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Plant Diversity and Vegetation Characteristics of the Forest over Limestone Mining Site in Tubay, Agusan del Norte, Philippines

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A B S T R A C T

Mining in areas with high diversity and endemism pose serious and highly specific threats to biodiversity. The study aims to assess the plant diversity, community structure, and vegetation characteristics of the limestone forest mining site in Tubay, Agusan del Norte, Philippines. The limestone mining project is covered by the Mineral Production Sharing Agreement (MPSA) of Agata Mining Ventures Incorporated (AMVI). A field survey was carried out in twelve (12) 20 m x 20 m nested plots established in the two sampling sites; Site 1 (Payong-payong) and Site 2 (Tinigbasan). Payong-payong can be categorized as a forest over limestone while Tinigbasan is an agricultural, planted forest. Results revealed 206 plant species belonging to 78 families and 145 genera. Of these, fourteen were identified as threatened species. When plants are grouped into plant habit, results revealed that trees and shrubs had the highest number of species among the group. *Vitex parviflora* (tugas) and *Artocarpus blancoi* (Antipolo) obtained the highest species importance value (SIV) in sites 1 and 2, respectively, indicating that the two are the most influential and important species. Both areas showed a high diversity of plants with a composite Shannon diversity of 3.97. Multivariate analysis showed significant variation in plant community structure (Anosim R=0.7, p<0.001), which suggests differences and uniqueness of plant species composition between the two sampling sites. The differences in species diversity and community structure of plants can be attributed to the variety of forest habitat types and physical attributes found in the two areas. Our data provide valuable information in creating pragmatic and effective conservation and management strategies for the sustainable use of resources while preserving the ecological integrity and biodiversity as mining progresses in the limestone forest.

Keywords: *Forest over limestone, Mining, Plant Diversity, Vegetation*

1 Introduction

Mining in areas with high diversity and endemism poses serious and highly specific threats to biodiversity. However, mining can also be a means for financing alternative livelihood paths that, over the long-term, may prevent biodiversity loss. Complex and controversial issues associated with mining and biodiversity conservation are often simplified within a narrow frame oriented towards the negative impacts of mining at the site of extraction, rather than posed as a series of challenges for the conservation science community to embrace (Sonter et al. 2018). More than half of the estimated mineral wealth of the Philippines is found in Mindanao where almost 50 percent of gold and 60 percent nickel reserves of the country (DOST-PCIEERD 2017). Its mineral deposits are valued at $312 billion or about 40 percent of the country's total mineral reserves of $840 billion (NEDA 2010). In Caraga Region, approved mineral production sharing agreements (MPSA) as of the latest record have reached a total of 301, covering an area of more than 500, 000 hectares (DENR MGB – Caraga 2020). In 2018, the economic contribution of mining and quarrying in Caraga Region is more than 17 billion, which accounted to almost 17 % of the total Gross Regional Domestic Product (GRDP) (DENR MGB-Caraga 2019). Despite the economic benefits of mining industry in the region, little is known about its potential impacts on terrestrial ecosystems and biodiversity, particularly on plants.

Agata Mining Ventures, Inc. (AMVI) is one of the mining corporations in the region that invested a substantial portion of its operational budget into research for crafting sound reforestation and rehabilitation plans. A good management plan guarantees sustainable use of existing natural resources such as soil, water, timber, and biodiversity with the preparation and revision of this is a very crucial process, thus, appropriate knowledge on these resources is vital. However, during mining activities where mineral ores were extracted utilizing the open-pit method, many biota having ecological and scientific importance were still displaced (Sarmiento 2020).

The company proposes a new limestone project located south of the Agata North Laterite Project (ALNP) mine pit, near the causeway at Sitio Payong-Payong, Barangay Tinigbasan, Tubay, Agusan del Norte (TVIRD 2013). The limestone project is covered by the Mineral Production Sharing Agreement (MPSA) of AMVI. The company is currently securing a new ECC to conduct mining activity in the proposed limestone project site. The mineral limestone deposit is estimated to have 36 million tons at 55% Calcium oxide (97% $CaCO_3$) (TVIRD 2013). A limestone forest ecosystem is extremely diverse because of its rugged topography and various communities, which are in different stages of succession (Zhu et al. 1996, 1998). Previous studies in a forest over limestone (FOL) in Dinagat Islands revealed high species richness (144 species) and diversity (H'=3.9) (Lillo et al. 2019). The need for limestone forest research has been recognized as a conservation priority for the sustainability of these forests, particularly because natural and anthropogenic disturbances are increasing (Sodhi et al. 2010). Hence, empirical data on plant diversity and surrounding habitats of the proposed limestone mining site is needed to monitor changes in the ecosystem health of limestone forest as mining progresses in the area.

