinal gradient for NNNP.

Zone I. Tropical Lower Montane rain forest (Figure 8). *Crypteronia paniculata, Acer laurinum, Weinmannia hutchinsonii, Syzygium* sp.*, Viburnum glaberrimum, Alphitonia excelsa, Shorea contorta,* and *Ficus* sp. forest zone, 643m to 1256 m altitude (23 sampling sites). That is composed of 94 recorded species, characterized by early to advanced second growth stand maturity. That was further characterized by emergent trees 1 to 10 m tall (53%), 10 to 49 cm DBH (91%), and 0.55 $m^2 \cdot Ha^{-1}$ average basal area (BA). This zone was further split into three sub-clusters as indicators of varying successional patterns most likely influenced by micro drivers like the elevation range and dominant species (Banaticla and Buot 2005). The sub-clusters were delineated at a Euclidian distance of 150. Zone IA for plots within 643 to 985 m asl. was dominated by *Alphitonia excelsa, Shorea polysperma, Weinmannia hutchinsonii, Syzygium* sp., *Shorea almon, Cyathea* sp., *Ficus variegata, Astronia cumingiana, Listea* sp. 2, *Caldcluvia celebica, Ficus ulmifolia, Macaranga stonei, Canarium asperum, Viburnum glaberrimum, Crypteronia paniculata*, and *Bagosantol**. The Zone IB for plots between 822 to 1,182 m asl. was dominated by *Acer laurinum*, Weinmannia. Zone IC of the plot within 908 to 913 m asl. was dominated by *Crypteronia paniculata*, *Syzygium* sp., *Alphitonia excelsa*, *Gmelina arborea, and Shorea contorta. hutchinsonii*, *Viburnum glaberrimum, Shorea contorta,* and *Canarium asperum*. The three plots not categorized into subgroups are outliers due to anthropogenic clearing and are characterized by the absence of epiphyte vegetation (Tables 7, 8, 9, 10).

Zone II. *Tropical* upper montane rain forest (Figure 9). *Dacrydium cf. beccarii* forest zone, 1421 m to 1470 m altitude. The 1182 recorded species for this zone were mainly composed of *Dacrydium cf. beccarii,* with the maturity stand advanced second growth. They recorded the maximum DBH of 400 cm and MH of 40 meters in sampling plot P2Q2. Despite the extensive clearing activities in the past decades in the forest of northern Negros, *Dacrydium cf. beccarii* survived in the higher elevations of the park. The difficulty in access contributed to the preservation of most of these species inside NNNP. It is usually found on mossy ridges, rising above the low mixed mountain shrubs (Tropical Plants Database). *D. beccarii* was classified as the least concern species in the IUCN Red List Threatened Species (IUCN Red List 2021). The dominance of *D. beccarii* in the upper montane rainforest is also observed on Dinagat island (Lillo et al. 2018). The zone was further characterized by emergent trees 1 to 10 m tall (50%), 50 to 99 cm DBH (50%), and 6.12 $m^2 \cdot Ha^{-1}$ average basal area (BA) (Tables 7, 11).

