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Vegetation structure of forests over limestone and its influencing environmental factors in Samar Island Natural Park, Philippines

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Abstract. *Villanueva ELC, Obeña RDR, Origenes MG, Buot IE Jr. 2022. Vegetation structure of forests over limestone and its influencing environmental factors in Samar Island Natural Park, Philippines. Biodiversitas 23: 6492-6512.* Samar Island National Park (SINP) forests over limestone, a nominee to the UNESCO World Natural Heritage List, needs a comprehensive study of its vegetation structure as the baseline for monitoring and effective conservation. Thus, an inventory was conducted in SINP inland forests over limestone with the following objectives: 1) to discuss the woody vegetation structure in the forests of SINP, and 2), to determine the environmental factors affecting the characteristic physiognomy and ecology of Paranas and Taft forests. Standard vegetation techniques in a total of eighteen 20m x 20m plots, classification and ordination analyses were conducted. A total of 3,578 tree individuals in 72 species, under 46 genera belonging to 35 families, were recorded from Paranas and Taft. Cluster analysis revealed 3 vegetation clusters named after the dominant species: 1) *Shorea-Manilkara-Walaceodendron* Cluster, 2) *Shorea* and *Dracaena* Cluster, and 3) *Shorea-Manilkara-Hancea* Cluster. Canonical correspondence analysis identified temperature as the most important environmental variable influencing the vegetation of SINP. Other environmental variables, despite their high rate of change and little effect on other species, may have multiple effects and indirect influences on other factors influencing the structure of vegetation in SINP. Thus, the development of appropriate conservation strategies is a must.

Keywords: Cluster analysis, karst forest, limestone, ordination analysis, Paranas, Taft, vegetation dynamics

INTRODUCTION

Forests over limestone are geologically unique forest formations in tropical forests with ages ranging from the Cambrian to the Quaternary (Day & Urich 2000). This formation is quite extensive, particularly in South-East Asia, northern Central America, southeastern Brazil and the Greater Antilles (Tang et al. 2011). The Philippines is one of the countries in the ASEAN region with vast forests over limestone landscapes (Fernando et al. 2008) and Samar Island, the third largest island in the country, has one of the most extensive forests over limestone (Quimio 2016; Tolentino et al. 2020). The unique geology of forests over limestone has afforded a rich biological diversity in this type of forest formation (Clements et al. 2006), thus contributing to the megadiversity status of the Philippines (Mittermeier 1997). Various studies report the uniqueness of the forests over limestone flora and fauna in various localities in the country (Cadiz and Buot 2009, 2010; Caringal et al. 2019, 2020, 2021; Lillo et al. 2019, 2020a, 2020b, 2020c; Malaki et al. 2020a, 2020b). Incidentally, these studies made mention of several species under threat in this forest formation. The *Cinnamomum cebuense* of Mount Cantipla, Mount Tabunan, and Mount Alcoy has been classified as endangered under IUCN (Cadiz and Buot 2009, 2010; Lillo et al. 2019, 2020a, 2020b, 2020c). The *Hancea wenzeliana*, *Cynometra copelandii*, and *Horsfieldia samarensis* are some of the critically endangered species found on Samar Island.

Forests over limestone are important arcs of endemism and speciation; however, there is a dearth in biological data. Dearth in data may be due to its relatively difficult and dangerous (sinkholes are sporadic) general terrain (Brewer et al. 2003), and fewer studies were proposed and conducted except for inventories (Quimio and Patindol 1999; Caringal et al. 2020; Fernandez et al. 2020; Lillo et al. 2020c, Tolentino et al. 2019, 2020; Villanueva et al. 2021a, 2021b; Obeña et al. 2021; Buot et al. 2022; Buot et al. 2022a). Biodiversity assessments conducted in various municipalities of Samar Island reveal that the municipality of Paranas recorded 99 plant species from 63 genera and 44 families (Villanueva et al. 2021a). The municipality of Basey recorded 67 plant species representing 54 genera and 38 families (Villanueva et al. 2021b), and Taft, Eastern Samar, recorded 30 floral species representing 22 genera and 18 families (Obeña et al. 2021). Fernandez et al. (2020) also recorded 41 floral species belonging to 17 families and 24 genera on Calicoan Island in Guiuan, Eastern Samar.

Inventory studies in forests over limestone are critically important since they provide information regarding forest dynamics and sustainable forest management (Tang et al. 2011; Villanueva et al. 2018; Lillo et al. 2019, 2020c). Recent botanical expeditions in Samar Island Natural Park has led to the discovery of new species. Species new to science from Samar Island include *Decaisnina tomentosa*

(Tandang et al. 2022), *Corybas kaiganganianus* (delos Angeles et al. 2022a) and *Begonia normaaguilariae* (delos Angeles et al. 2022b). Unique biota could be answers to current problems related to food and medicine, among others. Equally significant studies regarding vegetation structure (Buot and Okitsu 1998, 1999; Chanthavong and Buot 2017; Santiago and Buot 2018; Villanueva and Buot 2018; Caringal et al. 2019) and the environmental factors affecting such characteristic structure in forests over limestone should be explored. Data sets will help understand environmental variables affecting vegetation structure hence, enhancing a better understanding of the dynamics of the landscape.

It is on this premise that this study was conducted in SINP inland forests over limestone. Firstly, the paper discusses the woody vegetation structure in the Paranas and Taft forests of the SINP. Secondly, it predicts the environmental factors affecting the characteristic physiognomy and ecology of the Paranas and Taft forests using ordination analysis.

MATERIALS AND METHODS

Study area

Samar Island Natural Park is the Philippines' largest terrestrial protected area, with 333,300 hectares of the protected area and 125,400 hectares of the buffer zone (UNDP-GEF 2014). The park was designated as a forest reserve in 1996, but it was upgraded to the status of a natural park in 2003 by Presidential Proclamation No. 442 in accordance with Republic Act No. 7586 (NIPAS Act of 1992). SINP has an interior highland with distinct accordant peaks and a surrounding limestone or karst terrain. The southern part of SINP is characterized by jungle-covered limestone ridges. Its geology is predominantly Miocene and Holocene, with sedimentary formations composed of basement rocks and overlying clastic rocks or limestone (Patindol 2016). The study focused on the forests in the municipalities of Paranas and Taft in Samar Island, the third largest island of the Philippines (NAMRIA 2013) (Figure 1). It is located along with the islands of Biliran and Leyte, in Region VIII, the Eastern Visayas Region of the Philippines, with the geographic coordinates of 11°48'50.96'' N 125°09'40.22'' E.

Samar Island is divided into two regions and weather types under Modified Coronas Climate Classification. Type II, with no dry season and a very pronounced rainy period, occurs on the Northeastern part of the island. Type IV is the climate type of the southeastern region, with rainfall distributed evenly throughout the year. The island is frequently visited by strong typhoons and people in the locality are always at a disadvantage. Hence, ecosystems must be stabilized to sustain ecosystem services for human communities and villages.

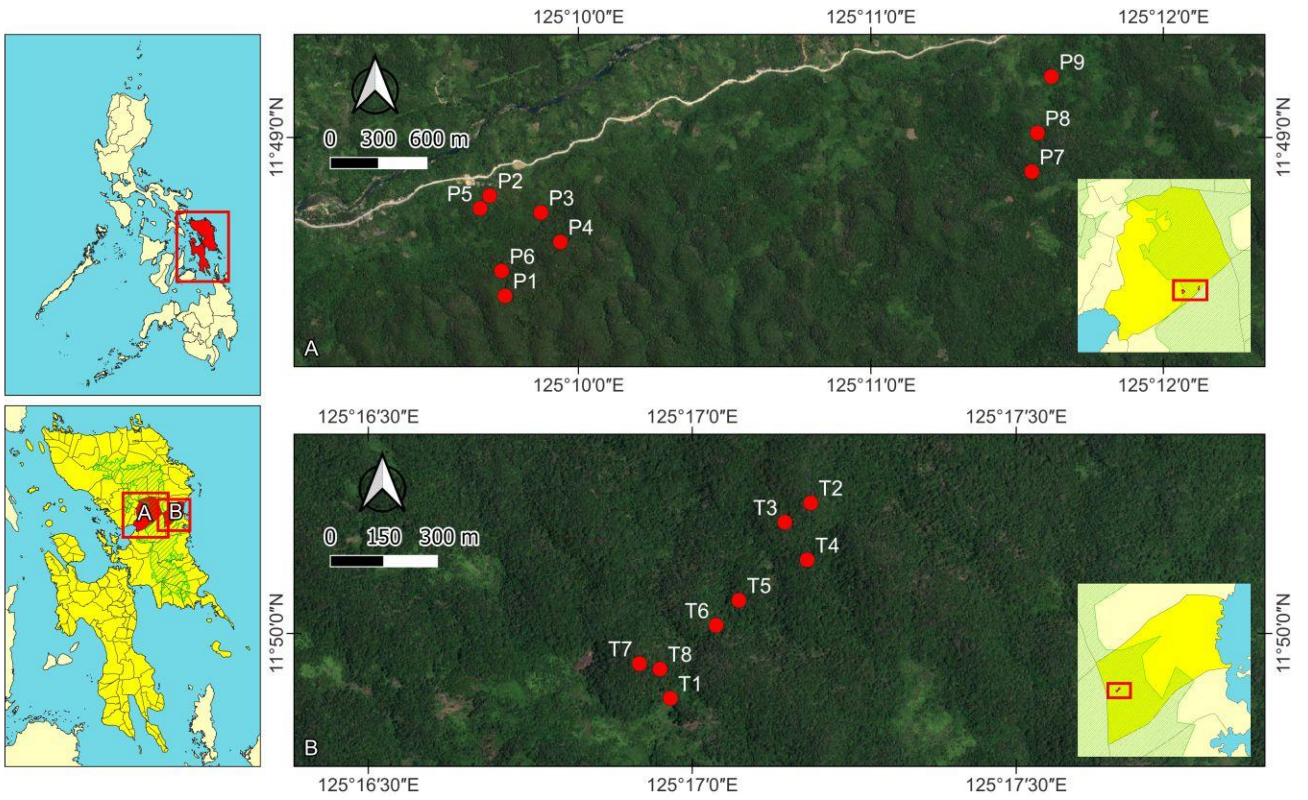


Figure 1. Location of the study sites at Samar Island Natural Park, Samar Island, Philippines. a) Map shows the location of Paranas and Taft in Samar Island, Philippines, and b) the two maps on the right show the positions of the sampling sites in the two selected municipalities, Paranas on top and Taft on the bottom. Maps were generated using QGIS version 3.4.15

