*Vol. 3, No. 3, pp. 324-336, (September 2022)*
DOI: 10.21608/aujes.2022.145108.1072
**Aswan University Journal of Environmental Studies (AUJES)**
Online ISSN: 2735-4237, Print ISSN: 2735-4229
Journal homepage: https://aujes.journals.ekb.eg/ E-mail: AUJES@aswu.edu.eg

Original research

# Diversity assessment and geospatial mapping of mangroves in Matalom, Leyte, Philippines

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Received: 16/6/2022 Accepted: 22/8/2022


## Abstract:

Eastern Visayas abounds with mangrove forests which serve as bioshields to coastal communities and habitats. However, many mangrove assessments are confined to parts of the region severely damaged from typhoons, thereby rendering little information to southern areas like Matalom. This study assessed the abundance, structure, and diversity of the mangroves along the coast of Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines through the Transect Line-Plot method. Spatial distribution was determined through the use of GIS. Results revealed that the study area, covering a total of 39.82 hectares, has a low diversity (H'=1.2456) with seven mangrove species belonging to four families. Rhizophoraceae is the most represented family with a total of three species *(Rhizophora mucronata, R. stylosa,* and *Bruguiera sexangular). Sonneratia ovata*, was classified as Near Threatened in the IUCN Red List. Analysis of the gathered data showed that *R. mucronata* had the highest relative frequency and *Avicennia marina* had the highest relative dominance; while *B. sexangula* had the lowest value in both fields. Furthermore, no defined zonation pattern was observed as the species were scattered homogeneously in the site. Overall, habitat assessment of the sampling area revealed that the mangroves had an excellent regeneration potential in terms of density of young plants, with a capacity of 300%, and an average tree height of 4.285m, thus constituting a good forest condition. Such findings indicate the need for conservation programs not only for maintaining its good forest condition but also in alleviating the community's low diversity level for a more stable mangrove ecosystem in the long run.

**Keywords:** mangroves, geospatial mapping, diversity, Sonneratia ovata, Matalom, Leyte

## 1- Introduction

It is claimed that the areas covering the highest mangrove diversity are situated along the coastlines of the Indian and Pacific Ocean (Abantao et al., 2015). Accordingly, the Philippines has a relatively high diversity of mangrove species and is considered as one of the richest worldwide.

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Due to its numerous benefits, the mangal or mangrove community is considered to be one of the most biologically important ecosystems, especially in coastal areas. Mangrove areas house different species of epibenthic, infaunal and meiofaunal invertebrates (Canizares & Seronay, 2016). Furthermore, a large carbon pool has received a lot of attention as it is a promising pathway for the reduction of net greenhouse gas emissions in the atmosphere. However, due to anthropogenic activities, human disturbances and the inevitable climate change, mangrove areas are slowly being destroyed and exploited for other uses despite its great importance (Abantao et al., 2015). In the Philippines, only very little information has been studied and presented regarding the current condition and abundance of its mangrove communities. Matalom, Leyte is one of the local areas in Eastern Visayas with resilient mangrove communities, yet very limited research has been conducted about it.

Hence, this research aims to fill that gap by assessing the abundance, structure and diversity of mangroves situated in Matalom, Leyte, Philippines, as well as provide a spatial map of the mangroves' species distribution. Determining the mangroves' species composition plays an important role in understanding the aspects of mangrove structure and function, especially in understudied areas such as the municipality of Matalom.

## 2- Materials and Methods

This study adopted a descriptive quantitative research design, specifically the descriptive correlational design. Descriptive quantitative design refers to the collection of information about variables without manipulating any of its environmental factors (Drummond & Murphy-Reyes, 2018). In this study, the identified mangrove site area in Matalom, Leyte, Philippines was studied through the collection of variables such as the mangrove population and species present, mangrove height and girth at breast height, canopy area, and basal area. Through these, the mangrove diversity and structure in the area was identified. This information was then utilized to produce a spatial distribution map of the mangroves in Matalom, Leyte, Philippines.

### 2.1 Study Site

Matalom is a coastal municipality from the province of Leyte. It is located at 10° 17' North and 124° 47' East. It is composed of 30 barangays. Matalom has a land area of 132 square kilometers which constitutes 2.09% of Leyte's total land area. The study area chosen is a coastal mangrove forest that stretches for approximately 2.53 km and has an area of approximately 0.52km$^2$. It is situated between Barangays Tabang and Cahagnaan alongside the Himo-aw Bay.

