Journal of Nature Studies 20(2): 48-60
Online ISSN: 2244-5226

LEAF SIZE CLASSES OF TREE SPECIES IN THE FORESTS OVER LIMESTONE OF SAMAR ISLAND NATURAL PARK, PHILIPPINES

Elaine Loreen C. Villanueva, Inocencio E. Buot, Jr.*, Ren Divien R. Obeña and Marjorie D. delos Angeles

Institute of Biological Sciences, University of the Philippines Los Baños, Laguna

*Corresponding author: iebuot@up.edu.ph

ABSTRACT – Leaf size is one of the plant functional traits that can explain ecosystem function. This study identified the leaf size classes of trees in the forest over limestone ecosystems of Samar Island Natural Park, Samar Island, Philippines. One-sided surface leaf areas of voucher specimens from 18 sites in SINP were measured and data obtained were calculated and further classified based on the Raunkier-Webb classification. Most of the leaf sizes recorded were mesophyll (15 spp.), followed by notophyll (11 spp.), microphyll (4 spp.), and megaphyll (2 spp.). Moreover, leaf size classes are highly diverse among the sampling plots, a characteristic that can enhance the diversity of faunal populations dependent on plants for food and shelter. The dominance of large leaf sizes in SINP confirms the results of similar studies in forests over limestone.

Keywords: kaigangan, mesophyllous, notophyllous, Raunkier-Webb classification

INTRODUCTION

Leaf sizes and other morphological and anatomical characteristics differ with agroclimatic and ecosystem types and even with altitude and latitude (Box 1981, Chabot and Hicks 1982, Givnish 1987, Grubb 1974, Liu 1993, Ohsawa and Ozaki 1992, Ohsawa 1993a, 1993b and 1995, Reich et al 1992, Richards 1996, Webb 1959, Whitmore 1984, Woodward 1987). Previous studies on leaf size classes in the Philippines had been conducted by Buot and Okitsu (1999) in Mount Pulag, northern Luzon Island and Lambio and Buot (2010) in Mount Makiling, southern Luzon Island, and by Aribal et al (2017) in a peat swamp forest in Agusan del Sur, Mindanao Island. All three papers revealed interesting findings related to ecosystem functions.

Studies on leaf size analysis have been conducted in the Philippines, particularly in mountain ecosystems with defined elevation zones such as in Mount Pulag (Buot and Okitsu, 1999) and in Mount Makiling (Lambio and Buot, 2011). Some are specific in lowland habitat types such as in a peat swamp forest (Aribal et al. 2017) and a mangrove ecosystem (Casilac et al., 2018). Studying the forests over limestone in Samar Island Natural Park (SINP), Samar Island, Philippines expands our current knowledge on leaf analysis studies to other forest types. SINP has been nominated to be a UNESCO World Natural Heritage site, recognizing its unique physical and biological treasures (Tolentino et al., 2020; Obeña et al., 2021; Villanueva et al., 2021a; 2021b). Plant species new to science had been reported in scientific literature such as *Calamus warayanus* Adorador & Fernando (Adorador & Fernando 2020), *Orania zheae* Adorador & Fernando (Adorador & Fernando 2020), and *Pseuderia samarana* Z.D.Meneses & Cootes

To cite this paper: Villanueva, E.L.C., Buot, I.E.Jr., Obeña, R.D.R. & delos Angeles, M.D.D. 2021. Leaf Size Classes of Tree Species in the Forests over Limestone of Samar Island Natural Park, Philippines. Journal of Nature Studies. 20(2), 48-60.

(Meneses & Cootes 2019). Other taxonomic novelties include new local records of plants such as *Tectaria calcarea* (J.Sm.) Copel., *Artocarpus rubrovenius* Warb., and *Hancea wenzeliana* (Slik) S.E.C.Sierra, Kulju & Welzen were recorded in SINP (Villanueva et al., 2021a). This research is the first study investigating the leaf size classes in the forest over limestone ecosystems of the Philippines.

This study aimed to identify leaf size classes of trees recorded in the forests over limestone of Samar Island Natural Park (SINP), Samar Island, Philippines. This research also determined the environmental factors influencing the leaf sizes of trees in SINP and shed light on the possible impacts of the leaf size classes on the animals dependent on the forests over limestone.

METHODOLOGY

Study Area

Samar Island Natural Park (SINP) is a protected area in Samar Island, the easternmost island in the Visayas group of islands (Figure 1). The protected area has a significant area of karst landscapes (Restificar, 2006). SINP contains a huge portion of inland forests, which has been home to different flora and fauna (Obeña et al., 2021; Villanueva et al., 2021).