Floral assessment

To assess the floral diversity, fieldwork was conducted in the municipalities of Paranas and Taft of Samar Island, Philippines. The selection of the sampling plots was based on the biophysical features of the area, including biota heterogeneity, topography, elevation, and the presence of human disturbances. Nine 20 m x 20 m plots were established in each municipality to assess the tree species (≥1m tall) for vegetation analysis.

The recorded information on trees included: (1) local name, (2) circumference of trees at breast height, (3) height of the tree, and (4) canopy cover. The circumference of the tree at breast height and the canopy cover were measured using a measuring tape, while the height was visually estimated after thorough practice and numerous comparisons with the measurements using a tree height meter at the periphery of the forest. This was done since it was extremely difficult to do height measurements inside the forests over limestone due to either steep topography or sharp outcrops or both. The coordinates and elevation of sampling plots were taken using the Garmin Montana 680 Global Positioning System (GPS). Within each plot, two 5-meter transects were established to assess the understory species. These transects were subdivided into 1-meter intervals. The height and cover of the understory species were measured using a tape measure.

Collection and Identification

Plant samples were collected, pressed, cured, and mounted as herbarium vouchers. These vouchers, including photographs of the fresh samples, were used to identify the plants in the sampling plots. Relevant literature such as the *Enumeration of the Philippine Flowering Plants* (Merrill 1923-1926), *Co's Digital Flora of the Philippines* (Pelser et al. 2011-onwards) and the latest botanical assessment in SINP (Quimio 2016) was used in identifying plants. The scientific names were validated in the International Plant Name Index (IPNI) and the classification follows that of the Angiosperm Phylogeny Group IV (APG IV) and Pteridophyte Phylogeny Group (PPG) classification. The voucher specimens were deposited at the Plant Biology Division Herbarium (PBDH) of the University of the Philippines Los Baños, Laguna and the Philippine National Herbarium (PNH), National Museum, Manila.

Vegetation analysis

The dominant tree species in the area were determined by obtaining the relative basal area (RBA), relative density (RD), and relative frequency (RF) using the formula adapted from Mueller-Dombois and Ellenberg (1974). Species diversity of each identified zone was also investigated. Shannon-Wiener index, Simpson's diversity index, and Fisher's alpha were all computed and graphed.

Dominance analysis

The dominant tree species were identified using dominance analysis (Ohsawa 1984) having the following equation:

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

Where d is the deviation between the actual relative density values and the expected share of the corresponding co-dominant-number model, N is the total number of species, x_i is the actual percent share (relative density) of the top species T, $\bar{x}$ is the ideal percent share based on the model, and x_i is the percent share of the remaining species U.

The equation assumes that the ideal dominance ("the expected share') of a single species is 100%, 50% if it is shared by two co-dominants, 33.3% for three co-dominants, and so on. Consequently, the number of dominant species is determined by the one that showed the least deviation value.

Cluster analysis

To identify the major plant communities in the *kaigangan* of Paranas and Taft, cluster analysis was done using the relative density of trees per plot. Jaccard index was calculated from the dataset using Paleontological Statistics (PAST) Software version 4.03 (Hammer 2001). A dendrogram was then constructed using the unweighted pair-group method with an arithmetic mean (UPGMA) algorithm.

Soil sampling

In each sampling plot, three replicates of soil samples weighing 1 kg, were collected. These samples were homogenized per plot and sent to the Analytical Services Laboratory of the Agricultural Systems Institute, College of Agriculture and Food Science (ASI-CAFS), of the University of the Philippines Los Baños (UPLB), for soil analysis.

Canonical Correspondence Analysis

To analyze the interaction between the tree species and environmental variables, Canonical Correspondence Analysis (CCA) was used for ordination. Environmental parameters such as rainfall, temperature, elevation, quantitative edaphic variables, and presence of anthropogenic disturbance were subjected to analysis along with the woody vegetation data per plot. A CCA ordination diagram was generated using the vegan package in R 4.1.1.

Gathering climate data

The climate data of Samar Island was requested from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Information on monthly temperature and rainfall data came from four weather stations of PAGASA. These weather stations were selected as these are the nearest weather stations to each study site of the project. For the weather stations of Guiuan, Catbalogan, and Tacloban City, 30-year climate data was obtained, while for Borongan weather station, climate data for the last 17 years was available.

From these data, climograph (Walter-Lieth diagrams) were generated using the climatol package (Guijarro 2019) through R version 3.6.1 (R Core Team 2019). The weather patterns are relatively similar among the four weather stations.

RESULTS AND DISCUSSION

Woody vegetation composition in Samar Island Natural Park

A total of 3,578 tree individuals of 72 species, under 46 genera in 35 families, were found in the sampling plots of Paranas and Taft in Samar Island Natural Park with respective coordinates and other plot characteristics indicated (Tables 1 and 2). Most represented families are Arecaceae (5 spp.), Dipterocarpaceae (5 spp.), Euphorbiaceae (5 spp.), and Sapotaceae (4 spp.) among the angiosperms and Tectariaceae among the ferns. This result differs from other forests over limestone in the country. In the forests over limestone of Nug-as forest Key Biodiversity Area in Alcoy, the southern part of Cebu Island, families Euphorbiaceae, Lauraceae, Moraceae, Clusiaceae, Myrtaceae, Meliaceae, Fabaceae, and Rutaceae were observed (Lillo et al. 2020c). In Lobo (Batangas, Luzon Island, Philippines) forests over limestone, common families include Fabaceae, Malvaceae, Lamiaceae, Apocynaceae, Euphorbiaceae, Moraceae, Asteraceae, Malvaceae, Poaceae and Rubiaceae. Various environmental factors unique to each locality influenced the occurrences of diverse species in different families in various forests over limestone in the Philippines.

Based on the relative basal area value, the dominant tree species in Paranas plots were *Shorea astylosa* Foxw. (Plot no. 1), *Hancea wenzeliana* (Slik) S.E.C. Sierra, Kulju & Welzen (Plot no. 2), *Manilkara fasciculata* (Warb.) H.J.Lam & Maas Geest. (Plot nos. 3, 4 and 5), and *Shorea negrosensis* Foxw. (Plot nos. 5, 6, 8, and 9) (Table 1). The dominant tree species in Taft plot were the *Hancea wenzeliana* (Slik) S.E.C. Sierra, Kulju & Welzen (Plot no.10), *Shorea astylosa* Foxw. (Plot nos.11, 13, 15 and 17), *Shorea negrosensis* Foxw. (Plot nos.12, 14, and 18), and *Dracaena angustifolia* (Medik.) Roxb. (Plot no.16) (Table 2). Additionally, *Shorea* species from the Dipterocarpaceae family dominate in Paranas and Taft. This is consistent with DENR's (2016) and Salvaña et al. (2019) observation that dipterocarp assemblages dominate lower montane forests in Southeast Asia.

Structural characteristics in Samar Island Natural Park

The structural characteristics of the sampling plots from the municipalities of Paranas and Taft, Samar Island, are illustrated in Figure 2. The graphs portray changes in the number of species, individuals, Shannon-Wiener Diversity Index, Simpson Index, and Fisher's Alpha along various elevation gradients. Among all plots in Paranas, the plot with the highest number of species was observed in Plot no.1 (368-385 masl) with 28 species. The plot with the highest number of tree individuals was recorded in Plot no.7 (311-315 masl), which had 244 tree individuals. Plot no. 2 (172-175 masl) was found to be the most diverse (H'=2.69), with 26 tree species and 220 tree individuals. Plot no. 8 had the highest maximum DBH, measuring 130.83 cm for the *M. fasciculata* species. Plot no. 4 (342-349 masl) had the highest maximum height value for the species *S. astylosa* (35 m).