### 2.2 Sampling techniques

The Transect line method (English et al., 1997) was implemented to determine the sample plots. A rope was used to establish the transect line and was laid perpendicular to the shoreline. Six transect lines at 250m intervals were created and divided into three zones. The length of each transect line ranged from the nearest mangrove in the shore up to the last mangrove standing at the landward zone. Ten-by-ten-meter sample plots were created along the transect line. The first sample plot was at the beginning of each transect line and the last was on the end transect line. The plots had an interval of 10 meters from each other and were alternately assigned as an established plot or a vacant plot.

The diameter at breast height or DBH is an essential tool in computing for the mangrove community's basal area and tree growth. It can be obtained by dividing the circumference of the tree trunk, or the girth at breast height (GBH), by pi. All adult mangroves, with a diameter at breast height (DBH) of greater than 12cm, from each sample plot were counted and identified with their respective species type. Furthermore, the total number of saplings (DBH < 12 cm and height > 1 m) and seedlings (DBH < 12 cm and height < 1 m) in each sample site was also tallied and recorded.

## 2.3 Identification of species

Mangrove trees on the site were first classified based on their morphology using the Field Guide to Philippine Mangroves by J.H. Primavera (2009). The mangroves' fruits, flowers, and leaves were studied and observed for the species identification and were compared with the field guide. Onsite species classification was later verified through consultation with a botanist.

## 2.4 Collection of measurements

Mangrove's girth at breast height (GBH) (English et al., 1997), tree height and number of seedlings and saplings (Deguit et al., 2004) were measured and recorded onsite. The GBH of each mangrove was measured as it is a factor which helped in determining the relative dominance of the mangrove species. The GBH of each mangrove was measured by stretching a measuring tape firmly around the mangrove's trunk at a height of 1.3 m above the ground. Trees that propped below 1.3 m had their branches measured as separate stems and were recorded separately as individual trees. On the other hand, those which propped above 1.3 m had their GBH measured at the tree trunk at breast height or just below the swelling caused by the fork. Furthermore, if the tree had a prop root occurring at breast height, the GBH was measured 20cm above the prop roots. The GBH of those with irregularities occurring at breast height was measured slightly above or below the irregularity.

The height of each mangrove was measured through an improvised clinometer. The clinometer was made using a pen taped the base of the protractor. A weighted string was also attached to the middle of the protractor base. The measurement was conducted on ground level with the tree at a distance (constant) such that the top of the tree was visible from the viewer. The angle of the clinometer was determined by aligning the pen at the improvised clinometer to the top of the tree at eye level. The weighted string was hung down freely and the value it crossed within the protractor was recorded. The recorded angle was then subtracted from 90° to obtain the final angle. The distance from the viewer to the tree as well as the height from the ground to the viewer's eye (eye-height) was measured and recorded.

## 2.5 Diversity Analysis

To determine species diversity, the mangroves' Shannon-Wiener index, Simpson's diversity index and evenness values were calculated.

*Shannon-Wiener Index* (Magurran, 1988), compares the diversity of a habitat with the assumption that each individual is sampled randomly from an independently large population with all species represented in the sample.

$$H' = -\sum(p_i)[ln\,(p_i)] \qquad (1)$$

H' : Shannon-Wiener index
$p_i$ : proportion of total abundance represented by $i^{th}$ species

*Simpson's Diversity Index (D)* (Hunter & Gaston, 1988) is used to quantify the species habitat based on species proportions.

$$D = \Sigma_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)} \quad (2)$$

D : Simpson's diversity index
$n_i$: no. of individuals for each species
$n$ : total number of individuals for all species
s : the number of species

*Evenness Index* (Pototan et al., 2020)

$$Evenness = \frac{H'}{ln\,(S)} \quad (3)$$

H' : Shannon-Wiener index
S : total no. of species in the area

*Effective Number of Species (ENS)* (Pototan et al., 2020)

$$ENS = \exp(H' \text{ index}) \quad (4)$$

**2.6 Community Structure**

Zonation, relative density, relative frequency, relative dominance and importance value of each species were calculated to analyze the site's community structure.

Relative density determines which species has the highest count per unit area. Relative frequency identifies the most occurring species in the location. Relative dominance establishes which species makes up for the largest part of the site's biomass. The importance value indicates which species are relatively acclimated or adapted to the study area. Relative density, frequency, relative frequency, basal area, relative dominance, and importance values were computed with the following formulas proposed by Misra as cited in Haruna et al. (2018).