Establishment of sampling sites for the tree inventory

Fieldwork was conducted last October 2-7, 2019 in SINP covering approximately 20 sq km of terrain. A total of 18 plots were established in the forests over limestone ecosystems of the municipalities of Paranas and Taft only. Nine 20m x 20m plots were established in each municipality for the assessment of trees (Mueller-Dombois and Ellenberg, 1974). Plot establishment was based on the biophysical characteristics of the area such as plant diversity heterogeneity, topographic attributes, and the presence of anthropogenic disturbances in the areas. Inside each sampling plot, three replicates of soil samples (1 kg.) were collected. These soil samples were homogenized per plot in the Plant Systematics Laboratory of IBS-UPLB and sent to the College of Agriculture and Food Science – Agricultural Systems Institute (CAFS-ASI) Analytical Services Laboratory for soil analysis.

Trees within each plot were recorded and identified. Voucher specimens were collected and processed to aid in the identification of tree species. Dried leaf samples from the processed vouchers were measured for the leaf size analysis. Vouchers were deposited at the Plant Biology Division Herbarium (PBDH) of the Institute of Biological Sciences, University of the Philippines Los Baños. For the species identification, the authors sought the assistance of the experts from the Philippine National Museum as well as the use of botanical works of literature (Merrill, 1923-1926; Rojo, 1999) and online resources (Pelser et al., 2011-onwards; IPNI) to confirm the identity and nomenclature of the species.

Leaf size measurement and classification

Plants with available voucher specimens at the Plant Biology Herbarium (PBDH), Institute of Biological Sciences, University of the Philippines Los Baños were retrieved for leaf size measurements. A total of 643 measurements were done for the one-sided leaf area using the formula of Cain and De Oliveira-Castro (1959):

$$Leaf\ Area = 2/3\ (L \times W)$$

Where L is the full length of the leaf and W is the width of the leaf at its widest portion (Figure 2). The measurable leaves from the voucher specimens were recorded and the mean leaf area for each species was computed. Based on the mean leaf area values, the leaf size class of each tree species was identified based on the Raunkier-Webb classification (Table 1).

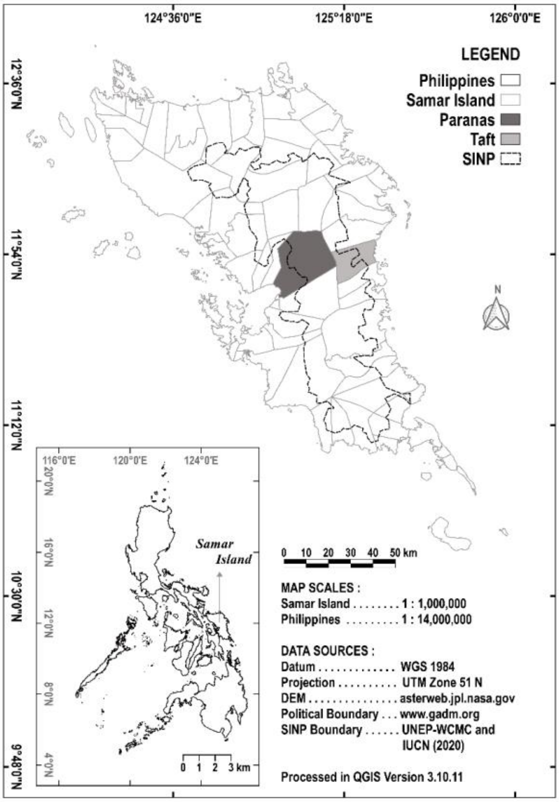

Figure 1. Map of Samar Island showing the location of the two municipalities as study sites. The boundary of Samar Island Natural Park is also indicated with the broken line within the island. The inset figure shows the Philippine map with the approximate location of Samar Island. Map generated by RDR Obeña.

Table 1. Leaf size classes based on Raunkier-Webb classification (Shimwell, 1971).

Leaf Size Class	Size Range (mm^2)
Leptophyll	< 25
Nanophyll	25 – 225
Microphyll	225 – 2,025
Notophyll	2,025- 4,500
Mesophyll	4,500 – 18,225
Macrophyll	18,225-164,025
Megaphyll	> 164,025

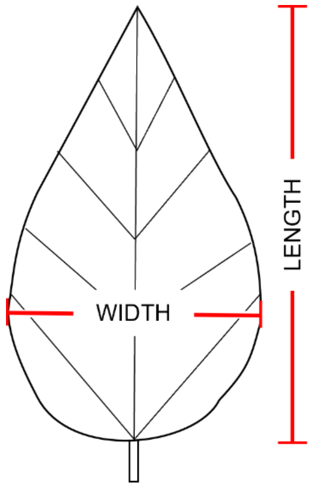

Figure 2. Diagrammatic illustration of a leaf showing the length (L) and width (W) for the measurement of the leaf area.

Data analysis

The relative frequency (RF) values of the recorded leaf size classes per plot were computed. For the climatic variables, the data records of the temperature and precipitation in the nearest weather stations from the study sites were requested from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Climatographs (Walter-Lieth diagrams) were generated using climatol package (Guijarro, 2019) through R version 3.6.1 (R Core Team, 2019).