On the other hand, among all the nine plots in Taft (Figure 2), the highest number of tree species was recorded in Plot no.16 (11 species), while the highest number of tree individuals was observed in Plot no.11 (255 individuals). The most diverse plot was Plot no.10 (174-186 masl) (H'=1.613), followed by Plot no.16 (H'=1.495). *Shorea astylosa* in Plot No. 11 (271-273 masl) had the highest maximum height (29 m), while *D. angustifolia* in Plot No. 16 (276-279 masl) had the highest DBH (141.3297 cm). Plots from Paranas have a higher species richness, Shannon, and Simpson 1-D values, whereas the plots from Taft have a higher number of individuals. This implies that species in Paranas are more diverse and abundant than species in Taft. Species diversity using Simpson (1-D) and Shannon Index (H') showed significantly higher values at lower elevations in Plot 2 (172-175 masl) in Paranas and Plot 10 (174-186 masl) in Taft. These were followed by varying values at different elevations. Fisher's alpha in Plots no. 1, 2, and 3, had significantly higher values, while Taft plots had lower values (Figure 2).

It was observed that the highest number of species (Plots 1 and 16) and highest diversity (Plots 2 and 10) in various elevational gradients were in contrast to the study of Sopsop and Buot (2013), which reported that plots with the highest number of species, were highest in species diversity as well. This implies that not all of the most diverse plots or sites have the greatest number of species due to a variety of factors, such as human activity, including agricultural expansion (Newbold et al. 2015; IPCC 2019). Anthropogenic disturbances, as well as other factors, have played a role in modifying vegetation in the Philippines' tropical forests (Sopsop and Buot 2013). This resulted in observable changes in the number of species and individuals along different elevational gradients across most of the mountains in the country (Villanueva and Buot 2018). These may be applicable to this study, as it was noticed that the number of species, number of individuals, Simpson values, Shannon, and Fisher's alpha, vary in each plot in Paranas and Taft. As a result, the findings of this study could be attributed to the fact that the fluctuation in the number of species is highly dependent on various environmental factors like human and natural disturbances (see Table 3). According to Casas and Baguinon (2008), the number of tree species in Samar Island Forest Reserve was lowest in areas with human activities. Tree species that are not resistant to strong winds, on the other hand, fell, resulting in a change in species diversity (Li et al. 2021). Initial field observations indicated a more shallow soil layer in many plots in Paranas, compared with that of Taft. In other words, the limestones in Paranas are much younger than that of Taft. Hence, Taft has a deeper soil layer and is more favorable to the growth and development of plants.

Table 1. Species composition and the respective relative basal area (RBA) values in various sampling plots of Paranas, Samar Island. Relative basal area (RBA) in % was derived from diameter at breast height (DBH) values

Plot	**Exsiccata**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Plot size		**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**
Coordinates		**125° 9' 44.92" E 11° 48' 27.47" N**	**125° 9' 41.79" E 11° 48' 48.04" N**	**125° 9' 52.29" E 11° 48' 44.58" N**	**125° 9' 56.28" E 11° 48' 38.53" N**	**125° 9' 39.82" E 11° 48' 45.45" N**	**125° 9' 44.23" E 11° 48' 32.6" N**	**125° 11'33.03" E 11° 48' 52.98" N**	**125°11'34. 16" E 11°49'0. 93" N**	**125° 11' 37.05" E 11° 49' 12.49" N**
Total BA (m^2)		**2.5760**	**1.3933**	**2.4005**	**1.7581**	**1.63683**	**2.1507**	**1.9135**	**3.9076**	**1.7849**
Total number of individuals		**194**	**220**	**145**	**191**	**190**	**185**	**244**	**146**	**181**
Total species number minus dead tree		**28**	**26**	**23**	**16**	**15**	**14**	**11**	**7**	**7**
		RBA %	**RBA %**	**RBA %**	**RBA %**	**RBA %**	**RBA %**	**RBA %**	**RBA %**	**RBA %**
ARALIACEAE										
Polyscias nodosa (Blume) Seem.	Obeña 7112 (PBDH)	-	2.03	-	-	-	-	-	-	-
ARECACEAE										
Caryota cumingii Lodd. ex Mart.		0.08	0.23	-	-	-	-	-	-	-
Caryota rumphiana Mart.	Obeña 7133 (PBDH)	0.07		0.03	-	-	-	-	-	-
Heterospathe intermedia (Becc.) Fernando	Obeña 7107 (PBDH)	0.51	7.24	2.61	0.97	0.81	2.17	4.5	0.3	0.1
Oncosperma tigillarium (Jack) Ridl.		0.23	-	0.04	-	-	-	-	-	-
BURSERACEAE										
Canarium hirsutum Willd.	Obeña 7125 (PBDH)	-	0.25	0.25	-	-	-	-	-	-
CASUARINACEAE										
Gymnostoma rumphianum (Miq.) L.A.S.Johnson	Obeña 7099 (PBDH)	-	-	-	1.22	-	-	-	-	-
CLUSIACEAE										
Calophyllum soulattri Burm.f.	Obeña 7128 (PBDH)	10.81	11.89	0.71	2.98	0.35	0.11	0.42	0	0.53
Garcinia rubra Merr.	Obeña 7115 (PBDH)	-	0.87	-	-	-	-	-	-	-
Garcinia sp.	Obeña 7145 (PBDH)	0.02	0.54	-	0.004	-	-	-	-	-
CORNACEAE										
Mastixia sp.	Obeña 7148 (PBDH)	0.04	-	0.05	0.35	-	0.35	-	-	-
DIPTEROCARPACEAE										
Hopea philippinensis Dyer	Obeña 7116 (PBDH)	1.47	0.12	8.61	5.42	21.21	7.81	-	-	-
Shorea astylosa Foxw.	Obeña 7151 (PBDH)	38.89	0.03	0.04	26.05	25.98	20.18	30.85	15.7	32.82
Shorea contorta S.Vidal		0.05	-	-	-	-	0.04	-	-	-
Shorea negrosensis Foxw.	Obeña 7122 (PBDH)	24.4	5.53	24.06	18.95	38.2	61.51	12.85	44.26	42.5
Vatica mangachapoi Blanco	Obeña 7113 (PBDH)	-	7.55	-	-	-	-	-	-	-
EBENACEAE										
Diospyros blancoi A.DC. *syn.: D. discolor Willd.*	Obeña 7119 (PBDH)	0.52	-	-	-	-	-	-	-	-
EUPHORBIACEAE										
Codiaeum macgregorii Merr.		-	0.82	-	-	-	-	-	-	-
Codiaeum sp.	Obeña 7144 (PBDH)	0.005	0.81	-	-	-	-	-	-	-
Hancea wenzeliana (Slik) S.E.C. Sierra, Kulju & Welzen	Obeña 7103 (PBDH)	3.37	21.11	11.38	9.77	9.23	1.21	11.62	4.24	23.42
Macaranga bicolor Müll.Arg.	Obeña 7102 (PBDH)	0.01	-	0.19	-	-	-	-	-	-
Tritaxis ixoroides (C.B.Rob.) R.Y.Yu & Welzen		-	0.55	-	-	-	-	-	-	-

FABACEAE										
Wallaceodendron celebicum Koord.	Obeña 7108 (PBDH)	-	1.34	12.35	2.91	1.97	1.41	0.11	-	-
LAMIACEAE										
Vitex turczaninowii Merr.	Obeña 7120 (PBDH)	-	-	0.04	-	-	-	-	-	-
MALVACEAE										
Kleinhovia hospita L.		-	-	-	0.05	0.08	-	-	-	-
MELIACEAE										
Aglaia rimosa (Blanco) Merr.	Obeña 7143 (PBDH)	0.16	4.18	0.03	-	-	-	-	-	-
MORACEAE										
Artocarpus rubrovenius Warb.	Obeña 7147 (PBDH)	0	7.02	0.19	0.01	0	0.24	0.08	0.12	-
Ficus ampelas Burm.f.	Obeña 7121 (PBDH)	-	-	-	0.02	-	-	0.96	-	-
Ficus glandulifera var. *camiguinensis*		-	13.47	0.42	-	-	-	-	-	-
PANDANACEAE										
Benstonea copelandii (Merr.) Callm. & Buerki *syn. Pandanus copelandii* Merr.		0.87	-	0.58	-	-	0.4	3.61	-	-
PHYLLANTHACEAE										
Bridelia glauca Blume	Obeña 7102 (PBDH)	-	3.37	-	-	0.11	0.59	-	-	-
RUBIACEAE										
Neonauclea formicaria (Elmer) Merr.	Obeña 7045 (PBDH)	-	6.42	2.61	1.49	0.73	0.95	3.26	-	-
Psychotria sp.		0.06	0.26	-	-	-	-	-	-	-
SALICACEAE										
Flacourtia sp.		0.7	-	-	-	-	-	-	-	-
SAPOTACEAE										
Manilkara fasciculata (Warb.) H.J.Lam & Maas Geest.	Obeña 7129 (PBDH)	0.09	0.07	34.25	28.87	0.06	3	31.74	35.38	0.62
Palaquium elongatum		0.01	-	-	-	-	-	-	-	-
Pouteria velutina Elmer	Obeña 7149 (PBDH)	0.02	1.01	0.02	-	0.01	-	-	-	-
Palaquium sp. (1)	Obeña 7105 (PBDH)	-	1.49	0.21	-	0.62	-	-	-	0.01
THYMELAEACEAE										
Aquilaria cumingiana (Decne.) Ridl.	Obeña 7098 (PBDH)	0.09	-	-	-	-	-	-	-	-
Gonystylus reticulatus (Elmer) Merr.		0.19	-	-	-	-	-	-	-	-
URTICACEAE										
Oreocnide rubescens (Blume) Miq.	Obeña 7123 (PBDH)	0.05	-	1.32	0.94	-	-	-	-	-
Unid (Barit)	Obeña 7109 (PBDH)	16.48	-	-	-	-	-	-	-	-
Unid (Buskayan)	Obeña 7114 (PBDH)	-	1.8	-	-	0.63	-	-	-	-
Unid (Sumol)	Obeña 7146 (PBDH)	-	-	0.03	-	-	-	-	-	-
Unid (Urukay)	Obeña 7150 (PBDH)	0.8	-	-	-	-	-	-	-	-
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 2. Species composition and the respective relative basal area (RBA) values in various sampling plots in Taft, Eastern Samar. Relative basal area (RBA) in % was derived from diameter at breast height (DBH) values