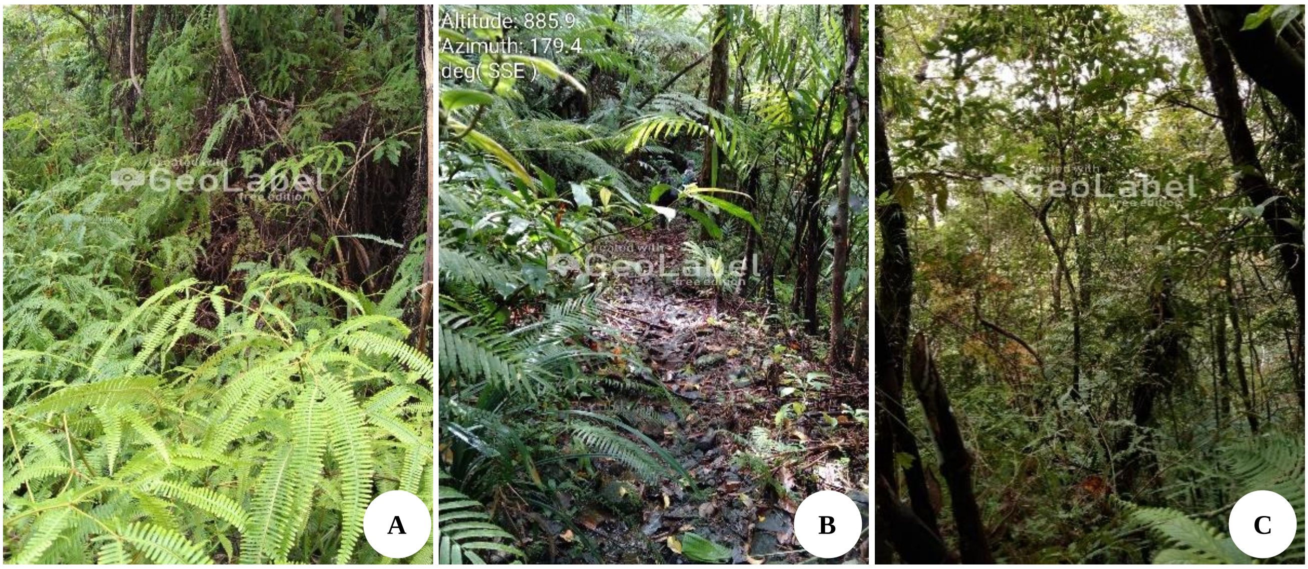


Figure 8. Vegetation along Northern Negros Natural Park, Negros Island Philippines. A. Subzone IA, B. Subzone IB, C. Subzone IC

Figure 9. Photo of vegetation along Zone II of Northern Negros Natural Park, Negros Island Philippines

Table 8. Zone IA species composition in the various sampling sites. Relative basal area (RBA in %) derived from diameter-at-breast height (DBH) values

Sampling site	**T2Q3**	**T2Q4**	**T1Q5**	**T1Q1**	**T1Q2**	**T1Q3**	**T3Q3**	**T1Q8**	**T3Q5**
Altitude (m asl.)	738	802	825	828	884	941	985	1023	1256
Altitudinal zonation	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane
Latitude	10.790283°	10.790283°	10.686516°	10.685000°	10.685478°	10.687191°	10.782966°	10.679000°	10.778617°
Longitude	123.19695°	123.196950°	123.186552°	123.179000°	123.181219°	123.182629°	123.208222°	123.185000°	123.208931°
Slope (degrees)	3.6	-54	-1	2	13.8	0.096	0.012	0.22	0.259
Plot size (sq m)	20	20	20	20	20	20	20	20	20
Number of species	21	21	18	26	22	27	31	23	29
Maximum DBH (cm)	20.1	44.6	56	42	136.9	40	40.7	110	26.1
Maximum height (m)	6	14	22	12	8	15	11	17	11
Proximity to human Disturbances (m)	783	1050	1047	1106	1782	2414	2612	2840	3317
	RBA	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**
Aceraceae									
Acer laurinum	0.828	1.345					1.699		4.038
Actinidiaceae									
Saurauia panayensis		0.688					1.438		
Araucariaceae									
Agathis philippinensis				0.134					
Burseraceae									
Canarium asperum					0.746	0.316			
Clethraceae									
Clethra sp.							0.225	0.176	
Cryteroniaceae									
Crypteronia paniculata	3.488								
Cunoniaceae									
Caldcluvia celebica		1.580						0.561	
Caldcluvia sp.							0.147		0.964
Weinmannia cf. lucida									
Weinmannia hutchinsonii				0.161		0.404	2.748		0.379
Dipterocarpaceae									
Parashorea malaanonan									0.497
Shorea contorta		2.365		0.659	0.183				
Shorea polysperma			0.176			0.177			
Euphorbiaceae									
Cleidion ramosii		0.733	0.161					0.250	
Homalanthus populneus		0.224							
Macaranga hispida					1.085				
Fabaceae									
Pterocarpus indicus				0.296				0.134	
Lamiaceae									
Gmelina arborea							0.336		
Melastomataceae									
Astronia sp.								0.828	
Meliaceae									
Sandoricum koetjape				0.115					
Swietenia macrophylla				9.732					
Artocarpus heterophyllus									0.161
Artocarpus odoratissimus				0.347					
Ficus botryocarpa				0.176	0.224				
Ficus magnoliifolia					0.448				
Ficus ruficaulis			0.286						
Ficus sp.					14.714				
Ficus variegata								0.705	
Myristicaceae									
Knema glomerata									0.109
Myrtaceae									
Syzygium sp. 2	0.314	0.436							
Pentaphylacaceae									
Eurya chinensis									0.379
Eurya sp.									0.326
Rhamnaceae									
Alphitonia excelsa				0.147		0.380			
Rubiaceae									
Neonauclea sp.									0.718
Rutaceae									
Melicope triphylla		0.268						9.503	
Sapindaceae									
Guioa sp.	0.484								
Sapotaceae									
Palaquium sp.						0.314		0.134	
Misc.4			2.331		0.241			0.944	
Misc. 1							0.268		