Quantitative data obtained through biodiversity inventories are useful to determine the nature and distribution of biotic resources and help in biodiversity conservation (Rennolls and Laumonier 2000). The present study aimed at assessing the plant diversity and community structure, ecological status, and vegetation characteristics on the proposed limestone forest mining site in Tubay, Agusan del Norte, Philippines. Our floristic data will serve as a basis for current and future conservation, management, and monitoring activities as mining progresses in the limestone forest within the MPSA of AMVI.

2 Materials and Methods

Study Site

Maps from the company were used to initially assess and identify the terrestrial flora biodiversity in the area. A Rapid Resource Assessment was employed to determine the present condition of floral species within and outside of the proposed mining project. Two sites were identified: Site 1 (Payong-payong) was located where the direct impacts are possibly observed and Site 2 (Tinigbasan) was located adjacent to site 1 and outside of the proposed mining project (Figure 1).

Sampling Design

Two km transects were established in each identified site (Figure 1). In each transect, six (6) 20 x 20 m plots were established for the assessment of trees. Smaller subplots measuring 5 x 5 m were established to assess the understory including the shrubs, herbs, and grasses. All species of flora were accounted for inside the established plot to measure the plant species richness, abundance, and diversity. A Global Positioning System (GPS) device was used to track the location of each plot. Transect walk was likewise done between plots to enrich the data on species richness. A transect walk

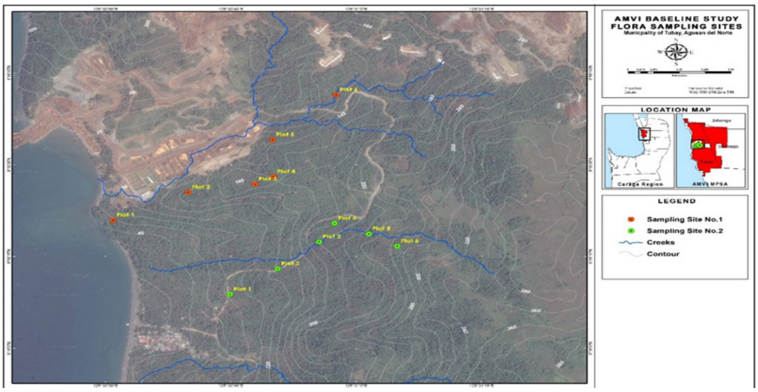

Figure 1. Flora Sampling Sites within Agata Mining Ventures Incorporated (AMVI), Tubay, Agusan del Norte, Philippines.

is a rapid biodiversity assessment technique that employs a hike, recording of species, and physical attributes. This method seeks all major ecosystems, determines stratified zones, and map the areas across the established transects.

Measurements of Physical Attributes

All measurements of physical attributes were conducted within the established plots to determine the vegetation characteristics of the sampling site. Air temperature and relative humidity were measured using a thermo-hygrometer. The slope was measured using a digital clinometer application in mobile phones. Leaf litter thickness was measured using a ruler. The percent canopy and percent ground cover were estimated by the researcher. The different vegetation types encountered along the transect and its dominant species and characteristics were also recorded.

Floral Identification and Assessment of Status

Plant species were identified to the lowest taxon possible through the help of a local guide and taxonomic keys from floras and monographs (Merrill 1926, Brummitt 1992, Madulid 1995b, Rojo 1999, and Regrario et al. 2017). Online websites such as philippineplants.org, and Co's digital flora of the Philippines (CDFP) facebook page were also utilized (Pelser et al. 2011). Documentation of diagnostic features (i.e flowers, fruits, leaves, and roots) was conducted. The conservation status of the identified species was assessed basing on the national list of threatened Philippine Plants (DENR Administrative Order 2017) and the IUCN red list of threatened species (IUCN 2020).

Statistical Analysis

Species diversity indices were analyzed using species richness, abundance, evenness, and dominance and Shannon diversity. Paleontological Statistics software (PAST) version 2.17c was used to analyze the biodiversity indices (Hammer et al. 2001). The most important species in the area was determined using the species importance value (SIV) index (English et al. 1997). The calculations were shown below:

$$\text{Density} = \frac{\text{Number of individuals of a species in all quadrats}}{\text{Total area sampled}}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species (100)}}{\text{Total number of occurrences of all species}}$$

$$\text{Frequency} = \frac{\text{Number of plots in which a species occurred}}{\text{Total number of plots sampled}}$$

$$\text{Relative frequency} = \frac{\text{Frequency value for a species (100)}}{\text{Total of frequency value for all species}}$$

$$\text{Dominance} = \frac{\text{Total basal area of each tree of a species from all plots}}{\text{The total area of all the measured plots}}$$

$$\text{Relative dominance} = \frac{\text{Dominance for a species (100)}}{\text{Total dominance for all species}}$$

Species Important Value (SIV) =Relative Density + Relative frequency + Relative Dominance

Statistical differences in the physical attributes and species diversity between the two sampling sites were analyzed using Student's *t*-Test in R software version 4.0.2 (R Core Team 2020). Prior to the analysis, assumptions of normality and homogeneity of variances were checked. Data were log-transformed if necessary to meet the assumptions of the test.