Plot	**Exsiccata**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Plot size		**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**	**20 x 20**
Coordinates		125° 16' 57.98" E 11° 49' 53.98" N	125° 17' 10.98" E 11° 50' 12.09" N	125° 17' 8.57" E 11° 50' 10.3" N	125° 17' 10.65" E 11° 50' 6.81" N	125° 17' 4.32" E 11° 50' 3.06" N	125° 17' 2.21" E 11° 50' 0.75" N	125° 16' 55.11" E 11° 49' 57.19" N	125° 16' 57.01" E 11° 49' 56.69" N
Total BA (m^2)		**0.8203**	**5.2620**	**3.2748**	**3.3651**	**2.4733**	**2.0302**	**3.3900**	**3.6272**
Total number of individuals		**167**	**255**	**219**	**208**	**205**	**150**	**229**	**252**
Total species number minus dead tree		**10**	**10**	**7**	**10**	**5**	**6**	**11**	**7**
		RBA%	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**	**RBA%**
ARECACEAE									
Heterospathe intermedia (Becc.) Fernando	Obeña 7043 (PBDH)	12.127	0.879	1.099	1.206	9.642	1.353	1.308	0.610
ASPARAGACEAE									
Dracaena angustifolia (Medik.) Roxb.	Obeña 7065 (PBDH	-	-	-	-	-	-	46.513	-
CLUSIACEAE									
Calophyllum soulattri Burm.f.		0.86	0.022	0.000	0.522	0.000	0.120	0.602	0.011
CYCADACEAE									
Cycas riuminiana Regel	Obeña 7056 (PBDH)	-	-	-	-	-	-	0.288	-
DIPTEROCARPACEAE									
Hopea philippinensis Dyer	Obeña 7116 (PBDH)	1.328	-	-	-	0.005	-	-	-
Shorea astylosa Foxw.	Obeña 7151 (PBDH)	2.254	79.504	24.645	50.918	29.659	39.491	21.487	57.051
Shorea negrosensis Foxw.	Obeña 7047 (PBDH)	27.852	18.904	54.404	26.614	52.908	32.253	25.500	27.934
EBENACEAE									
Diospyros blancoi A.DC. syn. *D. discolor* Willd.	Obeña 7119 (PBDH)	-	-	-	0.019	-	-	-	-
EUPHORBIACEAE									
Codiaeum macgregorii Merr.		-	-	-	-	-	-	0.004	-
Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	Obeña 7041 (PBDH)	45.716	0.329	19.776	14.629	7.786	20.434	2.665	12.200
FABACEAE									
Wallaceodendron celebicum Koord.	Obeña 7044 (PBDH)	-	0.015	-	-	-	-	-	-
GNETACEAE									
Gnetum gnemon L.	Obeña 7073 (PBDH)	-	-	0.016	-	-	-	-	-
MELIACEAE									
Vavaea amicorum Benth.	Obeña 7155 (PBDH)	-	0.022	-	-	-	-	-	-
MORACEAE									
Artocarpus rubrovenius Warb.	Obeña 7147 (PBDH)	0.190	-	-	-	-	-	-	-
PANDANACEAE									
Benstonea copelandii (Merr.) Callm. & Buerki syn. *Pandanus copelandii* Merr.		6.873	0.030	0.024	0.019	-	-	-	0.122
RUBIACEAE									
Lasianthus trichophlebus Hemsl. ex F.B.Forbes & Hemsl.	Obeña 7049 (PBDH)	-	0.007	-	-	-	-	-	-
Neonauclea formicaria (Elmer) Merr.	Obeña 7045 (PBDH)	2.788	-	-	0.776	-	-	0.114	-
SAPOTACEAE									
Manilkara fasciculata (Warb.) H.J.Lam & Maas Geest.	Obeña 7129 (PBDH)	0.009	0.288	0.036	3.355	0.000	6.350	0.019	2.073
Palaquium sp. (1)	Obeña 7105 (PBDH)	-	-	-	1.941	-	-	1.50	-
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 3. Environmental variables used in assessing the tree species-environment relationship in the forests over limestone of SINP

Plot	pH	OM %	N %	P mg/kg (olsen)	EC uS/cm	K	Na	Ca	Mg	Fe	Zn	Cu	Mn	Cl	Elevation	Rainfall (mm)	Temperature (°C)	Disturbance
PAR01	6.4	3.12	0.47	5.5	154	0.17	0.67	11.58	1.05	9.99	1.36	82.53	88.42	161	378.29	3034	25.96	-
PAR02	6.3	12.15	0.58	7.3	0.207	0.26	0.98	16.38	2.06	21.41	0.75	29.32	30.59	806	173.68	3034	27.19	+
PAR03	7	37.97	0.74	12.9	507	0.3	1.46	28.38	3.33	5.96	2.1	6.76	5.94	698	243.45	3034	26.77	-
PAR04	7.4	6.86	0.27	5.3	118	0.03	0.67	10.33	1.2	4.27	0.28	15.26	15.73	376	243.45	3034	26.77	-
PAR05	6.7	5.87	0.3	7.9	329	0.1	0.36	7.32	1.68	7.87	0.48	58.69	63.56	322	198.39	3034	27.04	+
PAR06	6.7	6.28	0.32	7.6	346	0.1	0.36	7.8	2.6	21.24	0.07	24.26	25.9	376	318.63	3034	26.32	-
PAR07	6.3	11.81	0.44	11	273	0.13	0.91	13.3	0.13	34.78	0.18	34.52	37.38	537	313.10	3034	26.35	-
PAR08	7.6	10.73	0.63	12.3	460	0.12	1.18	18.27	0.79	2.86	0.24	8.5	7.99	537	253.60	3034	26.71	+
PAR09	7.1	10.66	0.56	12.2	49	0.16	0.8	16.72	1.98	10.31	1.32	36.34	39.18	322	238.76	3034	26.80	-
TAF10	7.1	16.35	0.63	11.7	523	0.52	1.04	23.42	4.24	31.84	1.26	8.22	7.67	483	181.07	4682	26.13	+
TAF11	7	16.35	0.63	11.7	523	0.1	0.6	7.71	1.08	4.94	0	27.44	29.41	376	272.41	4682	25.58	-
TAF12	6.3	4.66	0.38	12.4	370	0.12	0.64	7.7	1.34	19.81	1.57	96.22	101.78	376	249.79	4682	25.72	-
TAF13	5.9	9.05	0.36	5.9	469	0.26	0.58	7.8	1.47	46.98	0.42	78.69	84.9	376	221.14	4682	25.89	-
TAF14	4.9	12.81	0.58	7.5	204	0.2	0.42	2.95	1.12	436.94	2.33	15.73	17.34	483	223.12	4682	25.88	-
TAF15	6.1	8.87	0.37	9.4	535	0.15	0.67	9.13	0.56	22.89	0.47	96.42	101.85	430	211.55	4682	25.95	+
TAF16	6.8	7.62	0.49	19.7	0.262	0.2	1.27	14.06	1.25	33.88	0.56	36.61	39.77	376	277.70	4682	25.55	-
TAF17	6	6.09	0.24	6.2	127	0.1	0.44	5.71	1.3	43.36	0	56.75	61.68	591	256.66	4682	25.68	-
TAF18	6.3	4.7	0.52	12.3	110	0.2	0.71	11.31	0.59	18.09	2.37	81.39	86.37	322	215.81	4682	25.92	-