Table 9. Zone IB species composition in the various sampling sites. Relative basal area (RBA in %) derived from diameter-at-breast height (DBH) values

Sampling Site	**T2Q9**	**T3Q1**	**T1Q4**	**T3Q2**
Altitude (m asl.)	907	907	908	913
Altitudinal zonation	Lower montane	Lower montane	Lower montane	Lower montane
Latitude	10.786500°	10.786438°	10.687515°	10.784863°
Longitude	123.205417°	123.206065°	123.184937°	123.207013°
Slope (degrees)	0.33	0.304	0.212	0.157
Plot size (sq m)	20	20	20	20
Number of species	17	23	23	28
Maximum DBH (cm)	47.7	59.2	50	30
Maximum height (m)	12	13	20	13
Proximity to human disturbances (m)	1254	1340	1630	1899
	RBA	**RBA**	**RBA**	**RBA**
Aceraceae				
Acer laurinum	2.879	0.161	2.463	1.304
Actinidiaceae				
Saurauia panayensis	0.379			
Annonaceae				
Miliusa vidalii			0.368	
Araliaceae				
Polyscias aherniana	0.147			
Araucariaceae				
Agathis philippinensis			0.424	
Burseraceae				
Canarium asperum	2.753			
Clethraceae				
Clethra sp.	0.121	0.232		0.081
Cryteroniaceae				
Crypteronia paniculata	0.109	0.832		
Cunoniaceae				
Caldcluvia celebica	1.485		0.207	
Weinmannia hutchinsonii	0.703		1.191	0.962
Dipterocarpaceae				
Shorea contorta			0.241	
Shorea polysperma			2.486	
Euphorbiaceae				
Macaranga sp.	0.352	0.703		0.512
Melastomataceae				
Memecylon sp.	0.191			
Meliaceae				
Swietenia macrophylla				0.401
Ficus ampelas	0.215			
Ficus botryocarpa	0.168			
Ficus sp.				0.097
Ficus ulmifolia	0.980			
Ficus variegata	1.071			
Myrtaceae				
Syzygium sp.			0.286	
Rosaceae				
Prunus grisea		0.589		
Fabaceae sp.	0.368			0.703