The forest structure data were analyzed using PRIMER 6 software (Clarke and Gorley 2006). A series of non-parametric multivariate analyses including cluster analysis, non-metric multidimensional scaling (nMDS), Analysis of Similarities (ANOSIM), and Similarity Percentages (SIMPER) were performed. Before the analysis, the species abundance data was transformed using the square root transformation technique to equalize the importance of rare and abundant species. The down-weighted data was subjected to Bray-Curtis Similarity matrix. The similarity matrix was used to analyze the community structure of plants using the above-mentioned analyses.

3 Results and Discussion

Forest Habitat Types and Characteristics

The variation and occurrence of site-specific habitat characteristics greatly affect the plant species diversity and structure of the sampling area. The vegetation type of proposed mining area in Payong-payong is a forest over limestone (FOL) with mountainous topography which lies at an elevation of 30-120 masl. The forest is characterized by having less dense vegetation, with diameter at breast height (DBH) of trees ranging from 12 cm -196 cm. The understory is composed of large exposed rocks with innumerable perforations and hollow areas, thin soil substrate and, undecomposed organic matter coming mostly from fallen leaves, downed trees, and twigs. The area is generally sloppy ranging from 44-115% slope which is significantly higher (mean=83, $p<0.05$) than Tinigbasan site (Table 1). The temperature ranges from 27-30 °C and relative humidity from 71%-90%, and did not vary between the sites. The Payong-payong limestone forest also have significantly higher canopy cover (69%, $p<0.05$), low ground cover (17%, $p<0.05$), and thick leaf litter (6.2 cm, $p<0.05$) content as compared to Tinigbasan. The presence of rocky substrate and high canopy over contributes to the accumulation of leaf litter and lower ground vegetation cover. Furthermore, the higher canopy cover ranging from 50-83% per 400m^2 plot is likely due to the dominance of trees in the area.

The major habitat types found in the limestone forest were; a) patches of the planted area dominated by *Cocos nucifera* (Fig. 2a), b) secondary forest dominated by stunted, medium-size trees such as *Adinandra* sp. and *Canthium* sp. and few large, tall trees such as *Ficus variegata*, *V. parviflora* and *A. blancoi* (Fig. 2b, 2c), c) riparian forest dominated by *Ficus gigantifolia*, *Pandanus* sp. and *Freycenetia* sp. growing near the river banks (Fig. 2d), and d) scrubland and grassland located in open areas near the foot of the mountain and dominated by sedges, grasses and some shrubs such as *Piper aduncum. Canthium* sp., a medium-sized, tree, was seen as a dominant species in the higher elevations, near the peak of the mountain (Figure 2c). Moreover, *V. parviflora* is a characteristic species and distributed throughout the limestone forest, similar to the findings of a floristic study in a forest over limestone (FOL) in Dinagat and Palawan Islands (Fernando et al. 2008, and Lillo et al. 2019), which is likely an indicator of limestone vegetation.

In Tinigbasan, the site is generally considered as an agricultural, planted forest with DBH of trees ranging from 10 cm – 204 cm. The area lies at 20-190 masl, and located near the local community. The substrate ranges from clayish to sandy with thick humus and has a portion of loss soils at higher elevations. The average air temp is 27.8°C, and relative humidity of 83%. The area generally has a lower average canopy cover (41%) and leaf litter thickness (3 cm), and higher ground cover (60%). The openness of the area due to lower canopy cover permits penetration of sunlight, allowing the growth of understory and ground vegetation, as well as, facilitating the faster decomposition of organic matter. Such attributes are typical characteristics of a planted forest dominated by *C. nucifera* (Lubi) and *Falcataria mollucana* (Falcata). The major habitat types were: a) *Cocos* dominated land, b) *Falcataria* dominated land, c) shrubland dominated by *Melastoma* and *Neonauclea*, d) grassland dominated by sedges, grasses, and some ferns and, e) patches of secondary forest dominated by remnants of large trees of *Artocarpus* (Antipolo) (Figure 3).

Table 1. The physical attributes of the two sampling sites. Shown are minimum, maximum and mean (± SEM) values. Values with asterisk (*) indicate significant differences and analyzed through parametric T-test.