To assess the influence of the soil on the leaf area measurements, a scatterplot was also generated using the tidyverse package in R (Wickham et al., 2019).

RESULTS AND DISCUSSION

Leaf size classes of trees in SINP

A total of 643 leaves were measured from 31 tree species represented by 19 families and 25 genera (Table 2). The most represented leaf size class are categorized as mesophyll at 61.3% (15 spp.), followed by notophyll at 35.5% (11 spp.), microphyll at 12.9% (4 spp.), and megaphyll at 6.5% (2 spp.). The dominance of the large leaf size class (mesophyll and microphyll) has also been observed in the limestone forests of China, specifically in Southern Yunnan (Zhu et al., 2003) and in Mt. Exianling (Zhang et al., 2017). This trend has also been observed in some of the mountain areas in east Asia (Tang and Ohsawa, 1999), where the tropical rainforests are mostly dominated by mesophyllous leaf size classes. The leaf sizes of the trees ranged from microphyll to megaphyll, while the majority of the species were of mesophyllous type.

Table 2. List of trees species recorded from SINP with available leaf area measurements and leaf size classes.

Family	Name of Species	No. of Leaves Measured	Mean Leaf Area (sq. mm)	Leaf Size Class	Exsiccata
Meliaceae	*Aglaia rimosa* (Blanco) Merr.	3	5625	Mesophyll	*Obeña 7143 (PBDH)*
Thymelaceae	*Aquilaria cumingiana* (Decne.) Ridl.	84	3206	Notophyll	*Obeña 7098 (PBDH)*
Moraceae	*Artocarpus rubrovenius* Warb.	7	10214	Mesophyll	*Obeña 7147 (PBDH)*
Phyllantaceae	*Bridelia glauca* Blume	21	5387	Mesophyll	*Obeña 7102 (PBDH)*
Burseraceae	*Canarium hirsutum* Willd.	16	9542	Mesophyll	*Obeña 7125 (PBDH)*
Arecaceae	*Caryota rumphiana* Mart.	19	8559	Mesophyll	*Obeña 7133 (PBDH)*
Euphorbiaceae	*Codiaeum* sp.	3	5299	Mesophyll	*Obeña 7144 (PBDH)*
Ebenaceae	*Diospyros discolor* Willd.	12	3865	Notophyll	*Obeña 7098 (PBDH)*
Moraceae	*Ficus ampelas* Burm.f.	18	1627	Microphyll	*Obeña 7121 (PBDH)*
Calophyllaceae	*Calophyllum* sp.	10	9849	Mesophyll	*Obeña 7128 (PBDH)*
Clusiaceae	*Garcinia rubra* Merr.	37	979	Microphyll	*Obeña 7115 (PBDH)*
Clusiaceae	*Garcinia* sp.	5	7015	Mesophyll	*Obeña 7145 (PBDH)*
Euphorbiaceae	*Hancea wenzeliana* (Slik) S.E.C.Sierra, Kulju & Welzen	9	8022	Mesophyll	*Obeña 7103 (PBDH), Obeña 7041 (PBDH)*
Dipterocarpaceae	*Hopea philippinensis* Dyer	45	3853	Notophyll	*Obeña 7116 (PBDH)*
Dipterocarpaceae	*Hopea* sp.	21	2284	Notophyll	*Obeña 7113 (PBDH)*
Rubiaceae	*Lasianthus trichophlebus* Hemsl. ex F.B.Forbes & Hemsl.	18	3795	Notophyll	*Obeña 7049 (PBDH)*
Euphorbiaceae	*Macaranga bicolor* Müll.Arg.	4	20158	Megaphyll	*Obeña 7127 (PBDH)*
Sapotaceae	*Manilkara fasciculata* (Warb.) H.J.Lam & Maas Geest.	12	3806	Notophyll	*Obeña 7129 (PBDH)*
Cornaceae	*Mastixia* sp.	22	6699	Mesophyll	*Obeña 7148 (PBDH)*
Rubiaceae	*Neonauclea* sp.	1	45240	Megaphyll	*Obeña 7045 (PBDH)*

Table 2 (Continued). List of trees species recorded from SINP with available leaf area measurements and leaf size classes.