Environmental factors influencing species distribution

The interesting zonation of NNNP has been influenced by several factors (Figure 10), as in many other mountains (Buot and Okitsu 1998, 1999, Buot 2006, Buot 2007, Villanueva and Buot 2018). A canonical correspondence analysis was performed. The resulting ordination diagram indicated that soil nitrogen level, elevation, wind speed, and human disturbance are the major environmental variables contributing to the distribution of tree species in Northern Negros Natural Park. Altitude has been known to have a great influence on the floristic composition change in the mountains of the Philippines (Buot 2008; Villanueva and Buot 2018; Buot and Okitsu 1998), South East Asia (Kitayama 1995; Van and Cochard 2017) and tropical mountains in general (Hemp 2006). Human disturbance has been observed to cause biodiversity loss (Barlow et al. 2016), alter plant species distribution patterns, and fragmentation habitats (Mligo 2011). Human disturbance also affects species diversity and promotes the growth of invasive weed species (Gogoi and Sahoo 2018), which is also observed in some areas of NNNP.

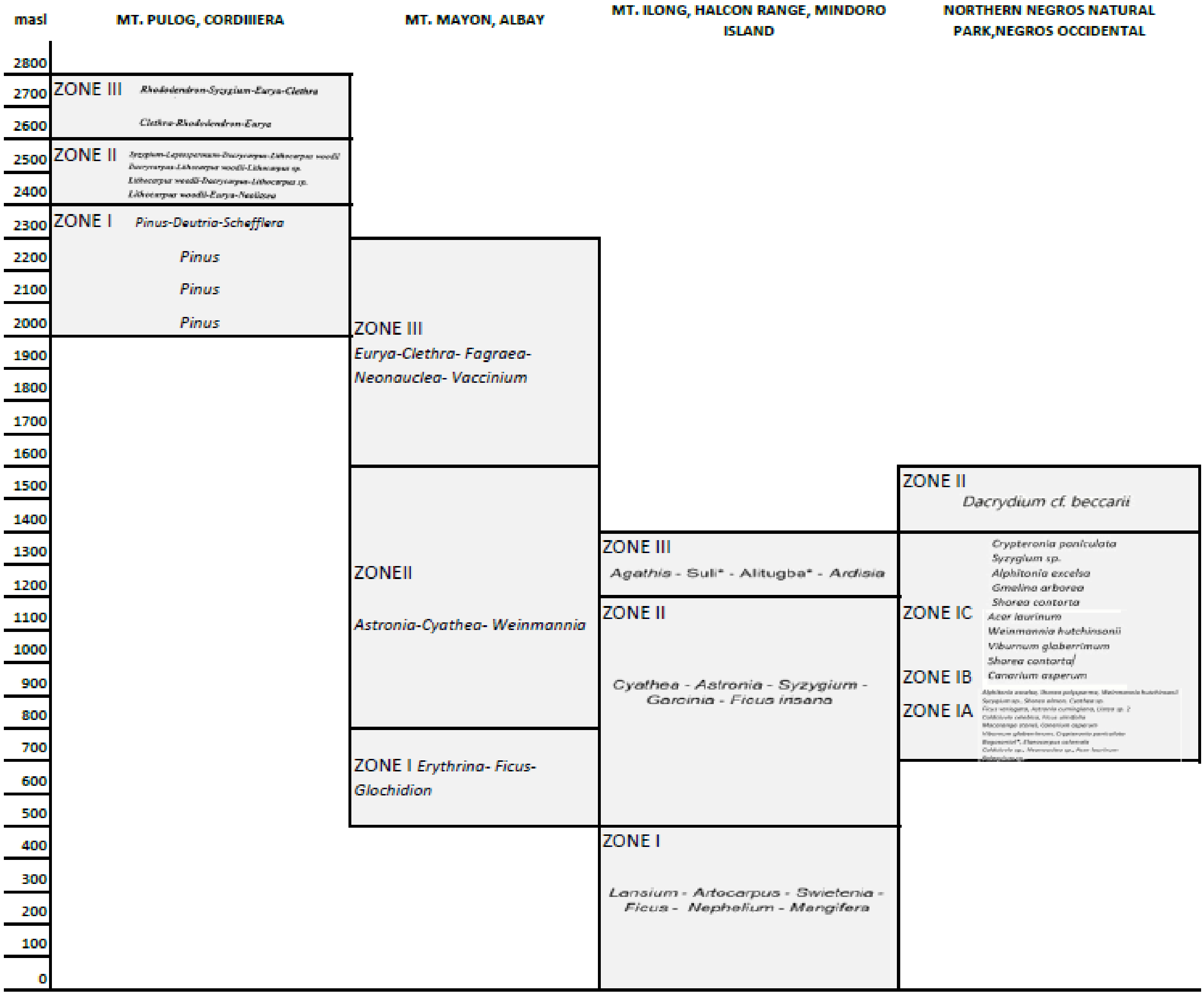
Table 10. Zone IC species composition in the various sampling sites. Relative basal area (RBA in %) derived from diameter-at-breast height (DBH) values