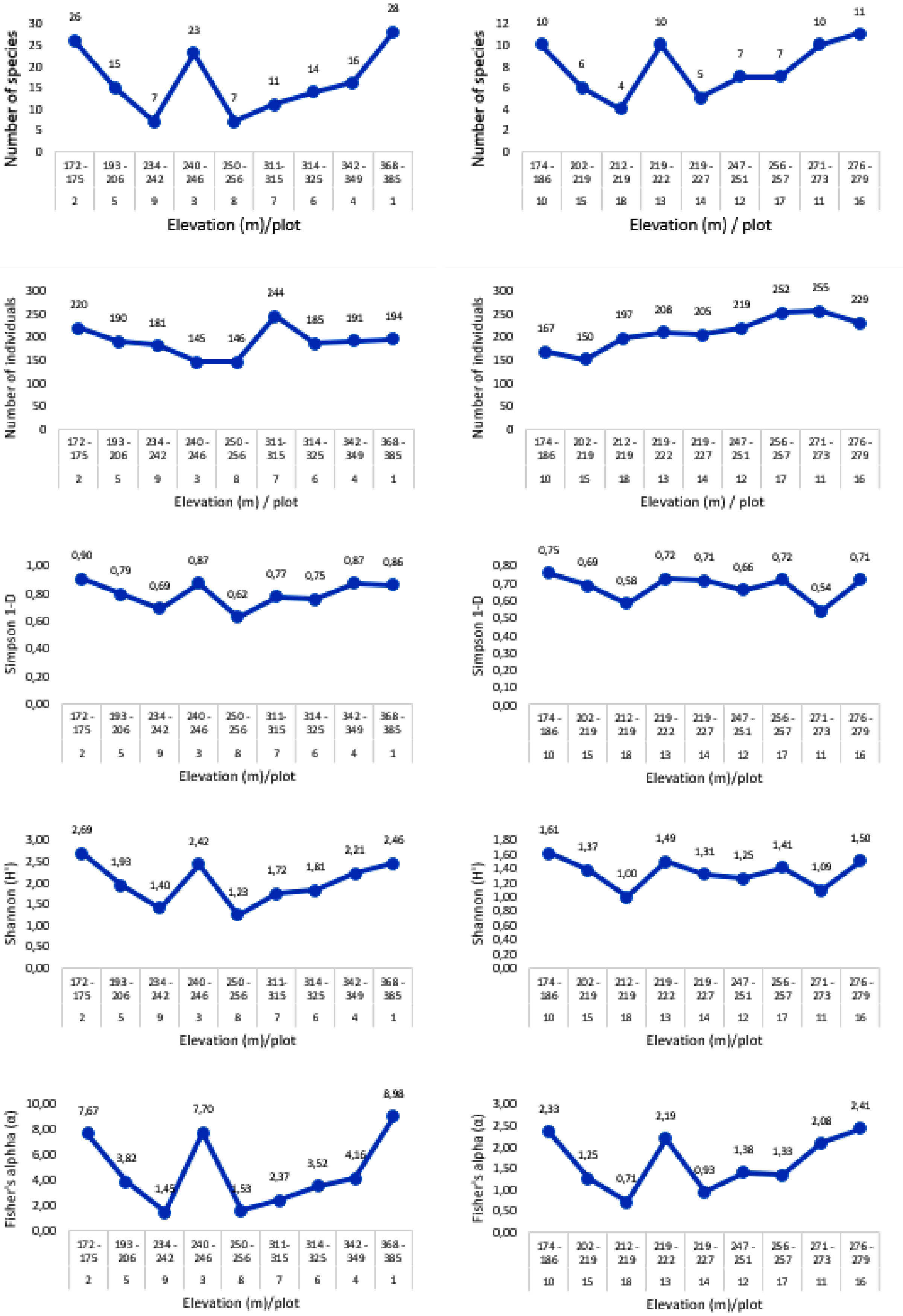


Figure 2. Structural characteristics of the sampling plots from Paranas (left column) and Taft (right column), Samar Island, Philippines: a) number of species, b) number of individuals, c) Simpson Index (1-D), d) Shannon Index (H'), and e) Fisher's alpha (α)

Clusters of vegetation in the forests over limestone of SINP

To identify the plant communities in SINP, a cluster analysis of woody plants was done using the relative density per plot (Figure 6). The resulting cluster analysis was measured using the Jaccard similarity index, and the dendrogram was created using the UPGMA algorithm in Paleontological Statistics (PAST) Software (Hammer 2001). At a similarity index of around 0.55, three clusters of vegetation are delineated forming Clusters I, II, and III. In this paper, clusters of vegetation are named after the dominant species.

Cluster I: *Shorea-Manilkara-Hancea-Calophyllum-Barit-Wallaceodendron* cluster

Cluster I (Figure 3) has a number of dominants based on the calculation suggested by Ohsawa (1984). It includes *S. negrosensis, S. astylosa, M. fasciculata, H. wenzeliana, C. soulattri,* Barit (unidentified species), and *Wallaceodendron celebicum.* The first cluster, with a similarity index of around 0.55, was formed by Plots PAR01 (368-385 masl), PAR02 (172-175 masl), and PAR03 (240-246 masl) from Paranas. These elevations are situated in low, mid, and highest elevations in Paranas plots. This cluster also has the highest diversity values, as shown in Figure 2, and has the greatest number of co-dominant species. Based on RBA, *S. astylosa, H. wenzeliana* and *M. fasciculata* are the dominant species. In terms of relative density, the dominant species are *C. soulattri*, *H. wenzeliana*, *S. negrosensis*, *S. astylosa*, *M. fasciculata*, *Aglaia rimosa*, *Heterospathe intermedia,* and *Neonauclea formicaria*, respectively. The highest DBH in this cluster was 78.94cm (*S. negrosensis* and *S. astylosa*) and the lowest DBH was 60.48 cm (*W. celebicum* and *M. fasciculata*). The maximum height was 30m (Barit) and the lowest was 25m (*M. fasciculata* and *S. negrosensis*). This cluster also has the least number of individuals per hectare (4,658.33). *Calophyllum soulattri* is the most numerous in this cluster. Incidentally, Ridley (1930) noted that this species is often dispersed by birds, monkeys, and bats. It is primarily found in the lowland rainforests of Southeast Asia (Ashton 1988). Additionally, *C. soulattri* is edible and used for housing, construction, and boat materials.

Cluster II: *Shorea-Dracaena* cluster

Cluster II (Figure 4) has a fewer number of dominants compared with Cluster I. These dominating species which tend to control the structure and dynamics of the zone are *S. astylosa, S. negrosensis,* and *D. angustifolia.* The second cluster is delineated at around a similarity index of 0.63, which is a huge cluster composed of 10 plots from Paranas (PAR08 and PAR09), with elevations ranging from 234-256 masl, and Taft (TAF11, TAF12, TAF13, TAF14, TAF15, TAF16, TAF17, and TAF18), with elevations ranging from 202-279 masl. Based on relative density, *S. negrosensis, S. astylosa,* and *H. wenzeliana* are the dominant species. This cluster also has the highest DBH value, with 141.33 cm (*D. angustifolia*), and the lowest is 46.15 cm (*S. negrosensis*), basal area at breast height per hectare and the number of individuals per hectare (5,115), indicating less anthropogenic activities in the area. The highest value in terms of height is 29 m (*S. negrosensis)* and the lowest is 17 m (*S. negrosensis* and *M. fasciculata*). Many of the species found in this cluster are *S. negrosensis*.

Cluster III: *Shorea-Manilkara-Hancea* cluster

Cluster III (Figure 5) has four dominant species, namely, *S. negrosensis, S. astylosa, M. fasciculata,* and *H. wenzeliana.* The third cluster has a similarity index of around 0.71 and consists of four plots in Paranas (PAR04, PAR05, PAR06, and PAR07) with elevations ranging from 193-349 masl, and one Taft plot (TAF10) with elevations ranging from 174 - 186 masl. Based on relative density, the dominant species are *S. negrosensis, H. wenzeliana, S. astylosa, M. fasciculata,* and *C. soulattri*, respectively. The maximum DBH value on this cluster is 89.13 cm (*S. negrosensis*) and the lowest is 44.56 cm (*H. wenzeliana)*. The maximum height is 35 m (*S. astylosa*) and the lowest is 15m (*H. wenzeliana*). *Shorea negrosensis* is the numerous species in this cluster and many of the plots were also influenced by human activities, most of which are observed in low elevations area.

Environmental factors in the forests over limestone of SINP

Climatic conditions. Using the assumptions of Sarmiento (1986) on the temperature changes across altitudinal gradients in tropical mountains, the temperature data for each sampling plot used in CCA was extrapolated from 1989 to 2018 in Catbalogan and 2001 to 2018 in Borongan, the nearest PAGASA synoptic stations from Paranas and Taft in Samar Island. The average temperature is 28.8ºC at Catbalogan and 27.2ºC at Borongan. The average annual rainfall records are high at 3034 mm for Catbalogan and 4682 for Borongan (Table 3). The highest rainfall records were recorded during the month of December (Figure 7).

Edaphic factors. Table 3 shows the edaphic factors and other environmental variables used in assessing the tree species-environment relationship in SINP. Results from soil analysis revealed variations in soil chemical characteristics across sites. Soil pH values across sites were identified to be slightly acidic. Acidic nature of soils can be explained by the intensive leaching of basic cations brought about by high rainfall (Calubaquib et al. 2016). Samar falls under Type II and Type IV climates, where the former is characterized by having no dry season with a pronounced maximum rain period throughout the year (Abino et al. 2014). Percent OM average was highest in Paranas (11.72%) and lowest in Taft (9.61%).

