BIODIVERSITAS
Volume 24, Number 9, September 2023
Pages: 5123-5136

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240957

Forests over limestone in Guiuan, Eastern Samar, the Philippines: Species composition and influencing environmental factors

INOCENCIO E. BUOT JR.♥, ELAINE LOREEN C. VILLANUEVA, MARNE G. ORIGENES, REN DIVIEN R. OBEÑA
Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños. CAS Building, Laguna, Philippines.
Tel.: +63-495-36 2893, ♥email: iebuot@up.edu.ph

Manuscript received: 8 August 2023. Revision accepted: 29 September 2023.

Abstract. *Buot Jr IE, Villanueva ELC, Origenes MG, Obeña RDR. 2023. Forests over limestone in Guiuan, Eastern Samar, the Philippines: Species composition and influencing environmental factors. Biodiversitas 24: 5123-5136.* Forests over limestone are critical ecosystems providing numerous ecosystem services. However, the ecology of these ecosystems is less studied like the Guiuan Marine Resource Protected Landscape and Seascape (GMRPLS) in Eastern Samar, Philippines which incidentally is affected by strong typhoons. Studies on forests over limestone are even more essential to understand the vegetation ecology providing insights in crafting appropriate management strategy to sustain ecosystem services. Hence, the study aims to identify the woody vegetation diversity and composition of forests over limestone in GMRPLS, and to analyze the environmental factors influencing the physiognomy and ecology of the forests. Standard vegetation techniques were used and a total of nine plots with size of 20 × 20m each were established to assess the tree species (≥1m height). Plant abundance data were recorded and computed. Soil samples were collected while climate data were obtained from the Guiuan, Eastern Samar Weather Station. Cluster analysis using relative density of trees per plot was done in order to identify major plant communities. Subsequently, a canonical correspondence analysis was carried out to pinpoint which environmental variables influenced the plant data set. Results show a total of 37 species belonging to 17 families, with 18 species are listed under by IUCN and seven species are listed by DAO 2017-11. Cluster analysis indicated 3 vegetation groupings or clusters named after the dominant species per plot, namely Cluster I (*Hancea-Calophyllum-Macaranga-Ficus-Gnetum*), Cluster II (*Monoon-Wallaceodendron-Artocarpus-Hancea*-Bago-eho), and Cluster III (*Bridelia-Monoon-Neonauclea-Gnetum-Artocarpus-Sterculia-Hancea*). GUI 02 plot (Cluster 1) was observed as the most diverse with the highest Simpson's index and Fisher's alpha, as well as the highest in total number of tree species. Canonical correspondence analysis indicated elevation, temperature and anthropogenic disturbances as the major factors influencing the vegetation diversity and composition. This can be used to formulate forest management strategies for the sustainable conservation of forests over limestone in GMRPLS.

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

INTRODUCTION

The study of landscapes and seascapes have been quite interesting recently (Buot 2008, 2010, 2014; IPSI 2014; Buot and Rabena 2020; Buot et al. 2020; Buot and Buhay 2022; Buot and Buot 2022; Buot et al. 2022a; Pungetti 2022). This is particularly eminent to working landscapes and seascapes, such as the Guiuan Marine Reserve Protected Landscape and Seascape (GMRPLS) in Samar Island, Central Philippines which has unique ecosystem of forests over limestone. These landscapes are closely associated with human activities (Buot and Osumi 2011; Sopsop and Buot 2013; Concepción et al. 2015; Wardle 2016; Médail 2017; Buot and Buhay 2022). In many parts of southeast Asia, these landscapes and seascapes have been overutilized, resulting in the degradation of natural resources and hence the critical ecosystem services beneficial for the neighboring human communities (Buot and Osumi 2011; Huyen et al. 2020; Buot and Buhay 2022; Pungetti 2022). The presence of intensive human activities is an important part of this working landscape, or also known as the socioecological production landscape and seascape (SEPLS). In 2010, working landscape was one of the important agenda of the Conference of the Parties (COP) of the Convention on Biological Diversity (CBD) of the United Nations (IPSI-UNU 2023), held in Nagoya, Japan. In that same COP meeting (COP 10), SEPLS or more popularly known as the Satoyama Initiative was approved as a conservation strategy (IPSI-UNU 2023). The initiative advocates for harmonious interaction between humans and nature.

Since 2010, there have been several initiatives launched, frameworks developed, and partnerships and networks established by the International Partnership for the Satoyama Initiative (IPSI) (IPSI-UNU 2023). Such efforts are aimed to ensure the success of this global initiative to hopefully diminish global species loss. More data are needed from different ecosystems all over the world in diverse contexts, to better understand human and nature interaction leading to crafting of appropriate sustainable biodiversity conservation management strategies. One important ecosystem type is the forests over limestone, which is quite extensive in the Philippines (Tolentino et al. 2019, 2020). It is one of the forest formation types in the Philippine tropical rainforests (Fernando et al. 2008), characterized by presence of caves, sinkholes, and aquifers

(BMB-DENR 2019). The forests over limestone provide unique ecosystem services to local communities including provisioning (food and medicine, timber), regulating (temperature regulation, carbon sequestration), and cultural services (esthetics, recreational) (Hamilton-Smith 2001; Clements et al. 2006; Struebig et al. 2009; BirdLife/FFI/ IUCN/WWF 2014; BMB-DENR 2019; Fernandez et al. 2020; Tolentino et al. 2019, 2020; Obeña et al. 2021; Villanueva et al. 2021a, b). It is also home to unique flora, fauna, and microbes which have coadapted and coevolved in this stressful environment (Hamilton-Smith 2001; Fernando et al. 2008; Tolentino et al. 2019, 2020; Obeña et al. 2021; Villanueva et al. 2021a, b). The forests over limestone, or *kaigangan* in the local *Waray* language, in Samar Island is one of the most extensive ecosystem types, not only in the Philippines, but in the entire Southeast Asia. The Guiuan Marine Resource Protected Landscape and Seascape (GMRPLS) of Eastern Samar is an interesting one. It is very near the beach and one can hear the splashing sound of the waves. However, due to the unfortunate geographic location of GMRPLS, along the Pacific Ocean, it is often visited by strong typhoons, storm surges and tsunamis, rendering the entire protected landscape being vulnerable to disturbances (Fernandez et al. 2020).

Few studies have been conducted on forests over limestone in the Philippines, including inventory and assessment of biodiversity in Samar Island Natural Park (Fernandez et al. 2020; Obeña et al. 2021; Villanueva et al. 2021a, b). Other studies were also conducted in different areas such as in Cebu (Cadiz and Buot 2009, 2010; Lillo et al. 2019, 2020a, b, c; Malaki et al. 2020a, b) and Verde Island Passage, Batangas (Caringal et al. 2019, 2021). Such forests over limestone have common problems, i.e., threat from anthropogenic activities such as mining, rapid land-use conversion, illegal hunting/poaching, and over-extraction of timber products (Clements et al. 2006; Struebig et al. 2009), resulting in forest fragmentation and species loss (Tolentino et al. 2020).

Among the studies, none had focused on typhoon-ravaged landscape like that of the Guiuan Marine Resource Protected Landscape and Seascape (GMRPLS), where environmental stresses had been doubly intensified. Hence, the current paper aims to assess the woody vegetation diversity and composition of forests over limestone in GMRPLS and to analyze the environmental factors influencing the characteristic physiognomy of GMRPLS. Results of this study will enhance our understanding on the vegetation of forests over limestone, particularly those under threat of typhoon and storm surges besides threat from human disturbances. Such understanding can help us craft sustainable biodiversity conservation strategies appropriate for the locality.

MATERIALS AND METHODS

Study area and period

This research was conducted from September to October 2019 in a socioecological production landscape and seascape (SEPLS) located in four barangays of the municipality of Guiuan, namely Pagnamitan, Baras, Ngolos, and Sulangan. These barangays are part of the Guiuan Marine Resource Protected Landscape and Seascape (GMRPLS), which is located off the coast of Guiuan at 11.0319° N latitude and 125.7261° E longitude. It is situated on the southernmost edge of the province of Eastern Samar, between the Leyte Gulf and the Philippine Sea, facing the Pacific Ocean (Figure 1).