$$\text{Relative Density (Rden)} = \frac{No. of\ species\ in\ a\ quadrat}{Total\ no. of\ all\ species\ in\ a\ quadrat} \times 100 \quad (5)$$

$$\text{Frequency} = \frac{No. of\ plots\ at\ which\ a\ species\ occur}{Total\ no. of\ plots\ sampled} \times 100 \quad (6)$$

$$\text{Relative Frequency (Rfreq)} = \frac{Frequency\ value\ of\ a\ specie}{Total\ frequency\ values\ for\ all\ species} \times 100 \quad (7)$$

$$\text{Basal area} = \pi \times 2(\frac{DBH}{2} \div 100) \quad (8)$$

$$\text{Relative Dominance (Rdom)} = \frac{Basal\ area\ of\ species\ in\ a\ quadrat}{Total\ basal\ area\ of\ all\ species\ in\ a\ quadrat} \times 100 \quad (9)$$

$$\text{Importance Value (IV)} = \text{Rden+ Rfreq+Rdom} \quad (10)$$

**2.7 Spatial Mapping**

A spatial map was constructed after data collection using the Quantum GIS (QGIS) Software. The GPS coordinates obtained during the field sampling was used to depict the six transect lines and the boundary of the study site. This final output was used as a visual representation of the study site.

## 3. Results and Discussion

**Mangrove Species Composition**

In the area covered during the assessment, a total of 490 individuals representing seven mangrove species belonging to four families were identified in Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines (Table 1). This represents 18% of the 39 mangrove species found in the Philippines. Overall, Rhizophoraceae was the most represented family with three species, followed by Sonneratiacaea with two species.

The conservation status of all species appeared in the International Union for Conservation of Nature (IUCN) Red List of 2010 with *S. ovata* classified as Near Threatened (NT), while the rest were categorized as Least Concern (LC). A Near Threatened classification is given to an organism that is likely to qualify for a threatened category in the near future due to factors that may affect its existence. Widespread and abundant species, on the other hand, are categorized as Least Concern. This finding could serve as a basis for prioritization in future conservation projects in the municipality.

**Table 1.** Mangrove species composition per transect line in Barangays Sta. Fe and Cahagnaan, Matalom, Leyte and their Conservation Status as determined by IUCN.

| Family | Species | Local Names | T1 | T2 | T3 | T4 | T5 | T6 | Conservation Status |
|---|---|---|---|---|---|---|---|---|---|
| Avicenniaceae | *Avicennia marina* (Forssk.) Vierh. | Miapi | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Least Concern |
| Rhizophoraceae | *Rhizophora mucronata* Lam. | Bakhaw babae | ✓ | | ✓ | ✓ | ✓ | ✓ | Least Concern |
| | *Rhizophora stylosa* Griff. | Bakhaw bato | | ✓ | ✓ | | ✓ | | Least Concern |
| | *Bruguiera sexangula* (Lour.) Poir | Pototan | | | | | ✓ | | Least Concern |
| Lythraceae | *Sonneratia ovata* Backer | Pedada | | | ✓ | ✓ | ✓ | ✓ | **Near Threatened** |
| | *Sonneratia alba* Sm. | Pagatpat | | ✓ | | | ✓ | ✓ | Least Concern |
| Arecaceae | *Nypa fruticans* Wurmb | Nipa | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Least Concern |