Figure 3. Cluster I vegetation in SINP forests over limestone ecosystem observed in plots PAR01, PAR02, and PAR03

Figure 4. Cluster II vegetation in SINP forests over limestone ecosystem is commonly found in plots of Paranas (PAR08 and PAR09), and Taft (TAF11, TAF12, TAF13, TAF14, TAF15, TAF16, TAF17, and TAF18)

Figure 5. Field scenario of Cluster III vegetation in SINP forests over limestone ecosystem commonly found in plots of Paranas (PAR04, PAR05, PAR06, and PAR07), and Taft (TAF10)

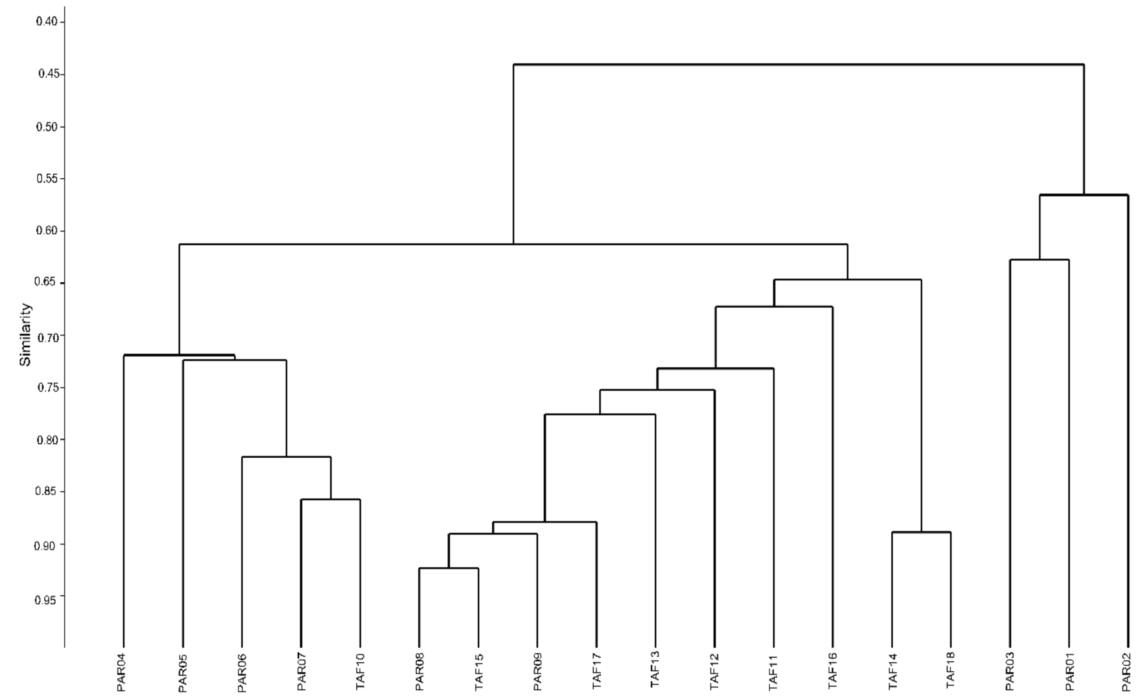
Variation in average soil OM across sites can be explained by differences in vegetation cover, amount of leaf litter, and continuous rain-promoting decomposition. Total average N was recorded to be highest in Paranas (0.48) and lowest in Taft (0.47). In a study conducted by Calubaquib et al. (2016), they found a positive relationship between OM and total N content in degraded soils collected in Luzon, Philippines. Available phosphorus in soil samples was recorded to be highest in Taft (12.87) and lowest in Paranas (9.11). Electrical conductivity was highest in Taft (317.92) and lowest in Paranas (248.47). Interestingly, most of the analyzed edaphic factors are uncharacteristic of forests over limestones. Karst surface deposits are characterized by a high pH, low organic matter content, and a heterogenous land surface (Abe et al. 2018).

Factors influencing the woody vegetation structure in the forest over limestone of SINP

Figure 8 shows the factors affecting the vegetation structure of the forests over limestone in Samar Island National Park, which includes rainfall, temperature, elevation, presence/absence of disturbance, and 14 edaphic variables. These environmental factors have a significant impact on the vegetation of SINP, particularly temperature, soil nutrients such as phosphorus (P) (indicated by long arrows), followed by the elevation, rainfall, and the presence of disturbances (Disturbance_Pr), which is positively correlated with the species distribution. Temperature appears to be the most important environmental variable influencing the vegetation of Samar Island forests over limestone. The same findings were reported by Buot and Okitsu (1998, 1999) of Mount Pulag, Sopsop and Buot (2013) in Aborlan Guba System, and Villanueva and Buot (2018) of Mount Ilong in Halcon Range, Mindoro Island. Contrarily, environmental variables represented by short arrows do not differ significantly across the diagram (ter Braak 1994). This is very evident in the case of soil nutrients such as OM, Zn, Cl, Mn, and pH.

Temperature (Figure 8) is the major factor influencing most of the species' relative basal area in SINP. The average temperature in Cabalogan (the nearest weather station in Paranas) is 28.8ºC and 27.2ºC in Borongan (the nearest weather station in Taft) (Figure 7). It was noticed, however, that as elevation increases, temperature decreases (Table 3). Temperature is the most important controlling variable on fractional vegetation coverage, especially at higher elevations (Buot and Okitsu 1998, 1999; Urban 2015; An et al. 2018; Guo et al. 2019; Sharma et al. 2019; Zhang et al. 2019; Bañares-de-Dios et al. 2022). It was also observed that the temperature decreases as the number of individual species recorded increases in the Taft plots, but this varies in the Paranas plots. For most plant species, the ideal growth temperature varies between 20ºC and 30ºC (Karlsson and Werner 2001; Knight and Knight 2012; Niinemets 2018). This implies that temperature has an impact on physiological performance (such as survival, growth, and reproduction) and species resource distributions (Bellard et al. 2012; Urban 2015; Howard et al. 2019; Kaspari et al. 2019).

Soil nutrients (Figure 8), such as phosphorus and EC (indicated by long arrow) are also important variables influencing SINP vegetation structure. Phosphorus, on the other hand, only affects species in plot TAF16, whereas EC, despite having a high rate of change, is negatively correlated with the distribution of some species. Other nutrients (K, Ca, Mg, N) have multiple correlations and little influence on other species, as shown in the diagram, despite the fact that they do not differ significantly across species. Vegetation naturally responds to the combined action of the various soil variables (Becknell and Powers 2014; Huang et al. 2015; Toriyama et al. 2015; Wang et al. 2016). Moreover, according to Freschet et al. (2018), soil selects certain species based on functional traits and ultimately shapes the plant community in terms of species taxonomy (species composition, number of species) and trait distribution (plant characteristics: architectural, morphological, physiological, etc.). This has been demonstrated in studies on forest formations in the Philippines, where some soil nutrients were discovered to affect vegetation structure (Katabuchi et al. 2012; Neri et al. 2012; Peña-Claros et al. 2012; Becknell and Powers 2014; De Jager et al. 2015; Rodrigues et al. 2016; Idowu et al. 2020; Bañares-de-Dios et al. 2022), which can be attributed to a variety of factors, including the complexity of karst forests (Sopsop and Buot 2013; Caringal et al. 2019), such as SINP. Plants compete for soil resources, and the most competitive species are those that can capture these resources first (Liu et al. 2014; Kim et al. 2016; Kunstler et al. 2016; Freschet et al. 2018), thereby eliminating other competing species.



Plot Characteristis	**CLUSTER III**	**CLUSTER II**	**CLUSTER I**
Dominants based on Relative Basal Area	*Shorea negrosensis* *Shorea astylosa* *Manilkara fasciculata* *Hancea wenzeliana*	*Shorea astylosa* *Shorea negrosensis* *Dracaena angustifolia*	*Shorea negrosensis* *Shorea astylosa* *Manilkara fasciculata* *Hancea wenzeliana* *Calophyllum soulattri* Barit *Wallaceodendron celebicum*
Dominants based on Relative Density	*Shorea negrosensis* *Hancea wenzeliana* *Shorea astylosa* *Manilkara fasciculata* *Calophyllum soulattri*	*Shorea negrosensis* *Shorea astylosa* *Hancea wenzeliana*	*Calophyllum soulattri* *Hancea wenzeliana* *Shorea negrosensis* *Shorea astylosa* *Manilkara fasciculata* *Aglaia rimosa* *Heterospathe intermedia* *Neonauclea formicaria*
Max Height	35 m	29 m	30 m
Mean Height	5.56 m	6.62 m	5.55 m
Max DBH	89.13 cm	141.33 cm	78.94 cm
Mean DBH	6.76 cm	8.25 cm	7.27 cm
Basal area at breast height (m2/ha)	41.5 m2/ha	77.35 m2/ha	53.83 m2/ha
Number of individuals per hectare	4985	5115	4658.33

Figure 6. Dendrogram showing the three clusters identified from the 18 sampling plots in Paranas and Taft, Samar Island. The dominant woody species and community structural features of each cluster are also indicated above. Features of each cluster are also indicated