Sampling site	T1Q6	T2Q8	T2Q5	T2Q6	T1Q7	T3Q4	T1Q9
Altitude (m asl.)	822	918	935	937	993	1131	1182
Altitudinal zonation	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane	Lower montane
Latitude	10.685000°	10.787517°	10.789817°	10.790815°	10.682000°	10.780904°	10.674988°
Longitude	123.185000°	123.203650°	123.201133°	123.202807°	123.185000°	123.208954°	123.187725°
Slope (degrees)	36.2	0.357	-0.215	-0.131	-0.1115	0.383	0.446
Plot Size (sq m)	20	20	20	20	20	20	20
Number of species	21	21	29	22	17	21	26
Maximum DBH (cm)	37	43	47.7	35	56	39.2	103.4
Maximum height (m)	12	13	20	12	14	11	11
Proximity to human disturbances (m)	1024	2086	2256	2207	2680	3039	3206
	RBA	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**
Aceraceae							
Acer laurinum	0.092	0.286	3.396	0.525			
Actinidiaceae							
Saurauia panayensis		0.703	0.176	6.164		0.134	
Annonaceae							
Miliusa vidalii	0.147						
Aquifoliaceae							
Ilex cf. crenata		0.277					
Araucariaceae							
Agathis philippinensis						0.645	
Calophyllaceae							
Calophyllum sp.			0.296			0.103	
Clethraceae							
Clethra sp.		0.232		0.349		0.127	0.215
Cryteroniaceae							
Crypteronia paniculata			0.296	1.298		0.140	4.339
Cunoniaceae							
Caldcluvia sp.						1.131	
Weinmannia cf. lucida						0.347	
Weinmannia hutchinsonii				0.630		3.375	
Cyatheaceae							
Cyathea sp.						0.103	
Dipterocarpaceae							
Parashorea malaanonan							0.199
Shorea contorta			3.759	0.630			
Shorea polysperma	0.176	1.598					
Elaeocarpaceae							
Elaeocarpus calomala				0.191	1.320		0.275
Ericaceae							
Vaccinium sp.		0.379					
Euphorbiaceae							
Cleidion ramosii					0.121		0.154
Homalanthus populneus				0.140			
Macaranga bicolor			0.561	0.176			
Macaranga hispida			0.336				
Macaranga sp.		1.450					
Lauraceae							
Cinnamomum mercadoi				0.081			
Listea sp. 2	1.075						
Litsea cordata	0.368						
Loganiaceae							
Willughbeia volubilis						0.659	
Melastomataceae							
Astronia cumingiana					2.463		
Meliaceae							
Ficus ampelas			0.241				
Ficus nota							0.081
Ficus ulmifolia	0.559						
Ficus variegata	0.357						