Variables	Payong-Payong (S1)			Tinigbasan (S2)			Significance
	Min	Max	Mean (± SEM)	Min	Max	Mean (± SEM)	(p-value)
Air temperature (°C)	27	30	28.2 ± 0.5	27	29	27.8 ± 0.4	p>0.05
Slope (%)	44	115	83.3 ± 9.8	26	60	39 ± 4.8	p<0.05*
Relative Humidity (%)	71	89	81.2 ± 2.7	80	90	83.2 ± 1.4	p>0.05
Canopy Cover (%)	50	83	68.7 ± 5.1	30	65	40.8 ± 5.4	p<0.05*
Ground Cover (%)	10	28	17.2 ± 3.1	20	90	60 ± 12	p<0.05*
Leaf Litter (cm)	4	8	6.2 ± 0.7	2	7	3 ± 0.8	p<0.05*

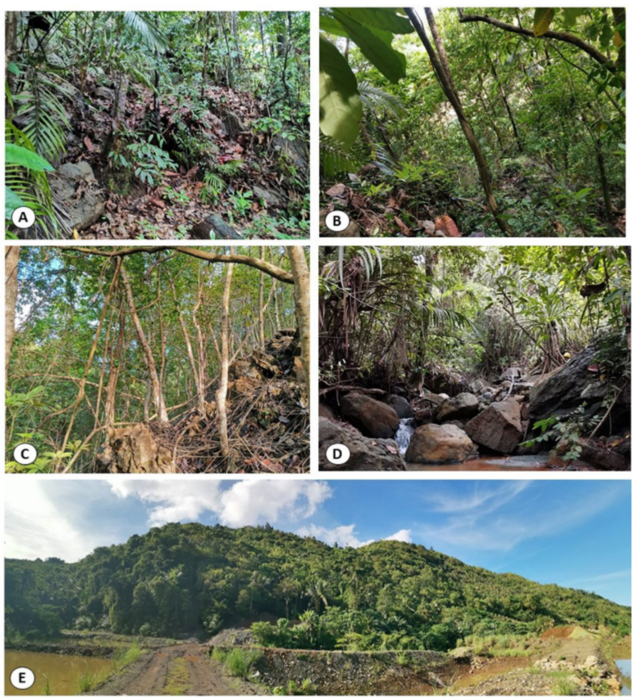

Figure 2. The forest habitat types in the proposed limestone mining project in Payong-Payong. Shown are a) agricultural forest, b) secondary forest dominated by mixed species, c) secondary forest dominated by *Canthium* sp., d) riparian habitat, and e) the panoramic view of the site. Photos by: Archie A. Along (July 16, 2020)

Taxonomic Values

The assessment of plants in the two sampling sites (12 plots and through transect walk) recorded a total of 206 species belonging to 78 families and 145 genera (Table 2). There were 181 species of angiosperms belonging to 66 families and 130 genera, while 25 species, 12 families, and 15 genera for Pteridophytes. Of the 206 species, 116 species were recorded within the plot. The two sampling sites differ in terms of plant species composition. Alpha taxonomy revealed higher taxonomic values for Payong-payong (149 species, 117 genera, 65 families) than Tinigbasan (133 species, 107 genera, 67 families) (Fig. 4). Existing studies on forest over limestones in the Philippines also documented high species richness of plants, which is mostly represented by angiosperms (Fernando et al. 2008, Lillo et al. 2019, and Aureo et al. 2020).

The most represented plant families in Payong-payong were Moraceae (9 species), followed by Arecaceae (8 species) and, Fabaceae and Euphorbiaceae (7 species) (Fig. 5). In