Family	Name of Species	No. of Leaves Measured	Mean Leaf Area (sq. mm)	Leaf Size Class	Exsiccata
Lauraceae	*Nothaphoebe leytensis* (Elmer) Merr.	7	11237	Mesophyll	*Obeña 7149 (PBDH)*
Urticaceae	*Oreocnide rubescens* (Blume) Miq.	10	3359	Notophyll	*Obeña 7123 (PBDH)*
Sapotaceae	*Palaquium* sp.	27	3164	Notophyll	*Obeña 7105 (PBDH)*
Araliaceae	*Polyscias nodosa* (Blume) Seem.	24	1173	Microphyll	*Obeña 7112 (PBDH)*
Dipterocarpaceae	*Shorea negrosensis* Foxw.	4	13630	Mesophyll	*Obeña 7122 (PBDH), Obeña 7047 (PBDH)*
Lamiaceae	*Vitex turczaninowii* Merr.	1	15657	Mesophyll	*Obeña 7120 (PBDH)*
Fabaceae	*Wallaceodendron celebicum* Koord.	121	436	Microphyll	*Obeña 7108 (PBDH), Obeña 7044 (PBDH)*
	unidentified (Barit)*	12	3242	Notophyll	*Obeña 7109 (PBDH)*
	unidentified (Buskayan)*	25	2587	Notophyll	*Obeña 7114 (PBDH)*
	unidentified (Langka-langka)*	24	2464	Notophyll	*Obeña 7155 (PBDH)*
	unidentified (Sumol)*	8	8446	Mesophyll	*Obeña 7146 (PBDH)*
	unidentified (Urukay)*	3	14362	Mesophyll	*Obeña 7150 (PBDH)*

Relative frequency (RF) values of leaf size classes per plot were computed (Table 3). The table shows that in terms of RF values, mesophyllous tree species are the dominant leaf size class followed by notophyll. It was also observed that the plots from Paranas (PAR 02, PAR 03, PAR 04, PAR 05, PAR 06, PAR 07) have highly variable leaf size classes ranging from microphyll to megaphyll (Figure 3).

It is also notable that the leaf sizes, although dominated by mesophyllous type (Table 3), are mostly varied across the plots sampled. This characteristic variety encourages the diversity of animal populations coexisting with them, such as pollinators, herbivores, predators and many others. This condition likely enhances more ecosystem interaction and ecological processes and services in the forests over limestone.

Table 3. Relative frequencies of different leaf sizes among the 18 plots of SINP.

Leaf size class	**Plot No. (PARANAS)** / altitude in meters above sea level (m asl)								
	1 378.29	**2** 173.68	**3** 243.45	**4** 346.68	**5** 198.39	**6** 318.63	**7** 313.10	**8** 253.60	**9** 238.76
Leptophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nanophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Microphyll	0.0	16.7	5.9	9.1	9.1	11.1	12.5	0.0	0.0
Notophyll	29.4	22.2	17.6	27.3	27.3	11.1	25.0	20.0	40.0
Mesophyll	64.7	55.6	64.7	54.5	54.5	66.7	50.0	80.0	60.0
Macrophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Megaphyll	5.9	5.6	11.8	9.1	9.1	11.1	12.5	0.0	0.0

Leaf size class	**Plot No. (TAFT)** / altitude in meters above sea level (m asl)								
	10 181.07	**11** 272.41	**12** 249.79	**13** 221.55	**14** 223.12	**15** 211.55	**16** 277.70	**17** 256.66	**18** 215.81
Leptophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nanophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Microphyll	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Notophyll	16.7	42.9	33.3	42.9	0.0	25.0	33.3	25.0	0.0
Mesophyll	66.7	42.9	66.7	42.9	100.0	75.0	50.0	75.0	100.0
Macrophyll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Megaphyll	16.7	0.0	0.0	14.3	0.0	0.0	16.7	0.0	0.0

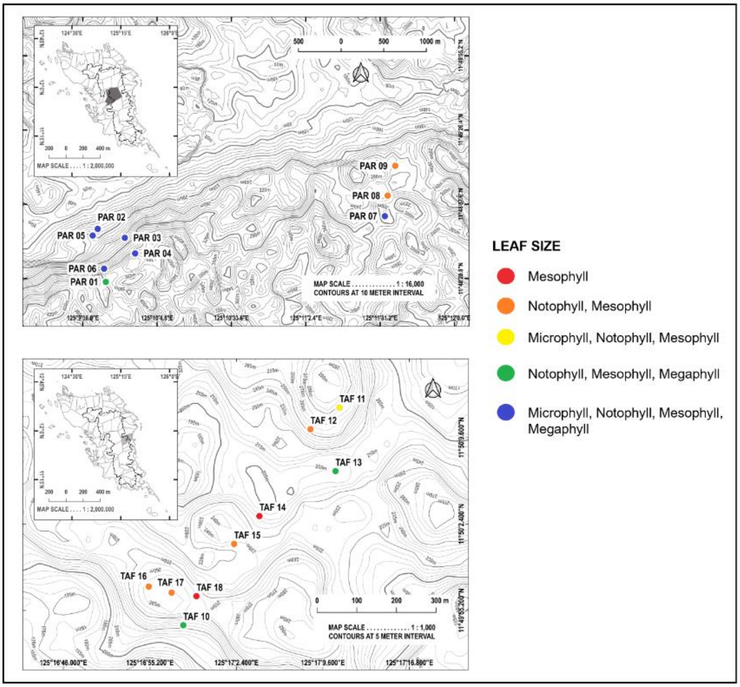

Figure 3. Maps of the sampling plots in the forests over limestone of Paranas (labeled as PAR, top map) and Taft (labeled as TAF, bottom map) in SINP. The locations of the sampling plots are marked with (●), each colored leaf size class available. Maps generated by RDR Obeña.