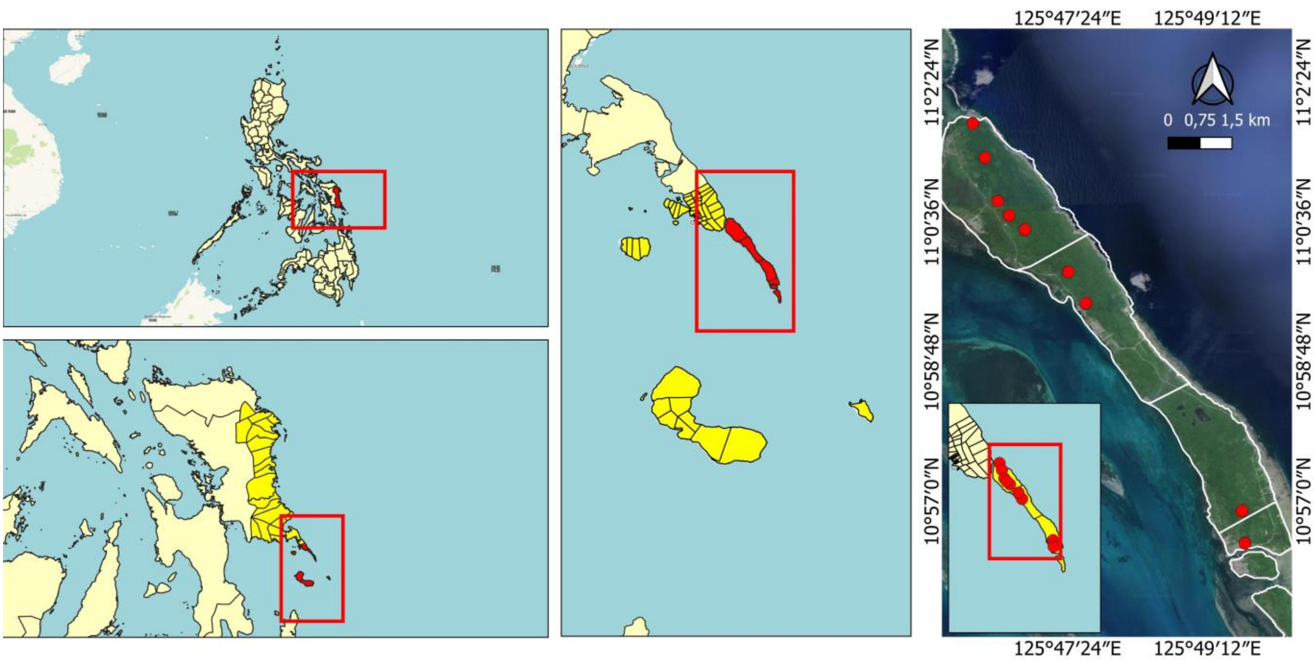


Figure 1. Map showing the location of the nine sampling plots in Guiuan, Eastern Samar, Philippines

The GMRPLS includes the coastal areas of Guiuan and its neighboring islands, as well as other small islands and their adjacent reefs, with a total area of 60,448 hectares (Fernandez et al. 2020). Additionally, the study sites are part of the declared protected landscape/seascape under the National Integrated Protected Areas System (NIPAS) Act of 1992 by Presidential Proclamation No. 469 series of 1994. People living close to the shore are dependent on marine resources through fishing, while those living in the inland are dependent on farming and other activities.

The study location has a Type II climate, with a prominent maximum rain period from December to February (UN WATER 2018). The municipality of Guiuan has no clear dry season the whole year round. Based on Guiuan weather stations, the lowest rainfall was recorded from April to October, and highest rainfall was recorded from December to January. The area has an average annual rainfall of 3146.6 mm (DA 2018) and an average temperature of 27.6°C based on the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The island, which is very close to the eastern coast, is vulnerable to the northeastern monsoon and falls within the typhoon belt.

Floral diversity assessment

A total of nine 20 m × 20 m vegetation sampling plots were set up across the four barangays as mentioned above where biophysical characteristics such as heterogeneity in terms of biota, topography, elevation, and the presence of anthropogenic disturbances were considered (Fernandez et al. 2020). These areas were chosen because they are part of Calicoan Island, the largest continuous forest over limestone area in the GMRPLS.

Trees (≥1 m height) and shrubs inside each plot were recorded and identified using keys and botanical literature. The nomenclature follows the study of Buot et al. (2022b) and Villanueva et al. (2022) in identifying plants. Voucher specimens of the unidentified plants were deposited at Plant Systematic Laboratory's Plant Biodiversity Division Herbarium (PBDH), Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños, Laguna, Philippines (Fernandez et al. 2020).

The documented species were then categorized based on their conservation status using the DENR Order No. 11 of 2017 (Updated National List of Threatened Plants and their Categories) and the IUCN Red List of threatened species (IUCN 2022).

Structural characteristics analysis

Vegetation analysis

Field data were collated and analyzed to characterize the floral composition in the study area. The following formula were used to calculate the relative density, relative dominance, and relative frequency of woody species (Mueller-Dombois and Ellenberg 1974):

$$Density = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ area\ of\ sampling}$$

$$Relative\ density = \frac{Density\ of\ a\ species}{Density\ of\ all\ species}\ x\ 100$$

$$Frequency = \frac{Number\ of\ plots\ of\ which\ a\ particular\ species\ occurs}{Total\ number\ of\ plots}$$

$$Relative\ Frequency = \frac{Frequency\ of\ a\ species}{Sum\ frequency\ of\ all\ species}\ x\ 100$$

$$Basal\ Area = \frac{Circumference^2}{4\pi}$$

$$Relative\ Basal\ Area = \frac{Basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species}\ x\ 100$$

Dominance analysis

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 density values and the expected share of 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, $\underline{x}$ is the ideal percent share based on the model, and x_j is the percent share of the remaining species U.

The equation demonstrates that the ideal dominance (the expected share) of a single species was based on the study of Ohsawa (1984), including the number of dominating species, which was determined by the one with the lowest deviation value.

Cluster analysis

The identification of the major plant communities in forests over limestone of GMRPLS was based on the cluster analysis using the relative density values. Datasets were calculated using the Paleontological Statistics (PAST) Software (Hammer 2001). The unweighted pair-group method with arithmetic mean (UPGMA) and Jaccard similarity index were then used to generate the dendrogram.

The species diversity of each identified zone was also examined. Diversity indices such as Shannon-Wiener index, Simpson's diversity index, and Fisher's alpha were also computed and graphed.

Species environment interaction analysis

Soil sampling

Following the methods of Villanueva et al. (2022), three (3) replicates of soil samples from the topsoil layer of around 30-cm depth and weighing 1kg were collected from each study plot in GMRPLS. These samples were homogenized per plot and submitted for soil analysis to the Analytical Services Laboratory of the Agricultural Systems Institute, College of Agriculture and Food Science (CAFS-ASI), of the University of the Philippines Los Baños (UPLB) for soil analysis (Villanueva et al. 2022).

Climate data

The climate data set of Samar Island was obtained from PAGASA. Information on monthly temperature and rainfall data came from Guiuan weather stations of PAGASA, the closest to the study sites of the project. A climograph (Walter-Lieth diagrams) of Guiuan was created using climatol package (Guijarro 2019) through R version 3.6.1 (R Core Team 2019), which includes the average monthly temperature and rainfall data for 25 years.

Canonical correspondence analysis

To determine the interaction between the tree species (relative density values) and the prevailing physical environment variables, canonical correspondence analysis (CCA) was used (Villanueva et al. 2022). Influences from environmental variables, such as temperature, elevation and quantitative edaphic variables, and the presence and absence of anthropogenic disturbance were subjected to analysis along with the woody vegetation data per plot. From these data, a CCA ordination diagram was created using Paleontological Statistics (PAST) Software (Hammer 2001). Temperature at different elevation levels was extracted from the climatic data obtained from PAGASA and assumed based on Sarmiento (1986) that there is a corresponding decrease of 0.6°C in temperature for every 100-meter elevation rise. Rainfall data was removed from the analysis since there is only one rainfall data entry in the nine plots, resulting in an error indicating that the standard deviation for rainfall is zero.

RESULTS AND DISCUSSION

Woody vegetation composition in GMRPLS

Results showed that in the study plots there were 29 plant species identified belonging to 17 families, with 11 endemic species. Eight species are yet unidentified making a total count of 37. Among the 37 species, some were classified as threatened, i.e. 18 by IUCN and 7 by the Philippine DAO 2017-11 (Table 1). The species listed in IUCN are *Hancea wenzeliana* (Slik) S.E.C.Sierra, Kulju & Welzen (Critically Endangered), *Shorea astylosa* Foxw. (Endangered), 3 Vulnerable species, *Heterospathe intermedia* (Becc.) Fernando, *Palaquium luzoniense* (Fern.-Vill.) Vidal and *Aquilaria cumingiana* (Decne.) Ridl. (Vulnerable), and 13 Least Concern species. On the other hand, species under DAO 2017-11, include *Shorea astylosa* as Critically Endangered, four species classified as Vulnerable (VU) i.e., *Shorea negrosensis* Foxw., *Wallaceodendron celebicum* Koord., *Palaquium luzoniense* (Fern.-Vill.) Vidal and *Aquilaria cumingiana* (Decne.) Ridl. and two other threatened species.

There is a need to monitor these species in the GMRPLS. They are major components in many tropical ecosystems (Caringal et al. 2019, 2021; Villanueva et al. 2022) and as such they contribute to ecosystem stability and resilience, enhancing the overall ecosystem services. However, because they are useful to humans and communities (Buot et al. 2022c), they are extremely vulnerable to gradual decrease in number and if unattended they can be locally extinct. The result of this study which recorded several threatened species implies that there is a need to prevent species loss and extinction by all means. Furthermore, biodiversity loss in the GMRPLS might affect the adjacent communities benefiting the ecosystem services it provides.