Myrtaceae							
Eugenia sp.				0.401			
Syzygium sp. 1		0.092					
Rhamnaceae							
Alphitonia excelsa				0.424			8.332
Rutaceae							
Melicope triphylla	0.357						
Sapindaceae							
Guioa sp.				0.579			
Sapotaceae							
Palaquium sp.					0.569		
Palaquium sp. 2							1.134
Planchonella sp.		0.484					0.154
Theaceae							
Polyspora luzonica				0.121			
Urticaceae							
Leucosyke capitellata	0.345						
Misc.8							2.734
Misc.3			0.296				
Fabaceae sp.		0.431					
Misc.4							
Misc. 1				0.748			

Table 11. Zone II Species composition in the various sampling sites. Relative basal area (RBA in %) derived from diameter-at-breast height (DBH) values

Sampling Site	**PSQ1**	**PSQ2**	**PSQ3**	**PSQ4**
Altitude (m asl.)	1421	1517	1470	1465
Altitudinal Zonation	**lower montane**	**upper montane**	**upper montane**	**upper montane**
Latitude	10°39'56.14"N	10°39'46.06"N	10°39'20.80"N	10°39'29.39"N
Longitude	123°11'3.54"E	123°10'58.73"E	123°10'45.00"	123°10'51.78"E
Slope (degrees)	-0.299	-0.9	0.253	-0.145
Plot Size (sq m)	20	20	20	20
Number of species	24	15	17	16
Maximum DBH (cm)	250	400	132	74
Maximum height (m)	31	40	30	25
Proximity to Human Disturbances (m)	2426	3117	3353	2657
	RBA	**RBA**	**RBA**	**RBA**
Aceraceae				
Acer laurinum	1.320			
Anacardiaceae				
cf. Semecarpus cuneiformis			4.072	
Cunoniaceae				
Caldcluvia celebica	4.778		4.749	3.280
Cyatheaceae				
Cyathea sp.		1.725		18.539
Elaeocarpaceae				
Elaeocarpus calomala		3.421	1.964	
Euphorbiaceae				
Cleidion ramosii	2.470	13.719	1.320	
Homalanthus populneus				2.124
Gesneriaceae				
Cyrtandra cf. incisa				1.810
Lauraceae				
Cinnamomum mercadoi	1.134			
Meliaceae				
Ficus variegata	0.855			6.177
Podocarpaceae				
Dacrydium cf. beccarii	83.984	231.160	16.061	
Primulaceae				
Ardisia sp. 4	0.855			
Rubiaceae				
Neonauclea sp.				2.124
Rutaceae				
Melicope triphylla	4.185			