Environmental Factors Affecting Leaf Size Classes Among Trees in SINP

Climate

In terms of climate conditions, no distinct dry season was observed throughout the year, at least for the study areas. Figure 4 shows the climogram of Catabalogan and Borongan weather stations, the nearest PAGASA synoptic stations from Paranas and Taft respectively. The climograms cover temperature and rainfall records from 1989 to 2018 in Catbalogan and 2001 to 2018 in Borongan. The average temperature is 28.8℃ at Catbalogan and 27.2℃. The average annual rainfall records are high at 3034 mm for Catbalogan and 4682 for Borongan. The highest rainfall records were recorded during December.

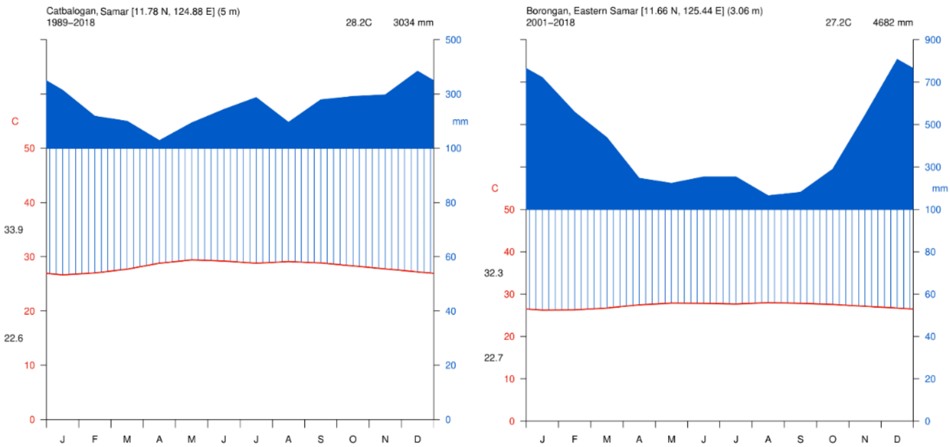

Figure 4. Climate diagram of Catbalogan, Samar (left) and Borongan, Eastern Samar, (right) the nearest weather stations to Paranas and Taft, respectively. For Catbalogan, the diagram was made from 30-year temperature and rainfall data, while a 17-year data were made from Borongan.

These climatic conditions (warm temperature and high precipitation) could have probably favored the growth of large leaf size classes among trees in SINP. A study by Wright et al. (2017) analyzed the leaf size variations worldwide and their climatic drivers. Large-leaf sizes tend to dominate in hot environments with high precipitation, as opposed to hot environments with low precipitation (i.e. arid environment). The study also pointed out that in terms of latitudinal locations, leaf sizes in equatorial regions are larger than in regions closer to the poles. Moreover, a decreasing change in the leaf size class has also been observed in increasing altitude (Tang & Ohsawa, 1999; Ashton, 2003). The sampling sites in SINP are situated in low elevations ranging from 174 to 378 meters. Thus, the tropical climate and geography of Samar Island, Philippines favor the growth of trees with large-sized leaves in its lowland forests.

Soil

Figure 5 shows a series of graphs, with x-axes showing different soil parameter values (N, P, K, Ca, OM, and pH and the y-axis containing the $\log_{10}$ values of leaf area per leaf measured. The data points in the figure are colored according to the leaf size classes of each leaf sample. Graphs do not show a linear trend across soil gradients. In terms of variability of leaf size classes, it is observed that it becomes more varied at increasing soil nitrogen (N) and organic matter (OM) values. High variability of leaf size classes is also observed at pH 7.