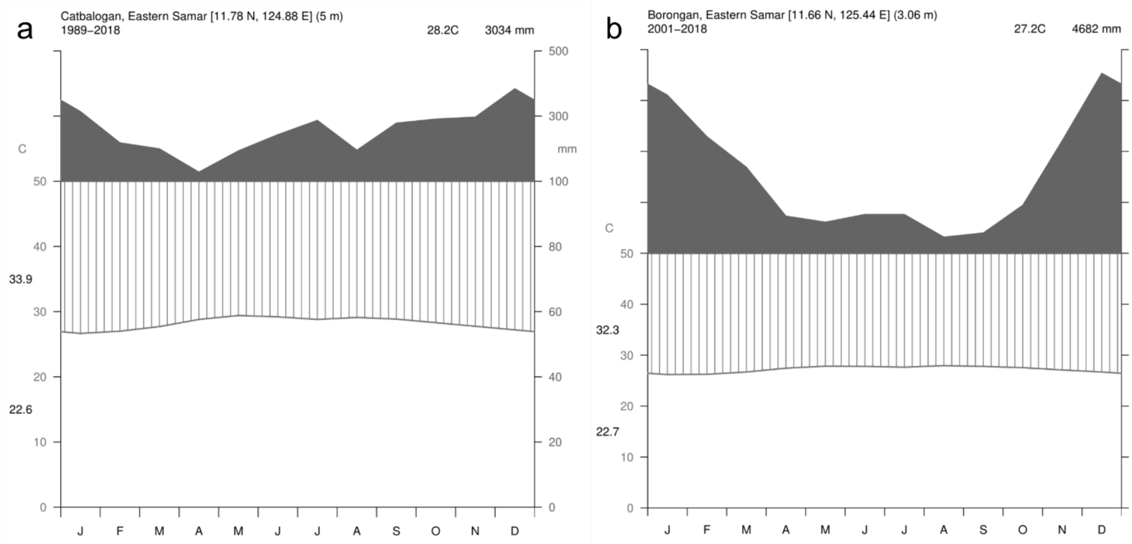


Figure 7. Climate diagrams of a) Catbalogan, Samar, the nearest weather station to Paranas, Samar, and b) Borongan, Eastern Samar, the nearest weather station to Taft, Eastern Samar. Diagrams were created based on the average monthly temperature and rainfall data from PAGASA (25 and 18 years), respectively

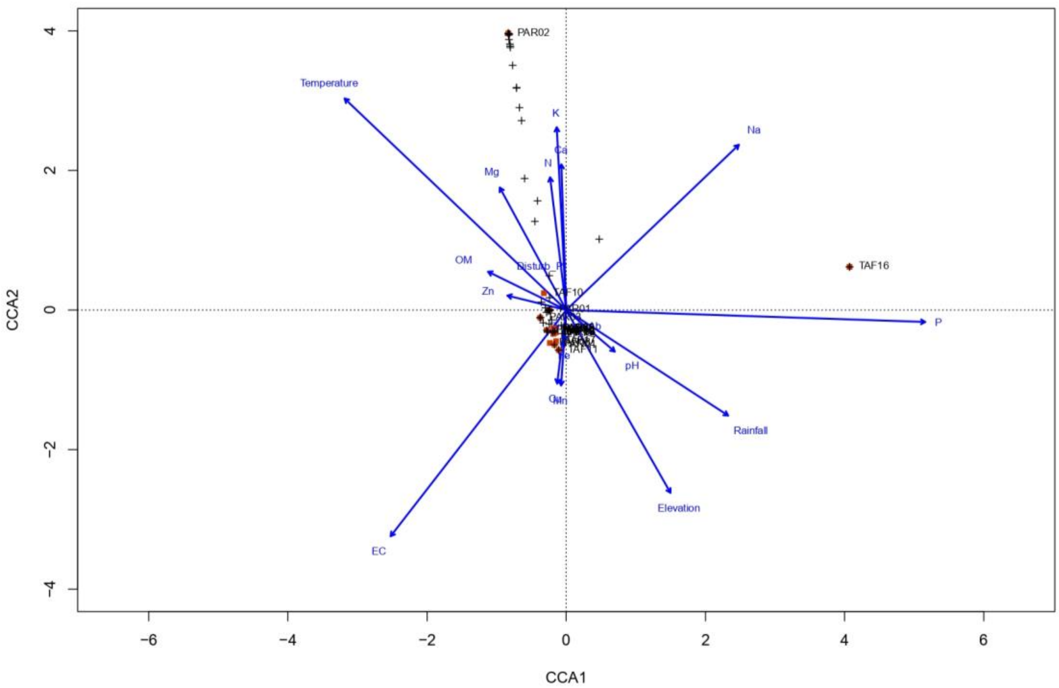


Figure 8. Canonical Correspondence Analysis (CCA) ordination plot showing the scores of the species ('+' symbols) and sites (red squares). A total of 18 environmental variables (rainfall, temperature, elevation, presence/absence of disturbance, and 14 edaphic variables) were also included in this analysis. The ordination plot shows 54.99% of the variation and patterns explained in the analysis

Elevation and the presence of disturbance (Figure 8) are two other factors influencing some species found in many of the sampling plots in SINP. As shown in Table 3, it was observed that the site points of disturbed plots (Disturbance_Pr) (PAR02, PAR05, TAF10, TAF15) have the lowest elevation of all sampling plots. This means these habitats are readily accessible, and humans can easily be tempted to engage in some destructive activities (Monge-González et al. 2019; Aureo et al. 2021) even unintentionally. PAR07 (Disturbance_Pr) is in mid-elevation and has the highest number of individual species in the Paranas plot. Plot PAR02, is plotted away from other disturbed plots, and has the second highest number of individuals, and is the most diverse of all plots (see Figure 2). This observation is similar to that of, Buot and Osumi (2011), Sopsop and Buot (2013), Chen et al. (2014); Gao et al. (2019), Xu et al. (2019), Aureo et al. (2021), Carreño-Rocabado et al. (2012), Newbold et al. (2015), Rana et al.

(2019) who found that varying degrees of human disturbances (e.g., kaingin farming) have shaped and continue to influence species composition and jeopardize the structural characteristics of the forest.

Although elevation did not affect all species in this study, it is known to be the most influential factor in changes in floristic composition and diversity in tropical mountains (Hemp 2006; Imani et al. 2016; Cabrera et al. 2018; Gilbert et al. 2020), including those in Southeast Asia (Nguyen et al. 2015; Van and Cochard 2017) and the Philippines (Buot and Okitsu 1998). Thus, this study assumes that there is no general pattern along the elevational gradients (Cirimwami et al. 2019) since it has little effect on vegetation structure in SINP. The elevation gradient is complex because it includes changes in climatic, edaphic, and biotic factors, as well as changes in plant community structure as a result of these factors (van Breugel et al. 2013; Girardin et al. 2014; Chen et al. 2015; Malhi et al. 2017; Yun et al. 2020; Homeier and Leuschner 2021; Yang et al. 2021).

Rainfall (Figure 8) is another factor that influences some species in SINP, particularly during heavy rains. As shown in Figure 7, the average annual rainfall records for Catbalogan and Borongan, the nearest PAGASA synoptic stations from Paranas and Taft, are both high at 3,034 mm and 4,682 mm, respectively. Taft plots are located in Eastern Samar, receiving the greatest amount of rainfall based on PAGASA records. Accordingly, Samar is one of the archipelago's most severely affected areas, having been hit by 25 tropical depressions, 51 tropical storms, and 58 typhoons between 1948 and 2009 (National Disaster Risk Reduction Management Council 2014). Following the typhoon, the composition and spatial distribution pattern of the species population changed, and some large and old trees, as well as tree species not resistant to strong winds, fell, resulting in a change in species diversity (Díaz-Yáñez et al. 2017; Taylor et al. 2019; Li et al. 2021). Taft plots also have the most individual species (1882), but the fewest number of species (4-10 # of species) (see Figure 2), indicating that a small number of species remained resilient, and others were quite vulnerable to natural disasters such as typhoons. Additionally, the species found in each plot are not particularly large.

The findings, as shown in the diagram (Figure 8), could be attributed to the fact that other environmental variables, despite their high rate of change (represented by long arrows) and little effect on other species, may have multiple effects and indirect influences on other factors in the structure of vegetation in SINP. CCA results, however, could only explain 54.99% of the variance in the data (Table 3), implying that there should be more environmental variables that could possibly explain the variation but were not included in the analysis. The distribution of tree species in tropical mountain ecosystems is the result of the interaction of multiple environmental factors that limit species distribution simultaneously (Mandle and Ticktin 2012; Diez et al. 2014; He et al. 2022). The literature has repeatedly emphasized that factors causing landscape heterogeneity are either natural or anthropogenic in nature or a combination of both (Keane 2017; Pham et al. 2021). Natural factors that have been identified as causing variation in species composition, including light conditions, temperature, and relative humidity, amount of rainfall (Buot and Okitsu 1999; Miao and Jianmeng 2015; Urban 2015; Winter et al. 2015; Trindade et al. 2018; Dong et al. 2019; Iturrate-Garcia et al. 2016; Diaci et al. 2020; Fan et al. 2020; Nepali et al. 2021), soil conditions, soil type, soil texture, soil moisture (Suzuki et al. 2002; Heryati et al. 2011; Davis et al. 2018; Toro et al. 2019), floristic composition and structure and abundance of microclimates (Richards 1996; Duchicela et al. 2021), microbial composition and natural disturbances particularly, typhoons, erosion, and landslides, as well as anthropogenic disturbance history (Hong et al. 1995; Muniandy et al. 2009; Buot and Osumi 2011; Cardinale et al. 2012; Jiang et al. 2016; Tran et al. 2016; Boukili et al. 2017), can greatly influence the species diversity in SINP.