Table 2 shows the composition of tree species in the sampling plots in the GMRPLS including information on basal area, density and frequency and the corresponding relative values. Among all the species recorded, *M. oblongifolium* had the highest number of individuals (n=206) with relative density of 19.62%. In terms of relative basal area (RBA), *S. comosa, H. wenzeliana, A. scholaris,* Bago-eho and *W. celebicum* were the top 5 dominant species. On the other hand, in terms of relative density (RD), *M. oblongifolium, B. glauca, H. wenzeliana, A. rubrovenius,* and *G. gnemon* were the top 5 dominants. Finally in terms of frequency or occurrences, *M. oblongifolium, H. wenzeliana, G. gnemon, S. comosa, B. glauca,* and *A. cumingiana* are the top dominant species. These dominant species imply that they have been well-adapted to the environmental conditions in the area and demonstrated their capacity to exploit available resources in the forests over limestone in GMRPLS. In future landscape planning, such as building of biodiversity corridors and reforestation, it would be best to consider these dominant vegetation.

Clusters of vegetation in forests over limestone in GMRPLS

Cluster analysis of woody species was done to identify plant communities in the sampling plots of GMRPLS. The result showed three clusters of vegetation based on relative density values, at a similarity index of around 0.4 (Figure 2). Each cluster was named based on the dominant species per plot (see Table 2 and Figure 2). Cluster I is named *Hancea-Calophyllum-Macaranga-Ficus-Gnetum* Cluster. On the other hand, Cluster II is named *Monoon-Wallaceodendron-Artocarpus-Hancea*-Bago-eho Cluster, while Cluster III is named *Bridelia-Monoon-Neonauclea-Gnetum-Artocarpus-Sterculia-Hancea* Cluster.

Cluster I: Hancea - Calophyllum-Macaranga-Ficus-Gnetum

Cluster I (Figure 2) was observed at two (2) plots, namely the GUI 01(92 - 94 m asl) and GUI 02 plots (90-93 m asl), with a similarity index of around 0.58. These plots were situated at the highest elevation among the other sampling plots ranging from 90-94 m asl. The dominant species based on relative density were *Hancea wenzeliana, Calophyllum soulattri, M. tanarius, F. ampelas,* and *G. gnemon*. This cluster had the highest number of species (23 species), the most diverse (H'=2.521), as well as highest in Simpson 1-D and Fisher's alpha diversity index (see Table 3). The highest DBH value on this cluster was 63.66 cm (*W. celebicum*) and the maximum height was 27 m (*M. tanarius*). This cluster also had the smallest number of individuals per hectare (2562.5). Figure 3 shows the general physiognomic characteristics of the vegetation in Cluster I where there were observable small stems common in the entire Guiuan forests over limestone, which could be due to the numerous limestones scattered in various plots.

Table 1. List of vascular plants recorded in the forests over limestone of GMRPLS, Eastern Samar, the Philippines and their conservation status

Family | scientific name	Common name	Exsiccata	Habit	Conservation status		Ende-micity
				IUCN	Dao 2017-2011	
Spermatophyta: Gymnospermae						
Gnetaceae						
Gnetum gnemon L.	Bago	Obeña 7073 (PBDH)	T	LC	NE	N
Spermatophyta: Angiospermae						
Annonaceae						
Monoon oblongifolium (C.B.Rob.) B.Xue & R.M.K.Saunders	Lapisan	Obeña 7164 (PBDH)	T	-	NE	E
Apocynaceae						
Wrightia sp.	Hamor-awon	Obeña 7083 (PBDH)	T	-	NE	-
Alstonia scholaris (L.) R. Br.	Dita	Obeña 7081 (PBDH)	T	LC	NE	N
Arecaceae						
Saribus rotundifolius (Lam.) Blume	Anahaw	Obeña 7040 (PBDH)	T	-	OTS	N
Heterospathe intermedia (Becc.) Fernando	Banga	Obeña 7076 (PBDH)	T	VU	-	E
Caryota rumphiana Mart.	Pugahan/ Tagabunga	Obeña 7087 (PBDH)	T	LC	NE	N
Clusiaceae						
Calophyllum soulattri Burm.f.	Pamintaogon	Obeña 7128 (PBDH)	T	LC	-	N
Cornaceae						
Mastixia sp.	Tul-anan	Obeña 7148 (PBDH)	T	-	NE	-
Dipterocarpaceae						
Shorea astylosa Foxw.	Yakal	Obeña 7151 (PBDH)	T	EN	CR	E
Shorea negrosensis Foxw.	Red lauan	Obeña 7122 (PBDH)	T	LC	VU	E
Euphorbiaceae						
Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	Apanang	Obeña 7072 (PBDH)	T	CR	NE	E
Macaranga tanarius (L.) Müll.Arg.	Binunga	Obeña 7085 (PBDH)	T	LC	NE	N
Fabaceae						
Wallaceodendron celebicum Koord.	Banuyo/ Salukigi	Obeña 7077 (PBDH)	T	-	VU	N
Lauraceae						
Nothaphoebe leytensis (Elmer) Merr.	Bagubahi	Obeña 7075 (PBDH)	T	-	-	E
Malvaceae						
Sterculia comosa Wall.	Balinad	-	T	LC	NE	N
Moraceae						
Artocarpus blancoi (Elmer) Merr.	Antipolo	-	T	LC	NE	E
Artocarpus rubrovenius Warb.	Tugop	Obeña 7147 (PBDH)	T	-	OTS	E
Ficus ampelas Burm.f.	Lanete	Obeña 7084 (PBDH)	T	LC	NE	N
Ficus minahassae (Teijsm. & Vriese) Miq.	Hagimit	Obeña 7082 (PBDH)	T	LC	NE	N
Ficus sp. (1)	Dalakit	Obeña 7079 (PBDH)	T	-	NE	-
Pandanaceae						
Benstonea copelandii (Merr.) Callm. & Buerki syn.: *Pandanus copelandii* Merr.	Bariw		S	LC	-	E
Phyllanthaceae						
Bridelia glauca Blume	Anislag	Obeña 7102 (PBDH)	T	LC	NE	N
Rubiaceae						
Neonauclea formicaria (Elmer) Merr	Hambabalud	Obeña 7045 (PBDH)	T	LC	-	E
Sapotaceae						
Palaquium sp.	Bagotambis	Obeña 7074 (PBDH)	T	-	NE	-
Palaquium luzoniense	Nato	Obeña 7086 (PBDH)	T	VU	VU	N
Thymelaeaceae						
Aquilaria cumingiana (Decne.) Ridl.	Agar/ Lapnisan	Obeña 7070 (PBDH)	T	VU	VU	N
Gonystylus reticulatus (Elmer) Merr.	Batuan	-	T	-	NE	E
Unidentified	Bago-eho	Obeña 7095 (PBDH)	T	-	-	-
Unidentified	Bayarong	Obeña 7078 (PBDH)	T	-	-	-
Unidentified	Dalunutan	Obeña 7080 (PBDH)	T	-	-	-
Unidentified	Amahoyan	-	T	-	-	-
Unidentified	Atipon	-	T	-	-	-
Unidentified	Bagnaw	-	T	-	-	-
Unidentified	Kuyakya	-	T	-	-	-
Unidentified	Lubi	-	T	-	-	-

Note: Habit: (T: tree, S: shrub); Conservation status: (CR: Critically Endangered, EN: Endangered, VU: Vulnerable, OTS: Other Threatened Species, LC: Least Concern; NE: Not evaluated); Endemicity: (E: Endemic and N: non-endemic)

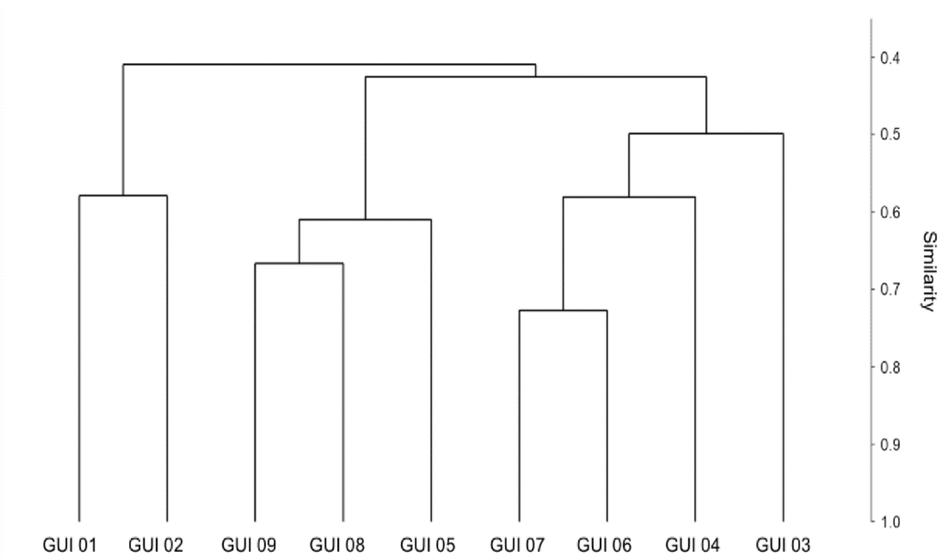
Table 2. Vegetation composition and characteristics in the forests over limestone in GMRPLS, Eastern Samar, the Philippines