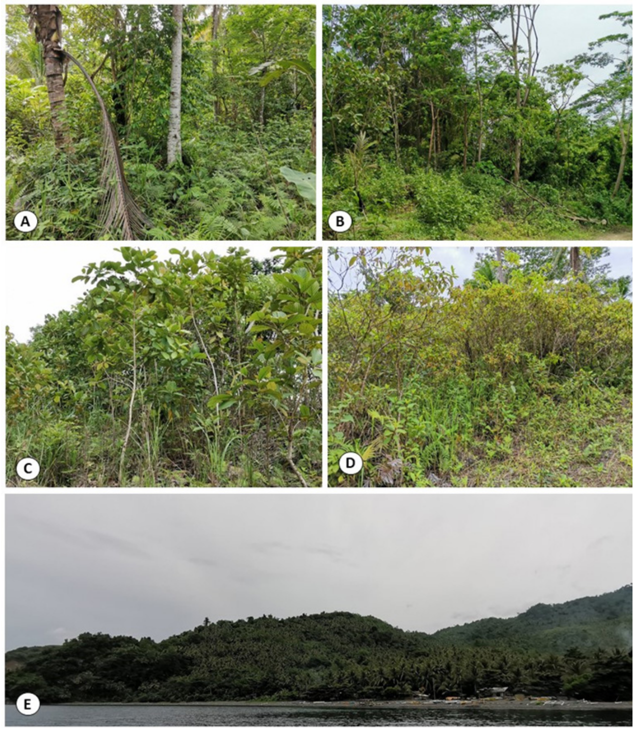

Figure 3. The forest habitat types in Tinigbasan, adjacent to the proposed Limestone project site. Shown are a) *Cocos* dominated land, b) *Falcataria* dominated land, c) *Neonauclea* dominated land, D) Shrubland dominated by *Melastoma* and E) Panoramic view of the site. Photos by: Archie A. Along (July 17, 2020)

Table 2. Summary of total number of families, genera, and species for each plant groups collected in the study stations.

Plant groups	Families	Genera	Species
Angiosperms	66	130	181
Pteridophytes	12	15	25
Total	78	145	206

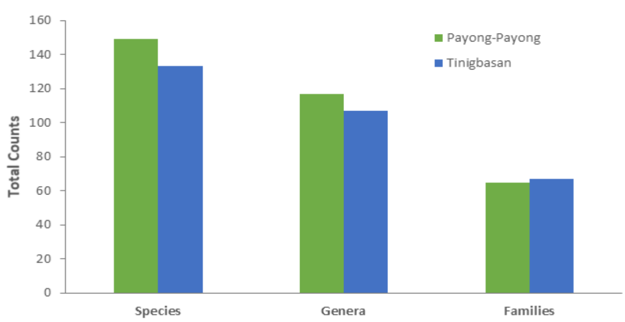

Figure 4. The taxonomic values in the two sampling sites.

Tinigbasan, family Moraceae (14 species) still dominated the area, followed by Fabaceae and Araceae with 6 species each. The Moraceae family commonly known as the mulberry or fig family has many representative species with cosmopolitan distribution and is widely spread in different habitats of the tropical region. The genus *Ficus* under the Moraceae family was revealed to have the highest number of species in Payong-payong (8 species) and Tinigbasan (11 species). The species under this genus serve as keystone species due to their essential role in tropical landscapes such as food for vertebrates (e.g bats, birds) and invertebrates (Bain et al. 2015). Family Fabaceae can thrive well in areas with low amounts of essential nutrients because of its ability to fix nitrogen in the atmosphere with the help of associated *Rhizobacteria* in their roots. Family Arecaceae, or the palm family, have various growth forms and can grow best in moist and shady areas and usually among the most cultivated plant families.

The plant species recorded in the area were characterized into six (6) plant habit groupings including herbs, grass, vine, palm, ferns and fern allies, and trees and shrubs (Fig. 6). When plants are grouped into plant habit, results revealed that trees and shrubs had the highest number of species among the group, while lowest for grasses for both areas. Payong-payong limestone forest harbors the highest number of trees and shrubs, palms, and fern and fern allies. Conversely, Tinigbasan contains relatively higher values for vines and grasses.

The uniqueness of habitat types and environmental conditions contributed to the differences in the plant species richness, diversity, and occurrence of different plant habits. Because of the diversity of topography, rocky substrate, steepness of slope, and soil depth in Payong-payong, there is a wide range of microhabitat for plants, owing to great spatial heterogeneity in the limestone forest. These attributes contribute to higher species richness and occurrence of multiple life forms in the area, especially the trees. The richness of trees support the growth of herbs and fern and fern allies since these life forms require shade from trees and a minimal amount of sunlight to flourish in the ground. In addition, the availability of flowing water in Payong-payong, which is not observable in Tinigbasan, is essential for the growth of different plant habits, particularly the herbaceous and ferns and fern-allies. On the other hand, the agricultural landscape pattern in Tinigbasan with open canopies allow for the growth of species of grasses, sedges, vines, and some ferns that thrive abundantly in semi-open areas. Such variability in site-specific habitat characteristics affects the species composition and diversity of plants in the two areas.

Species Importance Value (SIV)

The dominance and ecological success of a species are expressed as a single value in terms of the Importance Value Index (IVI). This index utilizes three parameters viz., relative frequency, relative density, and relative dominance or basal area. In the case of shrubs and herbs, only two former parameters are taken into consideration. High IVI values of a species indicate its high regeneration capacity and greater ecological amplitude (Lamont et al. 1977).