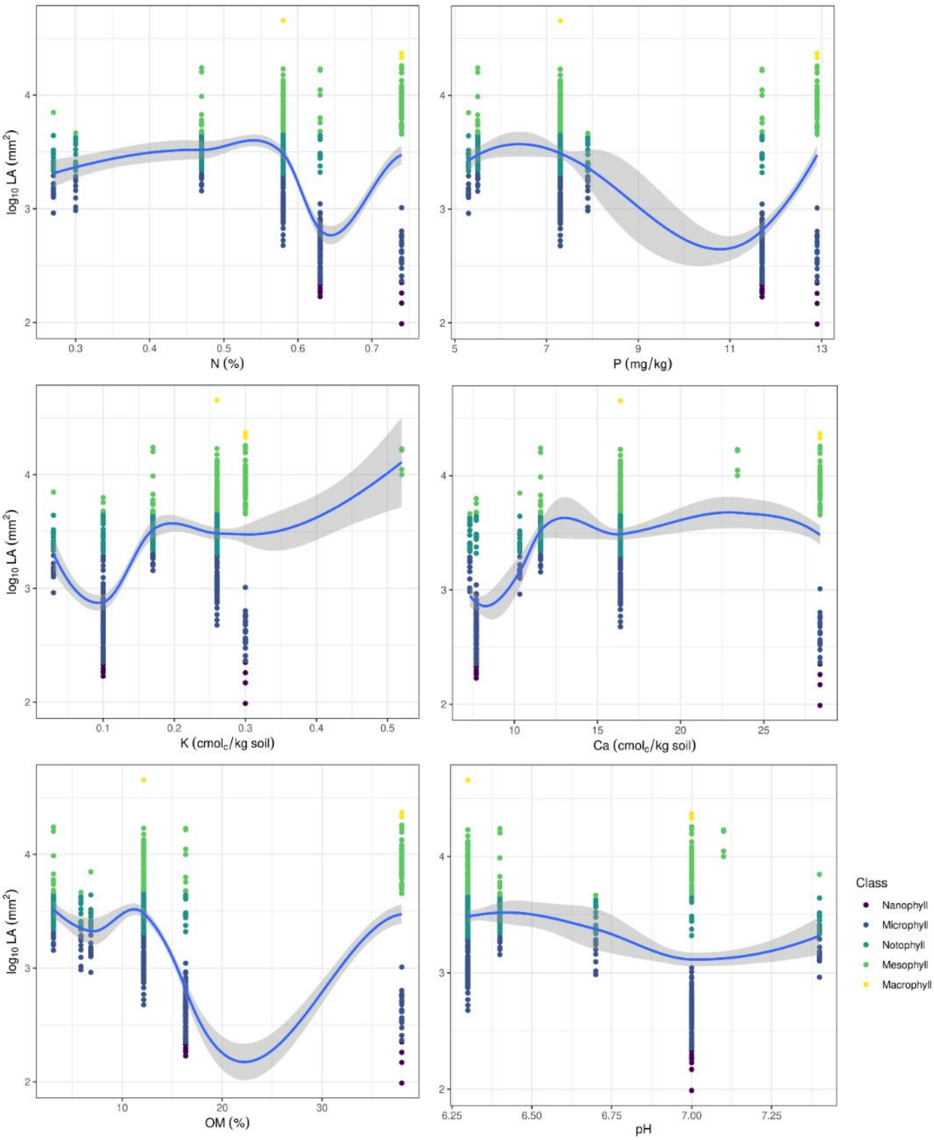

Figure 5. Leaf area (log_{10}, mm^2) of tree species along edaphic variable gradients (N, P, K, Ca, OM, and pH) of Samar Island Natural Park (SINP). Data points represent leaf areas of 618 leaf measurements with available soil data based on the sampling plot locations. The points are colored according to the leaf size classes per leaf sample.

Similar studies on the influence of soil on leaf size mostly suggested that the relationship between soil variables and leaf size is not significant. In a study on Amazon rainforest trees, Mahaldo et al. (2009) explained that the relationship between soil fertility and leaf size is complex and has no strong patterns. Moreover, in another leaf-trait-environment relationship study in Southeast China (Kröber et al., 2012), while some of the leaf traits provided some significant relationships to soil variables (C, N, CN, pH), leaf area did not provide a significant relationship among soil variables. Another study of a global plant trait dataset also assessed the relationship of soil and climate variables with several leaf traits (Maire et al., 2015), and it was found out soil variables were not strong predictors of specific leaf area (ratio of leaf area to leaf mass). Meanwhile, a study by Fonseca et al. (2000) assessed plant traits along rainfall and phosphorus gradients in New South Wales, Australia, and found that the specific leaf area and leaf width decreases along with soil phosphorus (P) content.

CONCLUSION AND RECOMMENDATIONS

This study provides an overview of how leaf size classes are distributed among the tree species in a Philippine forest over limestone landscape. The dominance of large leaf size classes such as mesophyll and notophyll in SINP is also observed in other forests over limestone in East Asia. Moreover, the climate and location of the Samar forests over limestone could have possibly favored the development and population of large-leaved trees. A variety of leaf size classes in the study plots, indicate the functional role of this trait to house diverse faunal elements dependent on the plant biota, enhancing ecological interaction and health and ecosystem services.

While there is no distinct leaf size pattern observed across the elevational and soil gradient of SINP forests over limestone, it is recommended to conduct further studies in other forests over limestone areas, especially in sites of higher elevation. It is also recommended to explore other limestone areas in SINP and the Philippines to observe the leaf size patterns of trees and woody species. Since leaf size classes have no specificity in various elevations, we project that this will be beneficial to organisms particularly for the herbivores to survive.