Family | scientific name	BA	RBA	D	RD	F	RF
Annonaceae						
Monoon oblongifolium (C.B.Rob.) B.Xue & R.M.K.Saunders	0.55	5.06	0.0572	19.62	0.89	7.48
Apocynaceae						
Alstonia scholaris (L.) R. Br.	0.79	7.22	0.0036	1.24	0.33	2.80
Wrightia sp.	0.004	0.04	0.0006	0.19	0.11	0.93
Arecaceae						
Caryota rumphiana Mart.	0.004	0.04	0.0003	0.10	0.11	0.93
Saribus rotundifolius (Lam.) Blume	0.02	0.15	0.0003	0.10	0.11	0.93
Heterospathe intermedia (Becc.) Fernando	0.02	0.17	0.0028	0.95	0.33	2.80
Clusiaceae						
Calophyllum soulattri Burm.f.	0.19	1.72	0.0094	3.24	0.22	1.87
Cornaceae						
Mastixia sp.	0.12	1.13	0.0008	0.29	0.11	0.93
Dipterocarpaceae						
Shorea negrosensis Foxw.	0.004	0.03	0.0011	0.38	0.22	1.87
Shorea astylosa Foxw.	0.23	2.10	0.0003	0.10	0.11	0.93
Euphorbiaceae						
Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	0.86	7.88	0.0347	11.90	0.89	7.48
Macaranga tanarius (L.) Müll.Arg.	0.34	3.09	0.0114	3.90	0.44	3.74
Fabaceae						
Wallaceodendron celebicum Koord.	0.77	7.04	0.0136	4.67	0.22	1.87
Gnetaceae						
Gnetum gnemon L.	0.08	0.69	0.0164	5.62	0.89	7.48
Lauraceae						
Nothaphoebe leytensis (Elmer) Merr.	0.04	0.36	0.0014	0.48	0.11	0.93
Malvaceae						
Sterculia comosa Wall.	1.34	12.25	0.0103	3.52	0.67	5.61
Moraceae						
Artocarpus blancoi (Elmer) Merr.	0.32	2.95	0.0008	0.29	0.11	0.93
Artocarpus rubrovenius Warb.	0.67	6.11	0.0203	6.95	0.56	4.67
Ficus ampelas Burm.f.	0.27	2.48	0.0075	2.57	0.33	2.80
Ficus minahassae (Teijsm. & Vriese) Miq.	0.73	6.68	0.0083	2.86	0.56	4.67
Ficus sp.	0.24	2.23	0.0028	0.95	0.44	3.74
Phyllanthaceae						
Bridelia glauca Blume	0.60	5.46	0.0450	15.43	0.67	5.61
Rubiaceae						
Neonauclea formicaria (Elmer) Merr.	0.11	1.05	0.0133	4.57	0.33	2.80
Sapotaceae						
Palaquium sp. (1)	0.002	0.01	0.0006	0.19	0.22	1.87
Palaquium luzoniense	0.42	3.84	0.0025	0.86	0.22	1.87
Thymelaeaceae						
Aquilaria cumingiana (Decne.) Ridl.	0.21	1.91	0.0072	2.48	0.67	5.61
Gonystylus reticulatus (Elmer) Merr.	0.07	0.62	0.0022	0.76	0.22	1.87
(Unid) Amahoyan	0.004	0.04	0.0003	0.10	0.11	0.93
(Unid) Atipon	0.07	0.67	0.0006	0.19	0.22	1.87
(Unid) Bagnaw	0.12	1.14	0.0014	0.48	0.11	0.93
(Unid) Bago-eho	0.78	7.08	0.0092	3.14	0.56	5.61
(Unid) Bayarong	0.56	5.07	0.0031	1.05	0.44	3.74
(Unid) Dalunutan	0.19	1.77	0.0011	0.38	0.11	0.93
(Unid) Kuyakya	0.07	0.60	0.0008	0.29	0.11	0.93
(Unid) Lubi	0.15	1.33	0.0006	0.19	0.11	0.93
Total		**100**		**100**		

Note: Unid: unidentified species; BA: basal area; RBA: relative basal area; D: density; RD: relative density; F: frequency; RF: relative frequency

Table 3. Diversity indices of trees per plot in the forests over limestone in GMRPLS, Eastern Samar, the Philippines

Index	GUI 01	GUI 02	GUI 03	GUI 04	GUI 05	GUI 06	GUI 07	GUI 08	GUI 09
Elevation (m asl)	92-94	90-93	82-85	49-53	62-66	72-80	68-78	31-38	57-61
Number of species	15	23	7	13	9	10	12	8	10
Number of individuals	61	144	110	105	147	172	141	63	107
Shannon-Wiener Index (H’)	1.981	2.521	1.252	2.279	1.476	1.875	1.688	1.582	1.7
Simpson 1-D	0.7536	0.8848	0.6428	0.8791	0.6742	0.8146	0.7547	0.7473	0.7407
Fisher’s alpha (α)	6.353	7.724	1.664	3.906	2.115	2.314	3.135	2.429	2.699



Plot characteristics	CLUSTER I Dominants	CLUSTER II Dominants	CLUSTER III Dominants
Relative density	*Hancea wenzeliana* *Calophyllum soulattri* *Macaranga tanarius* *Ficus ampelas* *Gnetum gnemon*	*Monoon oblongifolium* *Wallaceodendron celebicum* *Artocarpus rubrovenius* *Hancea wenzeliana* Bago-eho	*Bridelia glauca* *Monoon oblongifolium* *Neonauclea formicaria* *Gnetum gnemon* *Artocarpus rubrovenius* *Sterculia comosa* *Hancea wenzeliana*
Max height (m)	27 m	20 m	20 m
Mean height (m)	7.44	6.32 m	6.39 m
Max DBH (cm)	63.66	54.11	63.66
Mean DBH (cm)	9.64	6.70 cm	6.63 cm
Basal area at breast height (m^2/ha)	41.68	25.25	28.62
Number of individuals per hectare	2562.5	2641.7	3300

Figure 2 . Dendrogram of the nine sampling plots in the forests over limestone of GMRPLS, Eastern Samar, the Philippines, showing the dominant tree species and the community structural features of each cluster

Cluster II: Monoon-Wallaceodendron-Artocarpus-Hancea-Bago-eho

Cluster II (Figure 2) has a similarity index of 0.61, which comprised three plots, namely GUI 09, GUI 08, and GUI 05, with elevations ranging from 31-66 m asl. The dominant species based on relative density were *Monoon oblongifolium, Wallaceodendron celebicum, Artocarpus rubrovenius, Hancea wenzeliana*, and Bago-eho (unidentified species).

The general physiognomic characteristic of Cluster II vegetation is shown in Figure 4. Again, there is this prominent small stem dominating the landscape. This cluster has the highest DBH value of 54.11 cm (*Shorea astylosa* and *Palaquium luzoniense*) and the maximum height value was 20 m (Lubi and bago-eho). It can be noted that both *Shorea* and *Palaquium* are listed as threatened species.

Cluster III: Bridelia-Monoon-Neonauclea-Gnetum-Artocarpus-Sterculia-Hancea

Cluster III (Figure 2) has a similarity index of around 0.5 and comprised of four plots (i.e. GUI 07, GUI 06, GUI 04, and GUI 03) with elevations ranging from 49-85 m asl. The dominant species based on relative density were *Bridelia glauca, Monoon oblongifolium, Neonauclea formicaria, Gnetum gnemon, Artocarpus rubrovenius, Sterculia comosa,* and *Hancea wenzeliana*. This cluster had the maximum DBH value of 63.66 cm for *Artocarpus blancoi, Sterculia comosa* and *Ficus minahassae* species. The maximum height was 20 m for the species *Artocarpus blancoi, Sterculia comosa, Bridelia glauca* and *Ficus* sp. Moreover, this cluster had the highest number of individuals per hectare (3300). Figure 5 shows the general vegetation growth pattern of Cluster III plots. Indeed, Guiuan Marine Resource Protected Landscapes and Seascapes vegetation is typical of younger forests over limestone characterized by small stems growing over rocky substrates with shallow soil layer.