A total of 150 individual trees were found within the established plots in both sampling sites. *V. parviflora* (Tugas), *Adinandra elliptica* (Sagimsim), and *Radermachera pinnata* (Magasili) obtained the highest importance value in Payong-payong while in Tinigbasan, *A. blancoi* (Antipolo),

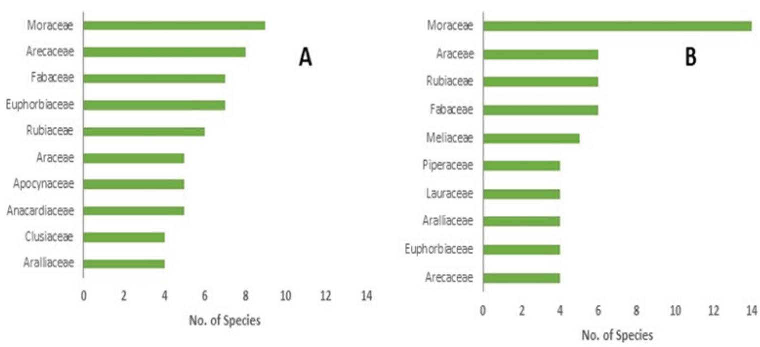

Figure 5. The top 10 most represented families in Payong-Payong (A) and Tinigbasan (B)

Falcataria mollucana (Falcata), and *Gmelina arborea* (Gmelina) dominated the area (Table 3). The results suggest that these species were the most influential and important species with higher counts and greater frequency per unit area. The removal of these species in the area may affect the survival of the other species. Furthermore, as observed many wildlings and samplings of these aforementioned species were found in the vicinity indicating that these particular trees had a very good capacity for regeneration.

Payong-payong had more species of trees (31) but stunted in growth compared to Tinigbasan with 21 species with bigger and taller species. The DBH of trees in Payong-payong had a mean diameter of 18.13 cm while Tinigbasan had 21.55 cm. Among the species, *A. blancoi* was the most distributed tree species in the whole area and was observed to have the largest canopy cover. The average height of trees in the area ranges from 3.0 to 20 m. As such, the vegetation is dominated by naturally stunted trees in a limestone forest.

Plant Diversity and Conservation Status

Plot-based sampling revealed a composite Shannon diversity (H') of 3.97 for the whole area. The sampling sites has a computed species diversity value of 404 species abundance, 0.64 evenness, 116 species richness, and 0.02 dominance. The value of species diversity estimations suggests that the area has a high diversity of plants (Macdonald 2003, and Ulfah et al. 2019). There was no significant variation ($p>0.05$, $n=6$) of plant diversity between sites, and that, both the Payong-payong limestone forest (H=3.49) and Tinigbasan (H=3.76) harbors a high diversity of plants (Table 4). The high diversity in limestone forests is attributed mainly to lower dominance (0.04) and higher evenness (0.74). The results conform to the study of forest over limestone (FOL) in Dinagat Islands, which revealed high

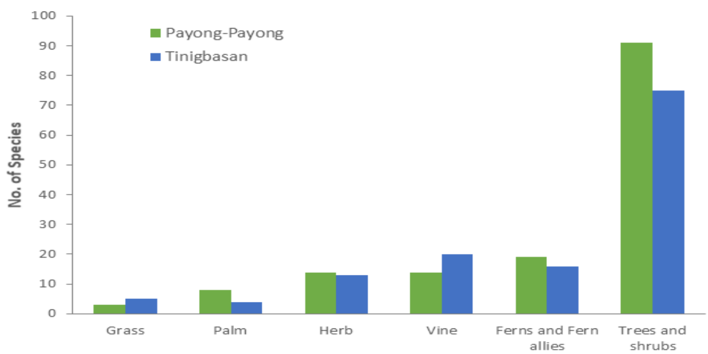

Figure 6. Comparison of the number of species per plant habit in the two sampling sites.

Table 3. Top 3 species with the highest SIV in each site

Site	Species	SIV (%)
Site 1	*Vitex parviflora* A. Juss (Tugas)	24.42
	Radermachera pinnata (Blanco) Seem. (Magasili)	18.34
	Adinandra elliptica C.B. Rob (Sagimsim)	17.59
Site 2	*Artocarpus blancoi* (Elmer) Merr. (Antipolo)	35.17
	Falcataria mollucana (Miq.) Barneby and J.W.Grimes (Falcata)	33.52
	Gmelina arborea Roxb. (Gmelina)	28.56

Table 4. The computed diversity metrics in the two sampling sites within AMVI.

Variable	Payong-Payong (S1)	Tinigbasan (S2)	Overall
Species Richness	61	85	116
Abundance	122	282	404
Dominance	0.04	0.03	0.02
Shannon Diversity	3.49	3.76	3.97
Evenness	0.74	0.66	0.64

plant diversity values (n=144 species, H=3.88, 0.9 evenness) (Lillo et al. 2019). The varied ecological niches and complex terrains contributed to high species diversity within the limestone landscapes (Asanok and Marod 2016, and Tolentino et al. 2020). The analysis also detected a significantly lower evenness ($p<0.05$, n=6) in Payong-payong than in Tinigbasan. This suggests that no particular species dominate the area and most of the species present were evenly distributed across the site. On the other hand, the relatively higher diversity in Tinigbasan might be explained by the higher abundance (282 individuals), richness (85 species) and, lower dominance (0.03) of plant species.