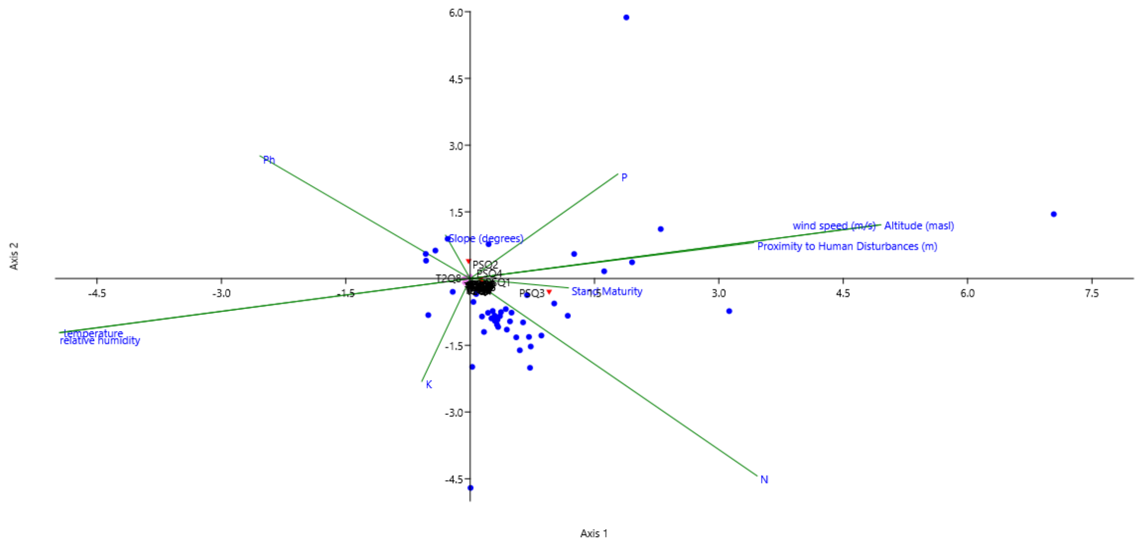


Figure 10. CCA ordination diagram of plant RBA in Northern Negros Natural Park showing sampling plots (lower montane rain forest (♦), upper montane rain forest (▼)) and species (•), which are positioned concerning environmental variables (green lines). The first axis is horizontal; the second axis is vertical. The environmental variables are: altitude: mean elevation, stand maturity: stand maturity, pH: soil pH, N: nitrogen level, P: phosphorus level, K: potassium level, proximity to human disturbance: proximity to human disturbance, temperature, Relative Humidity, and Wind speed. The eigenvalues of axis 1 (CCA1) and axis 2 (CCA2) are 0.0089324 and 0.0052328, respectively. The eigenvalues of axes 3, 4, 5, 6, 7, 8. 9, 10and 11 are 0.0032042, 0.0019103, 0.0013345, 0.00069705, 0.00048241, 0.00035562, 2.51E-14, 8.48E-19, and 3.25E-19 respectively. The most abundant species are: *Dacrydium cf. beccarii*, *Syzygium* sp., *Acer laurinum*, *Cyathea* sp., *Cleidion ramosii*, and *Caldcluvia celebica*

There is an increasing trend in soil nitrogen across a decreasing soil pH. This decrease could indicate the lesser need for immediate conservation to ensure sustainable utilization and management of the forest (Yirga et al. 2019). The increasing value for species abundance can be predicted by the increased soil surface acidity, which was also observed by Li et al. (2021) in their study "Species richness, not abundance, drives ecosystem multifunctionality in a subtropical coniferous forest." The inverse relationship between species abundance and soil surface acidity could also show their influence on the ecosystem's multifunctionality since it negatively correlates to them (Li et al. 2021). The increasing potassium level in soil indicated an increasing species abundance or vice versa. The conspecific negative density dependence of plant species, as the mechanism facilitating species coexistence in plant communities, was determined by major abiotic factors like total soil potassium (Zang et al. 2021) and thus explained their positive correlation.

In conclusion, in the attempt to clarify the floristic composition in NNNP, this study was able to record 242 species representing 72 families, of which 78 were tree species, 90 were herbaceous species, and 37 were epiphytes. Ten species are threatened, and 35 are endemic to the Philippines. Gymnosperms were also observed to have dominated NNNP. That is due to their ability to survive in a disturbed environment. The tropical lower montane rainforest had higher diversity (H'= 4.845) than the upper montane rainforest (H'= 3.37). Both zones' very high relative value rating does not necessarily reflect stand maturity nearing climax species in NNNP but rather a highly disturbed environment with early successional species. The vegetation structure has shown no linear pattern for the proportion of vegetation according to their layer (upper canopy, understory, ground cover, and epiphyte vegetation) along the elevational gradient. Two vegetative elevations were identified: Zone I (643 to 1,256 m asl.), which corresponded with the tropical lower montane rainforest within 600 to 1,300 m asl., and Zone II (1,421 to 1,470 m asl.), corresponded with tropical upper montane rainforest (1,300 to 1,850 m asl.). Environmental factors (N, altitude, and human disturbance) greatly influenced the species' abundance. That means anthropogenic activities influence the species distribution along the elevational gradient in NNNP. Therefore, policies regulating human disturbance in the park should be implemented to manage and conserve plant bioresources inside NNNP effectively.

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