Environmental variables influencing the typical physiognomy of GMRPLS

The ordination diagram of CCA analysis shows the environmental factors (e.g., temperature, elevation, disturbance, and 14 edaphic variables) that may have an influence on the structure and function of the forests over limestone in the GMRPLS (see Figures 6, 7 and Table 4). It illustrates the ordination plot with species (blue circles), sampling plots (red squares) and the environmental variables (arrows). The pattern of community variation illustrated in the ordination diagram is more closely related to environmental variables with long arrows than those with short arrows (ter Braak 1987). Different species found in different sampling plots in GMRPLS responded differently to the environment and their community structure changes with the seasons. As represented by long arrows, elevation and temperature were found to be the most important physical factors shaping the vegetation structure of GMRPLS. It was then followed by disturbances and other edaphic factors such as Na, Cu, pH, and Mn. Other factors, despite their lesser significance, have indirect and multiple effects on the distribution of some species in GMRPLS.

Elevation is one of the major factors influencing vegetation structure of GMRPLS, which is also positively correlated with Cu and less correlated with other edaphic factors, as shown in Figure 6. In a more detail, elevation has a significant influence on the species distribution found in plots GUI 03, GUI 05, GUI 06, and GUI 07 and is negatively correlated with plots in GUI 09, GUI 01, GUI 04, and GUI 02, which are found at elevations ranging from 49 to 94 meters above sea level. Elevation was found to be less significant in the GUI 08 plot, which has the lowest elevation and was more-affected by disturbances. GUI 01 and GUI 09 were two other plots that were influenced by human activity (see Table 4). It was noticed that the number of individual species decreased dramatically in the GUI 01 plot, which has the highest elevation of all sampling plots. Our analysis revealed that an increase in disturbances may result in a decrease in species diversity.

Anthropogenic disturbances have influenced vegetation in tropical forests of the Philippines particularly in GMPLRS. Human disturbances are widely believed to reduce species richness in tropical forest landscapes (Buot and Osumi 2011; Sopsop and Buot 2013; Nguyen et al. 2015; Imani et al. 2016; Van and Cochard 2017; Cabrera et al. 2018; Gilbert et al. 2020), as observed in the disturbed plots, such as GUI 08 (lowest elevation) and GUI 01 (highest elevation) (see Table 4). The results of this study agree with the findings of Sopsop and Buot (2013) in the Aborlan Guba System, that the lowest and highest portions of the forest experienced the greatest degree of human disturbance, with the former heavily impacted by *kaingin* farming or shifting cultivation and the latter by clearing due to resource harvesting. Similarly, Casas and Baguinon (2009) found that the number of tree species was lowest in areas with human activity on Samar Island Forest Reserve. Human impact on tropical mountain forests, such as logging and forest clearing for agriculture have transformed large portions of these ecosystems into human-dominated forest landscapes (Laurance et al. 2014; Chen et al. 2015; Newbold et al. 2015; IPCC 2019; Gao et al. 2019; Rana et al. 2019; Xu et al. 2019; Aureo et al. 2021). Globally, the magnitude and direction of changes in species richness are strongly influenced by the type, intensity, severity, frequency, and timing of disturbances (Buot and Osumi 2011; Sopsop and Buot 2013; Newbold et al. 2015; Barlow et al. 2018).

Figure 3. Cluster I vegetation in the forests over limestone of GMRPLS documented in GUI01 and GUI02 plots

Figure 4. Cluster II vegetation in the forests over limestone in GMRPLS documented in GUI09, GUI08, and GUI05 plots

Figure 5. Cluster III vegetation in the forests over limestone of GMRPLS documented in GUI07, GUI06, GUI04, and GUI03 plots

Table 4. Environmental conditions of the observation plots in the forests over limestone of GMRPLS

Plot	pH	OM	N	P	EC	K	Na	Ca	Mg	Fe	Zn	Cu	Mn	Cl	Elevation	Temperature (°C)	Disturbance
GUI 01	7.6	66.55	1.07	626	872	0.5	2.66	31.02	6.16	6.92	20.33	1.81	8.83	752	93.4	27.40	1
GUI 02	6.7	10.91	0.57	17	547	0.17	1.07	13.42	2.04	4.98	1.33	81.51	86.78	537	91.15	27.41	0
GUI 03	6.4	9.66	0.5	81.3	451	0.11	0.8	11.31	2.43	7.95	6.31	123.29	128.41	376	83.23	27.46	0
GUI 04	6.6	10.31	0.62	19.5	209	0.17	0.87	13.05	2.37	15.58	0.93	101.61	107.05	591	50.87	27.65	0
GUI 05	6.3	7.65	0.43	17	171	0.08	0.51	8.12	1.77	11.06	0.17	96.24	102.08	376	64.57	27.57	0
GUI 06	6.5	11.48	0.69	17.7	46	0.25	1.04	13.71	3.34	9.63	0.96	167.94	166.59	537	76.7	27.50	0
GUI 07	6.7	9.78	0.52	27	578	0.13	1.08	10.07	3.62	14.16	2.36	2.09	160.95	430	73.81	27.52	0
GUI 08	7.1	10.48	0.59	44	314	0.24	1.94	11.72	3.25	14	2.24	1.45	82.3	537	34.8	27.75	1
GUI 09	7.6	11.18	0.7	12.6	127	0.21	1.29	15.23	1.64	2.01	0.09	34.76	37.7	269	58.81	27.61	1

Note: Disturbance: (0: Absence, 1: Presence)

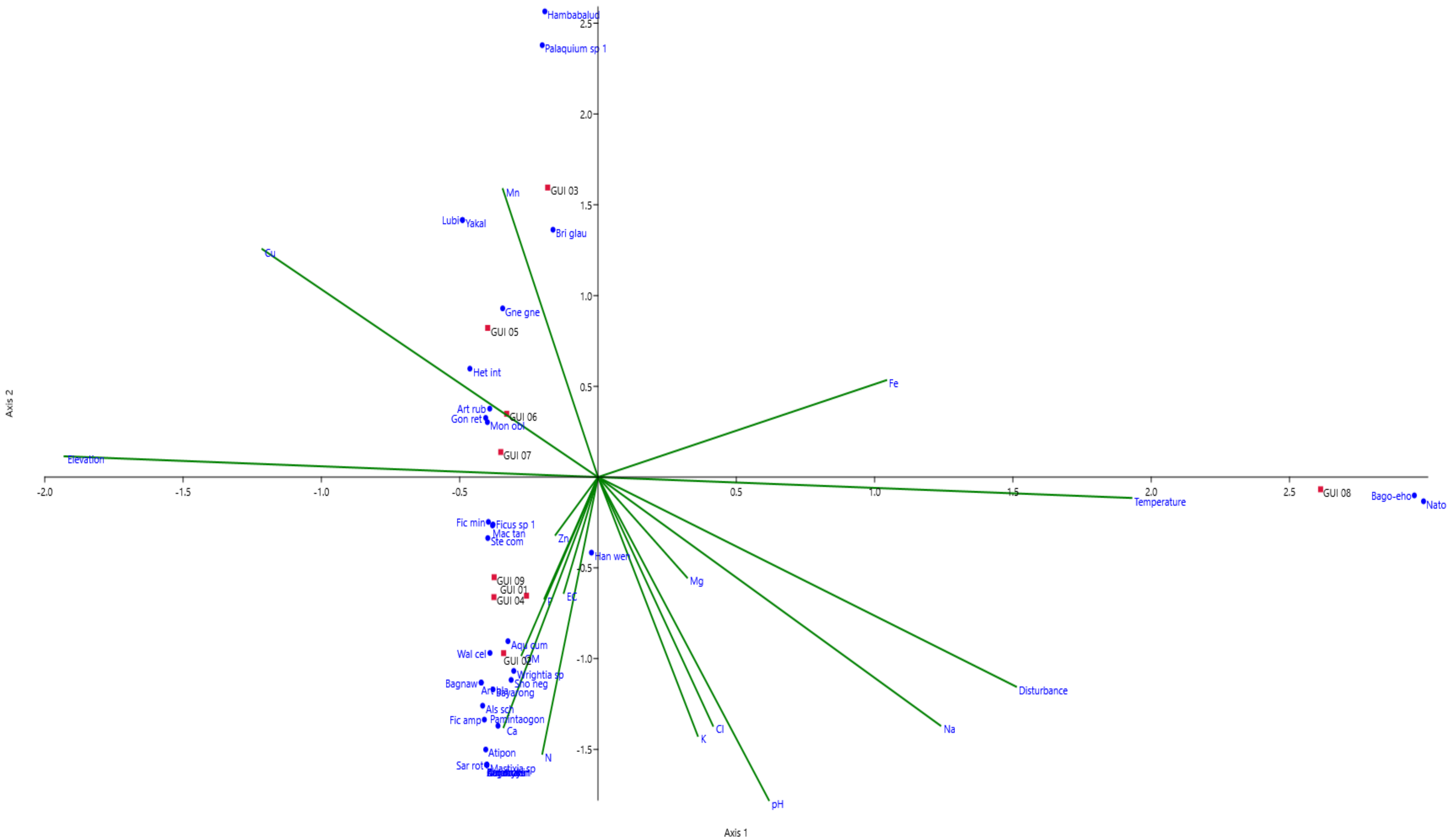


Figure 6. CCA ordination plot showing the species points (*blue dots*), plot points (*red squares*) and the environmental variables (*arrows*). A total of 17 variables were included in this analysis