Comparison of woody species in other forests over limestone

Table 4 shows the comparison of the attributes and characteristics of four forests over limestone in the Philippines, namely, Samar Island (SINP), Cebu, and Verde Island Passage, Batangas. As shown in the table, there are no common dominant elements common to the four forests over limestone, except for *Ficus*, which can be found in the forests of Cebu province. Rubiaceae and Moraceae dominate in three of the four locations, while Sapotaceae and Euphorbiaceae occur in only two. Actually, there are many factors that govern species distribution, such as the dispersal from the species pool (Pagel and Schurr 2012; Schurr et al. 2012; Cabral et al. 2012; Kang et al. 2014; He et al. 2022), responses to abiotic conditions, and biotic interactions in shaping species assemblages (Peña-Claros et al. 2012; Tscharntke et al. 2012; Kraft and Ackerly 2014; Arruda et al. 2015; Bernard-Verdier et al. 2012; HilleRisLambers et al. 2012; Ballabha et al. 2013; Benot et al. 2013; Hulshof et al. 2013; Stein et al. 2014; Ehrlén and Morris 2015; May et al. 2015; Sutcliffe et al. 2015; Li et al. 2017; Liang and Chan 2017; Liancourt et al. 2017; Sharma et al. 2018; Trindade et al. 2018; Dong et al. 2019; Zhou et al. 2019). We have to mention here that though, all these four locations are forests over limestone, firstly, they are in different geographies and could have been subjected to varying levels of ecological and evolutionary processes. Additionally, three are inland forests (Mt. Tabunan, Mt. Lantoy, and SINP), while one is coastal forests over limestone (Verde Island). Among the inland forests, Mt Tabunan is a remnant primary forest, while the others are largely secondary forests. As such, these four forests over limestone have different responses in terms of species adaptations as they are exposed to varied environmental factors influencing the species composition, structure, and diversity.

Table 4. Dominant species and families in SINP and other forests over limestone in the Philippines

	Samar Island Natural Park	Mount Tabunan, Cebu	Mount Lantoy, Cebu	Verde Island Passage, Batangas
Altitude (meters above sea level, masl)	172 - 385 masl	500 - 880 masl	< 200 masl and > 500 masl	8 - 321 masl
Status of Protection	Protected area under Proclamation No. 442. 2003, pursuant to the National Integrated Protected Areas System (NIPAS) Act of 1992 (Republic Act No. 7586) and Republic Act No. 11038.	Part of Central Cebu National Park (CCNP) (Proclamation No. 835-A on 27 March 1971) and the Kotkot-Lusaran Watershed Forest Reserve (Proclamation No. 932 on 29 June 1992) under Republic Act No. 9486 of 2007 (Central Cebu Protected Landscape).	Part of the Argao- Dalaguete Watershed Forest Reserve declared by a Presidential Proclamation (No. 414, 29 Jun 1994)	Not a declared protected area under NIPAS Act 1992, it is a marine key biodiversity area (KBA) with an EO # 578 that was signed to solidify commitment to protect Verde Island Passage through a Memorandum of Agreement (MOA) creating the VIP Marine Protected Area Network and Law Enforcement Network.
Dominant species	*Dracaena angustifolia, Hancea wenzeliana, Manilkara fasciculata, Shorea astylosa, Shorea negrosensis*	*Aglaia species, Ficus species, Garcinia species*	*Calophyllum blancoi, Cinnamomum cebuense, Dysoxylum pauciflorum, Elaeocarpus cumingii, Ficus benjamina, Gomphandra luzoniense, Goniothalamus elmeri, Gymnostoma rumphiana, Parishia malabog, Planchonella duclitan, Pometia pinnata, Syzygium simile*	*Tectona philippinensis, Terminalia polyantha, Garuga floribunda, Celtis latifolia, Tamarindus indica, Xylocarpus granatum*
Dominant families	Arecaceae, Dipterocarpaceae, Euphorbiaceae, Rubiaceae, Sapotaceae	Araceae, Meliaceae, Moraceae	Anacardiaceae, Elaeocarpaceae, Meliaceae, Moraceae, Rubiaceae, Sapotaceae	Fabaceae, Malvaceae, Lamiaceae, Apocynaceae, Euphorbiaceae, Moraceae, Asteraceae, Poaceae and Rubiaceae
Notes on anthropogenic activities	Unregulated limestone quarrying, coal and chromite mining, charcoal production, over-harvesting of non-timber forest products (including rattans), pollution from industries, alien species invasion, and the proliferation of small-scale illegal logging and forest clearing for agricultural purposes (SEARCA 2004).	The forest exterior is dominated by agricultural activities and exploitation of forest resources by the local residents and the widespread practice of swidden agriculture (Colina & Jumalon 1974)	Agricultural expansion, fuelwood collection, illegal logging, hunting, and widespread conversion of forests to agriculture (Bensel 2008)	Land conversion (from forest to sugar apple plantation and coastal area to resorts), habitat destruction, ecotourism projects, quarry operation, development of road networks and lateral expansion of urban settlements, kaingin (slash and burn farming), accidental fire during summer months, natural threats such as prolonged droughts caused by the El Nino phenomenon as well as pests and diseases (RDC-CALABARZON, 2006; Briones et al. 2017)
References	This study	Cadiz and Buot (2010)	Lillo et al. (2019)	Caringal et al. (2021)

Additionally, the four (4) forests over limestone clearly suffer from various anthropogenic activities in their respective areas of occurrence, and expectedly, the most common activities noted are related to agriculture, one of the many reasons for expansive land use conversions (Oduro et al. 2015; Symes et al. 2018; Acheampong et al. 2019; BGCI 2021) not only in forests over limestone but in many ecosystem types throughout the Philippines and even in many parts of the world. These anthropogenic activities are rampant because only three (3) of the four (4) forests over limestone are legally protected. The Verde Island Passage where the Philippine teak is growing is still unprotected by law and hence, is still threatened by human activities.

These unique forest formations facilitate the growth and survival of endemic species such as the endangered Philippine teak (*Tectona philippinensis*) found in the coastal landscapes of Verde Island Passage in Batangas Province and Ilin Island of Occidental Mindoro, Philippines (Caringal et al. 2019, 2021), the most endangered *Cinnamomum cebuense*, locally known as kalingag (Lillo and Alcazar 2015) and the critically endangered *Cynometra cebuensis* species (Seidenschwarz 2013; Pelser and Barcelona 2017) found in Cebu Island's forests over limestone, particularly in, Mount Tabunan (Cadiz and Buot 2010) and Mount Lantoy (Lillo et al. 2019), and the extremely rare and critically endangered species, the Philippine eagle (*Pithecophaga jefferyi*) (BirdLife International 2013), which naturally inhabits the rich forests over limestone of Samar Island (Bueser et al. 2003; Sutton et al. 2021). The presence of the Philippine eagle also confirms that Samar Island is part of the Mindanao PAIC (Pleistocene Aggregate Island Complex) (Siler et al. 2016). This explains the similarities in species composition and diversity between Samar Island and Mindanao Island (Heaney 1986, 1998), and it can elaborate phylogenetic relationships among taxa especially, in the younger Philippine islands (Vallejo 2014). Dipterocarp forests are known habitats for this species, which agrees with our findings showing dipterocarp species as dominant species and families (Table 4). The presence of the Philippine Eagle on Samar Island indicates that it still has rich, healthy, and ecologically balanced forests. Protecting this species' habitat throughout the country will result in the preservation of a significant portion of the Philippines' remaining tropical dipterocarp forests (Tabaranza 1997). It is imperative that these forests over limestone in Samar must be managed and protected in a sustainable manner to sustain the population of the critically endangered Philippine Eagle (Marcer et al. 2013; Syfert et al. 2014; McClure et al. 2018; Buechley et al. 2019). Likewise, the other 3 forests over limestone (Table 4) need to have extra protection as they host keystone endemics which are on various threatened statuses per IUCN (Bellard et al. 2016; Blackburn et al. 2019).

In conclusion, the inventory of tree species in Samar Island Natural Park (SINP) forests over limestone revealed a unique habitat for many endemics, indigenous, rare, and threatened species. SINP now nominated as a World Natural Heritage Site, is one of the most important conservation areas not only in the Philippines and the ASEAN but throughout the whole world as well. A total of 18 plots with 3,578 individual species were subjected to various ecological analyses such as vegetation, classification (cluster), and ordination (canonical correspondence analysis) analyses. Based on the results of the study, the plots from Paranas have a higher number of species (28 species), Shannon (H'=2.69), and Simpson 1-D values, whereas the plots from Taft have a higher number of individuals (255 individuals). The results of this study revealed that not all of the most diverse plots or sites have the greatest number of species due to a variety of factors. The temperature was identified as the most important environmental variable influencing the vegetation of SINP. Other environmental variables, despite their high rate of change and little effect on other species, may have multiple and indirect influences on other factors in the structure of vegetation in SINP. In addition, two *Shorea* species from the Dipterocarpaceae family were recorded to be the most dominant among the other species recorded. These species, along with others, will play a critical role in stabilizing and sustaining the forests over the limestone ecosystem landscape. The findings of the study can complement the development of appropriate forest resource management and conservation strategies that are beneficial to both the forest and the local communities. Thus, strict measures and sustainable management should be implemented to prevent any degradation that will affect such unique but vulnerable species. More studies on conservation prioritization of the threatened species population should be conducted to prevent large-scale irreversible ecosystem landscape destruction in Samar Island Natural Park.

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