ACKNOWLEDGEMENT

This research is part of the Assessment and Conservation of Forest over Limestone Ecosystem Biodiversity in Selected Municipalities of Samar Island, Philippines (CONserve-KAIGANGAN), a research program of the University of the Philippines Los Baños (UPLB) and Samar State University (SSU) The authors would like to acknowledge and thank the following: the Department of Science and Technology (DOST) for funding this research through the Grants-in-Aid Program; the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) for their guidance in the program implementation; the Protected Area Management Bureau of Samar Island Natural Park (SINP-PAMB) and the Region 8 Office of the Department of Environment and Natural Resources (DENR), for allowing us to conduct our study in Paranas and Taft (GP Nos. 2019-16, 2020-10); the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) for providing us the climate data from Catbalogan and Borongan synoptic stations; the local government units (LGUs) of Paranas and Taft for their logistical assistance, Basaranan nga Organisasyon han San Isidro Samar (BOSIS) for helping the authors to conduct the field work in SINP; and Science Education Institute (DOST-SEI) for providing opportunity for the 1st author to be part of this research project through its Career Incentive Program (CIP).

STATEMENT OF AUTHORSHIP

The first author drafted the write-up and performed the data analysis for this paper. The second author conceptualized the framework, supervised the conduct of this study in Samar Island Natural Park forests over limestone and in the laboratory and providing inputs and guidance throughout the writing of the manuscript. The third author collected the data in SINP, prepared the voucher specimens, measured the leaf sizes, and prepared the maps for this manuscript. The fourth author provided valuable insights during the review of the initial draft of this paper.

LITERATURE CITED

Adorador JT and Fernando ES. 2020. Two new species of rattans (Calamus, Arecaceae) from forests over limestone in the Philippines. Phytotaxa. 447 (2).

Aribal LG, Bonggay JG & Fernando ES. 2017. Leaf size indices and structure of the peat swamp forest. Global J. Environ. Sci. Manage. 3(1): 63-74.

Ashton PS. 2003. Floristic zonation of tree communities on wet tropical mountains revisited. Perspectives in Plant Ecology, Evolution and Systematics 6(1,2): 87-104.

Box WJ. 1981. Macroclimate and plant forms: An introduction to predictive modelling in phytogeography. Dr. W. Junk. The Hague, Netherlands.

Buot IE Jr. & Okitsu S. 1999. Leaf size zonation pattern of woody species along an altitudinal gradient on Mt. Pulog, Philippines. Plant Ecology 145: 197-208.

Cain SA & De Oliveira-Castro GM. 1959. Manual of vegetation analysis. Harper and Brothers Publishers, New York.

Casilac CS, Dali-on SLG, Escobal EC & Aribal LG. 2018. Inferring zonation in mangrove ecosystem via leaf size indices in *Rhizophora apiculata* Blume. Journal of Biodiversity and Environmental Sciences 13(3): 134-140.

Chabot BF & Hicks DJ. 1982. The ecology of leaf life spans. Ann. Rev. Ecol. Syst. 13: 229-259.

Fernando ES, Suh MN, Lee K & Lee DK. 2008. Forest Formations of the Philippines. ASEAN – Korea Environmental Cooperation Unit (AKECHU). Geobook Publishing Co. www.geobook.co.kr

Fonseca CR, Overton JM, Collins C & Westoby M. 2000. Shifts in trait-combinations along rainfall and phosphorus gradients. Journal of Ecology 88: 964-977.

Givnish TJ. 1987. Comparative studies of leaf form: Assessing the roles of selective pressures and phylogenetic constraints. New Phytol. 106 (Suppl.): 131-160.

Guijarro, G.A. 2019. climatol: Climate Tools (Series Homogenization and Derived Products). R package version 3.1.2. Available from: https://CRAN.R-project.org/package=climatol (1 December 2019).

Grubb PJ. 1974. Factors controlling the distribution of forest types on tropical mountains: new facts and a new perspective. Pp. 13-46. In: Fenley JR (Ed.) Altitudinal zonation in Malesia. Department of Geography, University of Hull.

International Plant Names Index. 2015. Available from https://www.ipni.org/index (Retrieved 10

November 2021).

Kröber W, Böhnke M, Welk E, Wirth C & Bruelheide H. 2012. Leaf trait-environment relationships in a subtropical broadleaved forest in South-East China. PLoS ONE 7(4): e35742. https://doi.org/10.1371/journal.pone.0035742

Lambio IAF & Buot IE Jr. 2011. Leaf size zonation pattern of woody species along the northeastern altitudinal gradient of Mount Makiling, Luzon Island, Philippines. Asia Life Sciences 20(2): 369-383.

Liu YS. 1993. A paleoclimatic analysis on early Pleistocene flora of Changseling formation, Baise Basin, Guangxi, China. Acta Paleontologica Sinica 32: 151-169.

Mahaldo ACM, Malhi Y, Whittaker RJ, Ladle RJ, ter Steege H, Phillips OL, Butt N, Aragão LEOC, Quesada CA, Araujo-Murakami A, Arroyo L, Peacock J, Lopez-Gonzalez G, Baker TR, Anderson LO, Almeida S, Higuchi N, Killeen TJ, Monteagudo A, Neill D, Pitman N, Prieto A, Salomão RP, Vásquez-MartínezR & Laurance WF. 2009. Spatial trends in leaf size of Amazonian rainforest trees. Biogeosciences 6: 1563-1576.