The sampling area recorded fourteen (14) threatened species of plants (Table 5). Threatened species are plants that face the brink of extinction due to a variety of natural and anthropogenic factors which can be categorized into three; vulnerable, endangered, and critically endangered. There were seven (7) vulnerable and seven (7) endangered which is 7% (14 out of 206 species) of the total number of species in the two sampling sites in AMVI. Of the threatened species, four were found in Payong-payong, three in Tinigbasan, and seven species were common in both sites. Some limestone forest in the Philippines is home to several endemic and threatened species of plants which can serve as trigger species for selecting conservation priorities (Replan and Malaki 2017, Lillo et al. 2019, and Aureo et al. 2020).

Plant Community Structure

The Bray Curtis Cluster and nMDS analyses were used to find natural grouping patterns of sampling units (plots) with similar species assemblages (Fig. 8). The cluster analyses showed two grouping patterns at 25% similarity. The two sampling sites clustered independently into two separate groups. These were composed of; 6 plots from Tinigbasan (plus plot 2 in limestone) as one big group, and the remaining five plots from Limestone forest as a separate group. However, higher bray curtis similarity (30%) revealed three clustering groups. Tinigbasan plots were divided into two; plot 2, 3, 4, 5 as one group, while plot 1, plot 6 both from Tinigbasan, and plot 2 from limestone forest as another group. The third group was the clustering of five plots located within the limestone forest. These findings were consistent with the result of nMDS analysis as shown in figure 9. The ordination showed a clear dispersion of plant communities in the two sites similar to the grouping as depicted in cluster analysis. The nMDS also show a stress value of 0.15 suggesting a good representation of the differences in the dataset. The clustering and proximity of sampling plots within a group as depicted in the nMDS and cluster graphs indicated a higher similarity of plant community which share similar species composition. Conversely, the separation of the sampling plots between groups indicated a lower community similarity of plants suggesting that the areas differ in plant species composition. Using ANOSIM, the differences between the two sampling sites as observed in nMDS and Cluster analyses were highly significant (Global R=0.7, $p<0.001$). The ANOSIM result showed moderate to high dissimilarity of plant species between the two

Table 5. The list of threatened plant species in the sampling sites.

Species	Common Name	Conservation Status	Site
Anisoptera thurifera (Blanco) Blume	palosapis	Vulnerable	Payong-payong
Artocarpus blancoi (Elmer) Merr.	Antipolo	Vulnerable	Both Sites
Begonia bolsteri Merr.	Begonia	Vulnerable	Tinigbasan
Cyathea contaminans (Wall. ex Hook.) Copel	Anonotong	Endangered	Both Sites
Diospyros philippinensis A.DC.	Kamagong gubat	Endangered	Both Sites
Dracontomelon dao (Blanco) Merr. & Rolfe	Dao	Vulnerable	Tinigbasan
Litsea leytensis Merr.	Bantuling	Endangered	Payong-payong
Myristica philippenses Lam.	Duguan	Endangered	Payong-payong
Pterocarpus indicus Wild.	Narra	Endangered	Both sites
Flueggea flexousa Mull. Arg.	Anislag	Vulnerable	Both Sites
Shorea negrosensis Foxw.	red lawaan	Vulnerable	Both Sites
Swietenia macrophylla King	Broad leaf Mahogany	Vulnerable	Tinigbasan
Vitex parviflora A. Juss.	tugas	Endangered	Both Sites
Xanthustemon verdugonianus	Mangkono	Endangered	Payong-payong

sites.

The plant species composition and structure differ significantly between Payong-payong and Tinigbasan sites. Based on SIMPER analysis, the limestone forest in Payong-Payong can be described as "*Vitex-Adinandra-Ficus*" community due to its higher contributions of the species similarity within the site with a cumulative percentage of 47%. Limestone forests are made up of diverse plant communities that are floristically unique compared to other forest types (Tolentino et al. 2020). In contrast, the forest in Tinigbasan can be characterized as an "*Artocarpus-Ficus-Falcataria*" community which together accumulate 40% of species similarity contributions. Despite the similarly higher diversity, it could be argued that both sites harbor unique plant species grouping, and that, some species can only be found and dominates, thereby shaping the community structure of the area. The differences in plant communities might indicate that plant growth in each site is site-specific and can only adapt to specific habitats and conditions. This poses a challenge when the agricultural landscape in Tinigbasan, adjacent site to payong-payong, will be made as a novel ecosystem for limestone specific plants. This may need a detailed suitability assessment and research for the survival of limestone-specific plants in such a new environment. Nevertheless, the phenotypic plasticity and adaptability characteristics of plants play an important role in survival and colonization in such environmentally diverse areas and new ecosystems. Lastly, the combination of diversity, vegetation, and community structure analyses and determination is necessary to better inform decision making.