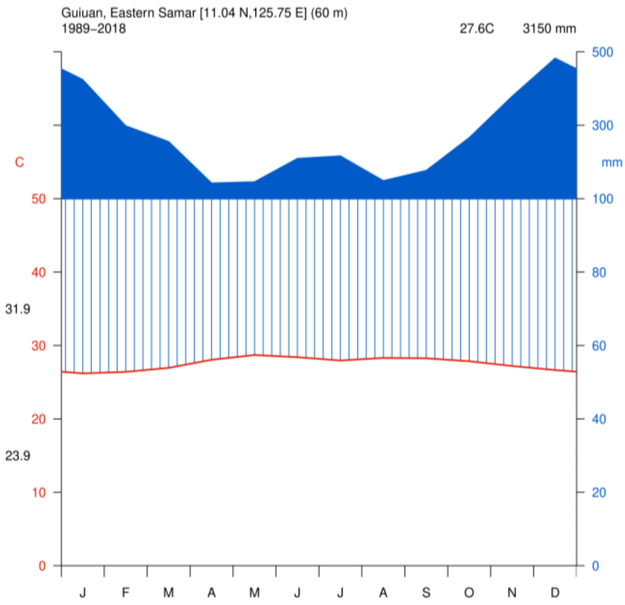


Figure 7. Average monthly temperature and rainfall data for the last 25 years for Guiuan, Eastern Samar. The data used for this climogram were obtained from PAGASA

Temperature is another important factor influencing the vegetation structure of GMPRLS (Figure 7). It influences the survival, growth, reproduction, and distribution of plants (Urban 2015; Howard et al. 2019; Kaspari et al. 2019). Temperature is positively correlated with Fe, disturbances, and the sampling plot GUI 08, with Nato and Bago-eho as dominant species. GUI 08 plot was located at the lowest elevation and had the second lowest number of species and individuals, and it was impacted by disturbances. Similar findings were also observed in Mount Pulag (Buot and Okitsu 1998, Aborlan Guba System (Sopsop and Buot 2013), and Mount Ilong in Halcon Range, Mindoro Island (Villanueva and Buot 2018).

Some edaphic factors, such as Na, Cu, pH, and Mn (represented by long arrows), have an impact on the vegetation structure of GMPRLS (Figure 6). Soil analysis revealed differences in soil chemical properties between sampling plots (Table 4), which can subsequently influence vegetation structure (Becknell and Powers 2014; De Jager et al. 2015; Rodrigues et al. 2016; Idowu et al. 2020; Bañares-de-Dios et al. 2022). As shown in Figure 6, Cu is correlated with sampling plots GUI 05, GUI 06, GUI 07, and GUI 03. However, it was observed that only GUI 06 had the highest Cu (167.94). In terms of soil pH, GUI 02 and GUI 04 plots were found to be slightly acidic, with pH values ranging from 6.6 to 6.7, while GUI 01 (7.6) and GUI 09 plots (7.6) had the highest pH value. Calubaquib et al. (2016) stated that the acidic nature of soils is induced by the extensive leaching of basic cations caused by too much rainfall. Karst surface deposits high pH, a low organic matter content, and a heterogeneous land surface (Abe et al. 2018). Furthermore, Mn influences sampling plots GUI 05 and GUI 03 and is less correlated with GUI 06, highest Mn (166.59) and GUI 07 sampling plots. In the study of Villanueva and Buot (2018), edaphic factors such as soil pH and nutrient levels were found to vary across an altitudinal gradient on Mt. Ilong, resulting in the delineation of tree communities reflecting different land use types.

The biplot shows 48.46% of the variations and patterns explained in the analysis. However, the remaining proportion of unexplained variations could be caused by other environmental factors that were not sampled or considered and could potentially explain the variation but were not included in the analysis. In general, the distribution of tree species in tropical ecosystems is the result of the interaction of multiple environmental factors that limit species distribution simultaneously (Diez et al. 2014*;* Keane 2017; Pham et al. 2021; He et al. 2022). This study provides an overview of the factors influencing vegetation in the forests over limestone of GMRPLS using the canonical correspondence analysis, and to some extent depth investigation on temperature, elevation and particularly, disturbance. These three major influencing environmental conditions along with the edaphic factors can be used to formulate management strategies for the sustainable conservation of forests over limestone in a typhoon ravished Guiuan, Samar Island.

In conclusion, the composition, distribution, and diversity patterns of species were investigated at nine sampling plots of forests over limestone in GMRPLS, which were mostly located at low elevations ranging from 31 to 94 m asl. There were 37 species belonging to 17 families, with 18 species on IUCN Red List and 7 species on Philippines' DAO 2017-11 Red List. GUI 02 plot was the most diverse, with the highest Simpson's index and Fisher's alpha, as well as the highest total number of tree species. The findings show the effects of anthropogenic activities on the abundance of species in disturbed plots. The number of individual species in GMRPLS plots GUI 08 (lowest elevation) and GUI 01 (highest elevation) decreased dramatically due to human disturbances. This finding implies that, despite the fact that the GMRPLS is a protected area, the species composition is changing over time as a result of threats and human disturbances. Other changes in the vegetation structure of species can be explained by the combined effect of elevation and temperature, which are the major factors influencing the vegetation structure of GMRPLS. Edaphic factors also contributed to the overall ecosystem structure in the Guiuan forests over limestone. The current study has provided valuable information which will serve as baseline for developing priorities for effective conservation and increased protection of GMRPLS.

ACKNOWLEDGEMENTS

The authors are grateful to the following organizations: the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) for providing rainfall data, the Department of Science and Technology- Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (DOST-PCAARRD) for providing funding the CONserve-KAIGANGAN program (Fund codes: N9A6323 & N926423) and serving as a monitoring agency that provided guidance to implement the project, the Department of Environment and Natural Resources Region VIII-Protected Area Management Board (DENR-PAMB) of Guiuan Marine Resource Protected Landscape and Seascape (GMRPLS) for issuing the Gratuitous Permit (DENR-GP No. 2019-16), the Basaranan nga Organisasyon han San Isidro Samar (BOSIS) for helping the authors to conduct the field work in SINP and to everyone who assisted the research team in doing field works (the field guides) and in the writing of the paper, especially in making suggestions for enhancement. Furthermore, the authors are also grateful to DOST-SEI for allowing the second and third authors to take part in this research program through the Career Incentive Program (CIP) and to the Plant Systematics Laboratory of the Institute of Biological Sciences, University of the Philippines Los Baños for providing a comfortable workspace to complete this research.

REFERENCES

Abe T, Tanaka N, Shimuzu Y. 2018. Plant species diversity, community structure and invasion status in insular primary forests on the Sekimon uplifted limestone (Ogasawara Islands). J Plant Res 131 (6): 1001-1014. DOI: 10.1007/s10265-018-1062-5.

Aureo W, Reyes Jr. T, Mutia FC, Tandang D, Jose R. 2021. Floristic composition and community structure along the elevational gradient of Balinsasayao Twin Lakes Natural Park in Negros Oriental, Philippines. One Ecosyst 6: e56536. DOI: 10.3897/oneeco.5.e56536.

Bañares-de-Dios G, Macía MJ, de Carvalho GM, Arellano G, Cayuela L. 2022. Soil and climate drive floristic composition in tropical forests: A literature review. Front Ecol Evol 10: 866905. DOI: 10.3389/fevo.2022.866905.

Barlow J, França F, Gardner TA, Hicks CC, Lennox GD, Berenguer E, Castello L, Economo EP, Ferreira J, Guénard B, Gontijo Leal C, Isaac V, Lees AC, Parr CL, Wilson SK, Young PJ, Graham NAJ. 2018. The future of hyperdiverse tropical ecosystems. Nature 559 (7715): 517-526. DOI: 10.1038/s41586-018-0301-1.

Becknell JM, Powers JS. 2014. Stand age and soils as drivers of plant functional traits and aboveground biomass in secondary tropical dry forest. Can J For Res 44 (6): 604-613. DOI: 10.1139/cjfr-2013-0331.

BirdLife/FFI/IUCN/WWF. 2014. Joint briefing paper on extraction and biodiversity in limestone areas. Cambridge, UK. https://www.birdlife.org/sites/default/files/Extraction-andBiodiversity-in-Limestone-Areas.pdf.

BMB-DENR. 2019. Protection and Conservation Strategy and Action Plan. http://www.bmb.gov.ph/bmb/CAWED/Proposed_Policy/CMPCSAP_ 2019-2028.pdf?cv=1

Buot IE Jr, Okitsu S. 1998. Vertical distribution and structure of the tree vegetation in the Montane Forest of Mt. Pulog, Cordillera Mountain Range, the highest mountain in Luzon Is., Philippines. Veg Sci 15: 19-32.