Maire V, Wright IJ, Prentice C, Batjes NH, Bhaskar R, van Bodegom PM, Cornwell WK, Ellsworth D, Niinemets Ü, Ordonez A, Reich PB & Santiago LS. 2015. Global effects of soil and climate on leaf photosynthetic traits and trees. Global Ecology and Biogeography 24: 706-717.

Meneses, ZD and Cootes, JE. 2019. *Pseuderia samarana* (Orchidaceae), a new species and genus record from the Philippines. Taiwania, 64(4): 353- 356.

Merrill, ED. 1923-1926. An Enumeration of Philippine Flowering Plants. Vol. 1-4. Bureau of Printing, Manila

Mueller-Dombois D, Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, USA.

Obeña RDR, Tolentino PJS, Villanueva ELC, Fernandez DAP, delos Angeles MD & Buot IEJr. 2021. Flora and Fauna Inventory of Limestone Forests in Taft, Eastern Samar, Philippines. The Thailand Natural History Museum Journal 15(1): 1-20.

Ohsawa M. 1993a. The montane forest and its gradational changes in southeast Asia. Pp. 163-170. In: Hamilton LS, Juvik JO & Scatena FN (Eds.). Tropical montane cloud forests. East-West Center, Hawaii.

Ohsawa M. 1993b. Forest pattern along hierarchical habitat gradients in east Asia. In Kawatanabe H, Ohgushi T & Higashi M (Eds.). Symbiosphere: Ecological complexity for promoting biodiversity. Biology International (IUBS), Special Issue 29: 30-36.

Ohsawa M. & Ozaki K. 1992. Plant biometeorology - Hierarchical analysis of vegetation/environment pattern for east Asian extra tropical evergreen broadleaved forests. Japan J. Biometeorol. 29 (Suppl.): 93-103.

Pelser PB., Barcelona JF & Nickrent, D.L. (Eds). 2011-onwards. Co's Digital Flora of the Philippines. Available from: http://www.philippineplants.org (28 October 2021).

QGIS. 2021. QGIS Geographic Information System. Open Source Geospatial Foundation Project. Available from: http://qgis.osgeo.org (20 November 2021).

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: https://www.R-project.org/ (1 December 2021).

Reich PB, Walters MB & Ellsworth DS. 1992. Leaf life-span in relation to leaf, plant, and stand characteristics among diverse ecosystems. Ecol. Monog. 62: 365-392.

Restificar SDF, Day MJ & Urich PB. 2006. Protection of Karst in the Philippines. Acta Carsologica 35(1): 121-130.

Richards PW. 1996. The Tropical Rainforest: An ecological study. Cambridge University Press, Cambridge.

Rojo JP. 1999. Revised Lexicon of Philippine Trees. Forest Products Research and Development Institute, DOST, College, Laguna, Philippines, 484pp.

Shimwell DW. 1971. Description and Classification of Vegetation. Sidgwick and Jackson, London, 322 pp.

Tang CQ & Ohsawa M. 1999. Altitudinal distribution of evergreen broad-leaved trees and their leaf-size pattern on a humid subtropical mountain, Mt. Emei, Sichuan, China. Plant Ecology 145: 221-233.

Tolentino PJS, Natividad JRL, delos Angeles MD, Fernandez DAP, Villanueva ELC, Obeña RDR, Buot IE Jr. 2020. Review: Biodiversity of forests over limestone in Southeast Asia with Emphasis on the Philippines. Biodiversitas 21 (4): 1597-1613.

Villanueva ELC, Fernandez DAP, delos Angeles MD, Tolentino PJS, Obeña RDR & Buot IEJr. 2021a. Biodiversity in Forests over Limestone in Paranas, Samar Island Natural Park (SINP) A UNESCO World Natural Heritage Site Nominee. Tropical Natural History 21(1): 119-145.

Villanueva ELC, Fernandez DAP, Tolentino PJS, Obeña RDR & Buot IE Jr. 2021. Checklist of the Flora and Fauna of the Karst Forests in Basey, Samar, Philippines. The Thailand Natural History Museum Journal 15(2): 147-160.

Whitmore TC. 1984. Tropical rainforests of the Far East. Oxford University Press, Oxford.

Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686

Woodward FI. 1987. Climate and plant distribution. Cambridge University Press, New York.

Wright IJ, Dong N, Maire V, Prentice C, Westoby M, Díaz S, Gallagher RV, Jacobs BF, Kooyman R, Law EA, Leishman MR, Niiemets Ü, Reich PB, Sack L, Villar R, Wang H & Wilf P. 2017. Global climatic drivers of leaf size. Science 357(6354): 917-921.