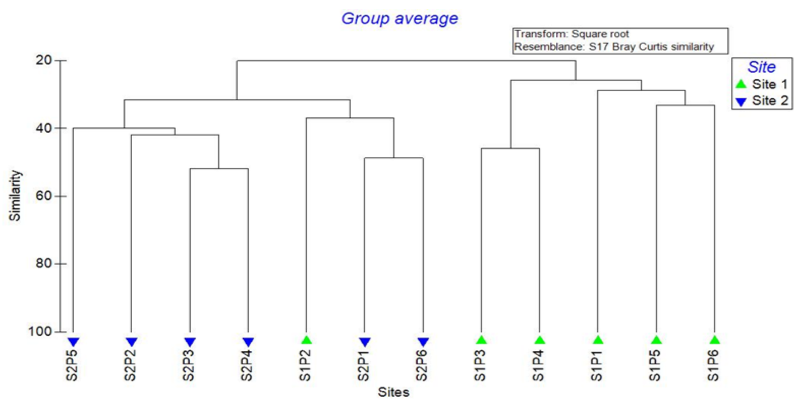

Figure 8. The cluster plot showing the Bray-Curtis Similarity of plant communities across sampling sites in AMVI. Site 1- Payong-payong; Site 2 – Tinigbasan

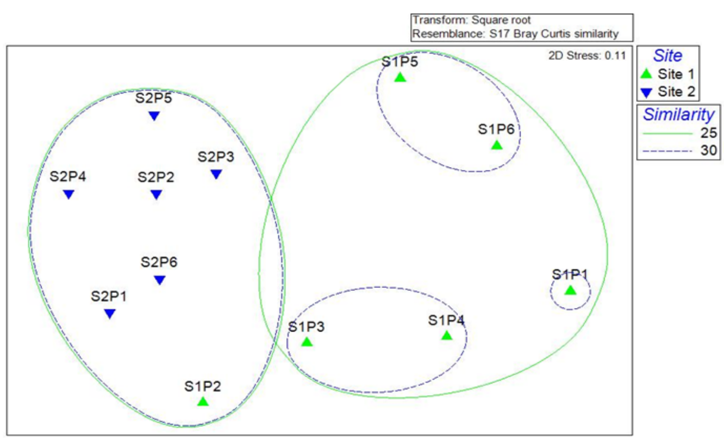

Figure 9. Non-metric multidimensional scaling (nMDS) plot showing the Bray-Curtis Similarity of plant communities across sampling sites in AMVI. Site 1- Payong-payong; Site 2 -Tinigbasan

4 Conclusion and Recommendations

The assessment of plants in the proposed limestone mining site within the MPSA of AMVI recorded a total of 206 species belonging to 78 families. Of the 206, 14 are considered as threatened species. *Vitex parviflora* and *Artocarpus blancoi* revealed to have the highest SIV and similarity percentage (SIMPER) contribution in Payong-payong and Tinigbasan, respectively. The proposed limestone project site in Payong-payong had relatively higher plant species richness and life forms, especially trees, than its adjacent area, Tinigbasan. Both areas showed a high diversity of plants with a composite Shannon diversity of 3.97. However, the two sites varied significantly in terms of community structure which suggests differences and uniqueness of plant species composition between the two sampling sites. The variability in plant communities and species diversity is likely attributed to the variety of habitat types and environmental conditions between the two areas. The forest habitat type in Payong-payong can be categorized as a forest over limestone whereas Tinigbasan can be described as an agricultural, planted forest.

The high species diversity recorded in the area is an implication that habitats and vegetation cover within the sampling locations hold several floral species and still in good condition. Regular monitoring of species population trends and its remaining habitat in the limestone forest mining site is needed to ensure maintenance and protection of species diversity and ecosystems as mining progresses in the area. Moreover, the establishment of a forest reserve within the direct impact site for protection and conservation of species diversity, particularly the threatened species is suggested. The establishment of a forest reserve involves the collection and growing of naturally source plantlets, the conduct of suitability assessment, and training of local staff for the maintenance and monitoring of the reserve. Recognizing the importance of the limestone ecosystem, our data provides valuable information in creating pragmatic and effective conservation and management strategies for the sustainable use of resources while preserving the ecological integrity and biodiversity in the limestone mining site within AMVI.

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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