Buot IE Jr. 2008. Sustaining environmental health in Philippine Satoyama landscapes. Asia Life Sci Suppl 2: 129-138.

Buot IE Jr. 2010. Satoyama-like landscape in the Philippines: Prospects in the light of the recently-launched International Partnership for the Satoyama Initiative at COP 10. Proceedings of the Third International Conference on Forest Related Traditional Knowledge and Culture in Asia. Philippines, January 2010.

Buot IE Jr. 2014. Conservation and sustainability of socio-ecological production landscapes and seascapes. IAMURE Intl J Ecol Conserv 10 (1): 1-1.

Buot IE Jr, Buhay AFV. 2022. Types of socioecological production landscapes of the Philippines based on dominant biodiversity: Status, problems and future directions. Biodiversitas 23 (7): 3755-3770. DOI: 10.13057/biodiv/d230752.

Buot IE Jr, Osumi K. 2011. Land use type pattern and woody species composition near human disturbed 7 (4): 306-315. DOI: 10.3844/ajessp.2011.306.315.

Buot IE Jr, Rabena MAF. 2020. Ifugao Rice Terraces as a Satoyama Landscape in the 21st Century. In: Garcia PG, Serrano JV (eds). University of the Philippines Open University. https://networks.upou.edu.ph/33036/ifugao-rice-terraces-as-a-satoyama-landscape-in-the-21st-century/

Buot IE Jr, Habito CD, Bulong MP. 2020. Conserving Ifugao Rice Terraces satoyama landscape. In: Garcia PG, Serrano JV (eds). University of the Philippines Open University.

Buot MM, Buot IE Jr. 2022. Volcanic Seascapes. In: Routledge Handbook of Seascapes. Routledge, Oxfordsire. DOI: 10.4324/9780429273452-30.

Buot IE Jr, Origenes MG, Obeña RDR. 2022a. Conservation status of native mangrove species in the Philippines. J Wetl Biodivers 12: 51-65.

Buot IE Jr, Origenes MG, Obeña RDR, Villanueva ELC, delos Angeles MD. 2022b Some threatened woody plant species recorded from forests over limestone of the Philippines. J Threat Taxa 14 (11): 22058-22079. DOI: 10.11609/jott.8119.14.11.22058-22079.

Cabrera O, Benítez A, Cumbicus N, Naranjo C, Ramón P, Tinitana F, Escudero A. 2018. Geomorphology and altitude effects on diversity and structure of vanishing Montane Forest of Southern Ecuador. Diversity 11 (3): 32. DOI: 10.20944/preprints201810.0283.v1.

Cadiz GO, Buot IE Jr. 2009. An enumeration of the woody plants of Cantipla Forest fragments, Cebu Island, Philippines. Philippine J Syst Biol 3 (1): 1-7. DOI: 10.3860/pjsb.v3i1.1008.

Cadiz GO, Buot IE Jr. 2010. An enumeration of the vascular plants of Mount Tabunan, Cebu Island, Philippines. Thai Nat Hist Mus J 4 (2) 71-77. DOI: 10.3860/pjsb.v3i1.1008.

Calubaquib MAM, Navarrete IA, Sanchez PB. 2016. Properties and nutrient status of degraded soils in Luzon, Philippines. Philipp J Sci 145 (3): 249-258.

Caringal AM, Buot IE Jr, Villanueva ELC. 2019. Woody plant communities in the Philippine teak forest landscape along Verde Island Passage, Batangas, Luzon, Philippines. Biodiversitas 20 (11): 3189-3198. DOI: 10.13057/biodiv/d201111.

Caringal AM, Buot IE Jr, Villanueva ELC. 2021. Endemic Philippine teak (*Tectona philippinensis* Benth. & Hook. F.) and associated flora in the coastal landscapes of Verde Island Passage, Luzon Island, Philippines. Curr Sci 120 (6): 1057. DOI: 10.18520/cs/v120/i6/1057-1065.

Casas EV, Baguinon NT. 2009. Optimizing landscape value for man and nature: A case study of land-suitability mapping to conserve biodiversity in Lawaan, Eastern Samar, Philippines. Applied GIS 5 (1): 1-27. DOI: 10.4225/03/57E1E3F4DDA61.

Chen L, Tang LN, Ren Y, Liao J. 2015. Ecological land classification: A quantitative classification and ordination of forest communities adjacent to a rapidly expanding urban area in southeast coastal China. ActaEcol Sin 35: 46-51. DOI: 10.1016/j.chnaes.2014.12.002.

Clements R, Sodhi NS, Schilthuizen M, Ng PKL. 2006 Limestone karsts of Southeast Asia: Imperiled arks of biodiversity. BioScience 56 (9): 733. DOI: 10.1641/0006-3568(2006)56[733:LKOSAI]2.0.CO;2.

Concepción ED, Moretti M, Altermatt F, Nobis MP, Obrist MK. 2015. Impacts of urbanisation on biodiversity: The role of species mobility, degree of specialisation and spatial scale. Oikos 124 (12): 1571-1582. DOI: 10.1111/oik.02166.

De Jager, NR, Rohweder JJ, Yin Y, Hoy E. 2015. The Upper Mississippi River floodscape: Spatial patterns of flood inundation and associated plant community distributions. Appl Veg Sci 19 (1): 164-172. DOI: 10.1111/avsc.12189.

Department of Agriculture-[RFU8] (DA). 2018. Eastern Visayas. https://www.darfu8.tripod.com.

DENR Administrative Order 2017-11. Updated National List of Threatened Philippine Plants and Their Categories. https://bmb.gov.ph/index.php/e-library/laws-andpolicies/denr-administrative-orders/dao-2017-2020?download=197:denradministrativeorder-2017-11 [13 July 2021]

Diez JM, Giladi I, Warren R, Pulliam HR. 2014. Probabilistic and spatially variable niches inferred from demography. J Ecol 102 (2): 544-554. DOI: 10.1111/1365-2745.12215.

Fernandez DAP, delos Angeles MD, Obeña RDR, Tolentino PJS, Villanueva ELC, Buot IE Jr. 2020. Fauna and flora of forests over Limestone in Calicoan Island, Guiuan Marine Reserve Protected Landscape and Seascape (GMRPLS), Eastern Samar, Philippines. J Mar Isl Cult 9 (2): 86-104. DOI: 10.21463/jmic.2020.09.2.07.

Fernando ES, Suh MH, Lee J, Lee DK. 2008. Forest Formations of the Philippines. ASEAN-Korea Environmental Cooperation Unit (AKECU), Seoul National University, Korea.
Gao M, Piao S, Chen A, Yang H, Liu Q, Fu YH, Janssens IA. 2019. Divergent changes in the elevational gradient of vegetation activities over the last 30 years. Nat Commun 10 (1): 2970. DOI: 10.1038/s41467-019-11035-w.
Gilbert KJ, Bittleston LS, Naive MAK, Kiszewski AE, Buenavente PAC, Lohman DJ, Pierce NE. 2020. Investigation of an elevational gradient reveals strong differences between bacterial and eukaryotic communities coinhabiting nepenthes phytotelmata. Microb Ecol 80 (2): 334-349. DOI: 10.1007/s00248-020-01503-y.
Guijarro GA. 2019. Climatol: Climate Tools (Series Homogenization and Derived Products). R package version 3.1.2. https://CRAN.Rproject. org/package=climatol
Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Paleontological Statistics Software package for education and data analysis. Palaeontol Electron 4 (1): 1-9.
Hamilton-Smith E. 2001. Current initiatives in the protection of karst biodiversity. Nat Croatica 10 (3): 229-242.
He C, Jia S, Luo Y, Hao Z, Yin Q. 2022. Spatial distribution and species association of dominant tree species in Huangguan Plot of Qinling Mountains, China. Forests 13 (6): 866. DOI: 10.3390/f13060866.
Howard C, Flather CH, Stephens PA. 2019. What drives at-risk species richness? Environmental factors are more influential than anthropogenic factors or biological traits. Conserv Lett 12 (2): e12624. DOI: 10.1111/conl.12624.
Huyen NT, Viet PB, Nguyen LD. 2020. Assessing the Applicability of Radar and Optical Images in Monitoring a Mangrove Forest: A Case Study of Ca Mau Province, Vietnam. In: Buot I Jr. E. (eds). Methodologies Supportive of Sustainable Development in Agriculture and Natural Resources Management: Selected Cases in Southeast Asia. Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) and the University of the Philippines Los Baños (UPLB), Laguna, Philippines.
Idowu GA, Olonimoyo EA, Idowu AM, Aiyesanmi AF. 2020. Impact of gas and oil-fired power plants on proximal water and soil environments: Case study of Egbin power plant, Ikorodu, Lagos State, Nigeria. SN Applied Sciences. Springer Nature, Switzerland. DOI: 10.1007/s42452-020-3150-0.
Imani G, Zapfack L, Kalume J, Riera B, Cirimwami L, Boyemba F. 2016. Woody vegetation groups and diversity along the altitudinal gradient in mountain forest: Case study of Kahuzi-Biega National Park and its surroundings, RD Congo. J Biodivers Environ Sci 8 (6): 134-150.
IPSI [International Partnership for the Satoyama Initiative]. 2014. The International Partnership For The Satoyama Initiative (IPSI): Working towards societies in harmony with nature. United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS, Shibuya-ku, Tokyo.
IPSI-UNU [International Partnership for the Satoyama Initiative - United Nations University]. 2023. The Satoyama Initiative. Published on the Internet, https://satoyama-initiative.org/
IUCN [International Union for Conservation of Nature]. 2022. The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org
IPCC. 2019. Global Warming of 1.5 C. An IPCC special report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. https://www. ipcc.ch/sr15
Kaspari M, Bujan J, Roeder KA, Beurs K, Weiser MD. 2019. Species energy and thermal performance theory predict 20-yr changes in ant community abundance and richness. Ecology 100 (12): e2888. DOI: 10.1002/ecy.2888.
Keane R. 2017. Disturbance regimes and the historical range and variation in terrestrial ecosystems. In: Reference Module in Life Sciences. Elsevier, Amsterdam. DOI: 10.1016/b978-0-12-809633-8.02397-9.
Laurance WF, Sayer J, Cassman KG. 2014. Agricultural expansion and its impacts on tropical nature. Trends Ecol Evol 29: 107-116. DOI: 10.1016/j.tree.2013.12.001.
Lillo EP, Malaki ABB, Alcazar SMT, Nuevo RU, Rosales R. 2019. Native Trees on Mount Lantoy Key Biodiversity Areas (KBA), Argao, Cebu, Philippines. Philipp J Sci 148 (2): 359-371.
Lillo EP, Malaki ABB, Alcazar SMT, Rosales RC, Redoblado BR, Gealon GGG, Diaz JLB, Pantinople EM, Buot IE Jr, Leano E. 2020a. Flora of Mount Capayas Key Biodiversity Area an Introductory Guide. Cebu Technological University (CTU), Argao Campus, Department of Science and Technology (DOST), and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Los Baños.
Lillo EP, Malaki ABB, Alcazar SMT, Rosales RC, Redoblado BR, Gealon GGG, Diaz JLB, Pantinople EM, Buot IE Jr, Leano E. 2020b. Flora of Nug-as Forest Key Biodiversity Area an Introductory Guide. Cebu Technological University (CTU), Argao Campus, Department of Science and Technology (DOST), and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Los Baños.
Lillo EP, Malaki AB, Alcazar SMT, Rosales R, Redoblado BR, Pantinople E, Nuevo RU, Cutillar RC, Almirante A, Buot IE Jr. 2020c. Diversity and distribution of ferns in forest over limestone in Cebu Island Key Biodiversity Areas (KBAs), Philippines. Biodiversitas 21: 413-421. DOI: 10.13057/biodiv/d210148.
Malaki ABB, Lillo EP, Alcazar SMT, Rosales RC, Redoblado BR, Gealon GGG, Diaz JLB, Pantinople EM, Buot IE Jr, Leano E. 2020a. Fauna of Mount Capayas Key Biodiversity Area. An Introductory Guide. Cebu Technological University (CTU), Argao Campus, Department of Science and Technology (DOST), and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Los Baños.
Malaki ABB, Lillo EP, Alcazar SMT, Rosales RC, Redoblado BR, Gealon GGG, Diaz JLB, Pantinople EM, Buot IE Jr, Leano E. 2020b. Fauna of Nug-as Forest Key Biodiversity Area an Introductory Guide. Cebu Technological University (CTU), Argao Campus, Department of Science and Technology (DOST), and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Los Baños.
Médail F. 2017. The specific vulnerability of plant biodiversity and vegetation on Mediterranean islands in the face of global change.Reg Environ Change 17 (6): 1775-1790. DOI: 10.1007/s10113-017-1123-7.
Mueller-Dombois D, Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, USA.
Newbold T, Hudson LN, Hill SLL et al. 2015. Global effects of land use on local terrestrial biodiversity. Nature 520 (7545): 45-50. DOI: 10.1038/nature14324.
Nguyen TV, Mitlöhner R, Bich NV. 2015. Environmental factors affecting the abundance and presence of tree species in a tropical lowland limestone and non-limestone forest in Ben En National Park, Vietnam. J For Environ Sci 31: 177-191. DOI: 10.7747/jfes.2015.31.3.177.
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. Thai Nat Hist Mus J 15 (1): 1-20.
Ohsawa M. 1984. Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji. Plant Ecol 57: 15-52. DOI: 10.1007/BF00031929.
Pham VV, Ammer C, Annighöfer P, Heinrichs S. 2021. Tree regeneration characteristics in limestone forests of the cat ba national park, Vietnam. BMC Ecol Evol 22 (1): 1-6. DOI: 10.21203/rs.3.rs-244706/v1.
Pungetti G. 2022. Routledge Handbook of Seascapes. Routledge, Oxfordshire. DOI: 10.4324/9780429273452.
Rana SK, Gross K, Price TD. 2019. Drivers of elevational richness peaks, evaluated for trees in the east Himalaya. Ecology 100: e02548. DOI: 10.1002/ecy.2548.
R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
Rodrigues PMS, Schaefer CEGR, Silva JdeO, Ferreira Júnior WG, dos Santos RM, Neri AV. 2016. The influence of soil on vegetation structure and plant diversity in different tropical savannic and forest habitats. J Plant Ecol 11 (2): 226-236. DOI: 10.1093/jpe/rtw135.
Sarmiento G. 1986. Ecologically crucial features of climate in high tropical mountains. In: Vuilleumier F. Monasterio M. (eds). High Altitude Tropical Biogeography, Oxford University Press, Oxford.
Sopsop LB, Buot IE Jr. 2013. The forest types in Aborlan Guba System, Palawan Island, Philippines. IAMURE Intl J Ecol Conserv 7 (1): 1-1. DOI: 10.7718/ijec.v7i1.729
Struebig MJ, Kingston T, Zubaid A, Le Comber SC, Mohd-Adnan A, Turner A, Rossiter SJ. 2009. Conservation importance of limestone

karst outcrops for Palaeotropical bats in a fragmented landscape. Biol Conserv 142 (10): 2089-2096. DOI: 10.1016/j.biocon.2009.04.005.
ter Braak CJF. 1987. The Analysis Of Vegetation-Environment Relationships By Canonical Correspondence Analysis. In Theory And Models In Vegetation Science. Springer, Netherlands. DOI: 10.1007/978-94-009-4061-1_7.
Tolentino PJS, Villanueva ELC, Buot IE Jr. 2019. Leaflet: Assessment and Conservation of Forest over Limestone Ecosystem Biodiversity in Selected Municipalities of Samar Island, Philippines. CONserve-KAIGANGAN, IBS, UPLB, College, Laguna.
Tolentino PJ, Navidad 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: 1597-1613. DOI: 10.13057/biodiv/d210441.
UN-Water country briefs Philippines. 2018. https://www.unwater.org.
Urban MC. 2015. Accelerating extinction risk from climate change. Science 348 (6234): 571-573. DOI: 10.1126/science.aaa4984.
Van YT, Cochard R. 2017. Tree species diversity and utilities in a contracting lowland hillside rainforest fragment in Central Vietnam. For Ecosyst 4: 9. DOI: 10.1186/s40663-017-0095-x.
Villanueva ELC, Buot IE Jr. 2018. Vegetation analysis along the altitudinal gradient of Mt. Ilong, Halcon Range, Mindoro Island, Philippines. Biodiversitas 19: 2163-2174. DOI: 10.13057/biodiv/d190624.
Villanueva ELC, Fernandez DAP, delos Angeles MD, Tolentino PJS, Obeña RDR, Buot IE Jr. 2021a. Biodiversity in forests over limestone in Paranas, Samar Island Natural Park (SINP) A UNESCO World Natural Heritage Site Nominee. Trop Nat Hist 21 (1): 119-145.
Villanueva ELC, Fernandez DAP, Tolentino PJS, Obeña RDR, Buot IE Jr. 2021b. Checklist of the Flora and Fauna of the Karst Forests in Basey, Samar, Philippines. Thai Nat Hist Mus J 15 (2): 147-160.
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. DOI: 10.13057/biodiv/d231248.
Wardle DA. 2016. Do experiments exploring plant diversity-ecosystem functioning relationships inform how biodiversity loss impacts natural ecosystems?. J Veg Sci 27 (3): 646-653. DOI: 10.1111/jvs.12399.
Xu W-B, Svenning J-C, Chen G-K, Zhang M-G, Huang J-H, Chen B, Ordonez A, Ma K-P. 2019. Human activities have opposing effects on distributions of narrow-ranged and widespread plant species in China. Proc Nat Acad Sci 116: 26674-26681. DOI: 10.1073/pnas.1911851116.