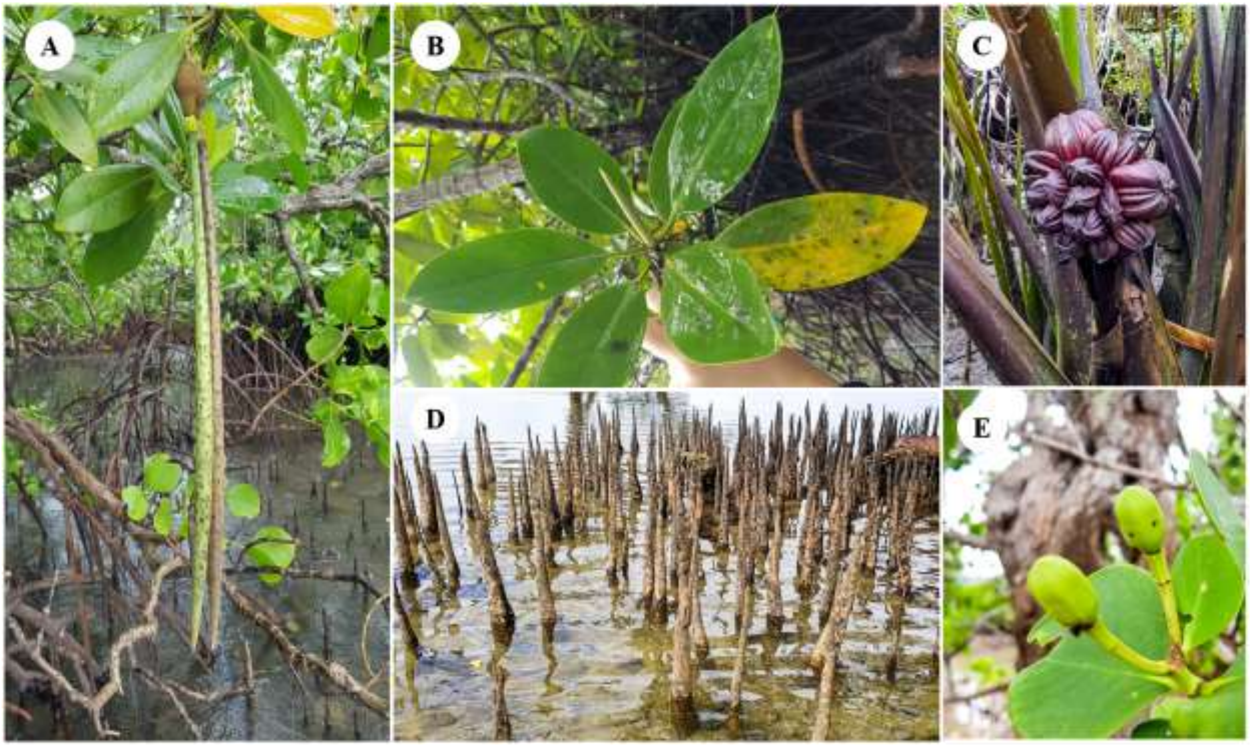


**Figure 1.** Field pictures showing A. fruit of *R. mucronata*; B. leaves and young fruit of *R. mucronata* ; C. Fruit of *Nypa fruticans*; D. roots of *S. alba*; and E. young fruits of *S. alba*

Figure 1 shows examples of mangrove species found in the study area highlighting the different parts of the plant. The fruits, leaf and root structures are essential in properly identifying mangroves.

## Abundance and Distribution

*R. mucronata* had the highest number of individuals, counted at 249 individuals, while *B. sexangula* had the least. One species, *A. marina*, was found to occur in all transects; *R. mucronata* appeared in five, while *B. sexangula* occurred in a single transect, Transect 5, only. In the landward zone, where water was not so brackish, *Nypa fruticans* or nipa were observed in extensive and dense stands which made measuring the parameters impossible to do. *A. marina* was found to dominate the seaward zones (0-89 meters from the first mangrove stand along the shore) of all six transect lines. The middleward zone (90-159 meters), on the other hand, was a mixed stand of *R. mucronata* and *A. marina*. Finally, the landward zone (160 meters and above) was primarily composed of *R. mucronata*. Rhizophora species have a high tolerance to high salinity and water levels; hence, it can survive in a zone of harsh conditions, such as the seaward zone. Sonneratia and Bruguiera, on the other hand, are less tolerant and tend to be inland (Miththapala, 2008). In Matalom, Leyte, *R. mucronata*, and Sonneratiaceae were observed in all zones while *B. sexangula* was recorded only in the landward zone.

In the study site, the zonation pattern was not very well defined. No distinct family was observed to clearly border the edges of each zone as the species were scattered homogeneously in the site. The study of Yuvaraj, et al. (2016) found that varying salinity, tidal inundations, and topographic arrangements among the different mangrove zones constituted for a defined mangrove zonation pattern in the Shoal Bay Creek. As such, the lack of a defined mangrove zonation pattern in the site could be attributed to a possible low variation in the environmental gradients in the area.

**Habitat Assessment**

Results of this study revealed that the mangrove forest in Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines consists of trees with a mean GBH ranging between 12.5 to 300 cm (Figure 3) and a mean tree height between 1.4 to 18.3 m (Figure 2). Mangroves were classified as seedlings or saplings based on their DBH and height. A height greater than one meter and a DBH greater than 12.5 cm are characteristics of a mature tree and measurements below these are said to be either seedlings or saplings. This classification was adapted from the methods of Deguit et al (2004). Among the mature trees, *A. marina* showed the greatest mean DBH ranging between 241 to 300 cm -wide trunks.

Height is one of the factors which determines how acclimated a tree is with its surrounding environment. The tallest tree observed was *A. marina* with an average height of 18.3 m, followed by *S. ovata*, *R. mucronata*, and *R. stylosa.* Height distribution analysis showed that 95% of the trees were less than 8.2 meters, majority of which measuring 1.4 to 4.7 meters tall. The forest falls under good condition in terms of tree height, with an average of 4.285 m, and an excellent regeneration potential. This classification was based on the methods of Deguit et al (2004).

Moreover, girth at breast height (GBH) analysis showed that 77% of the assessed individuals' GBH measured 13 to 60 cm. The forest is dominated by a mixture of mature (DBH > 12.5 cm) and old-growth trees (DBH of 21 to 40 cm) based on the definition of Magarik et al. (2019).

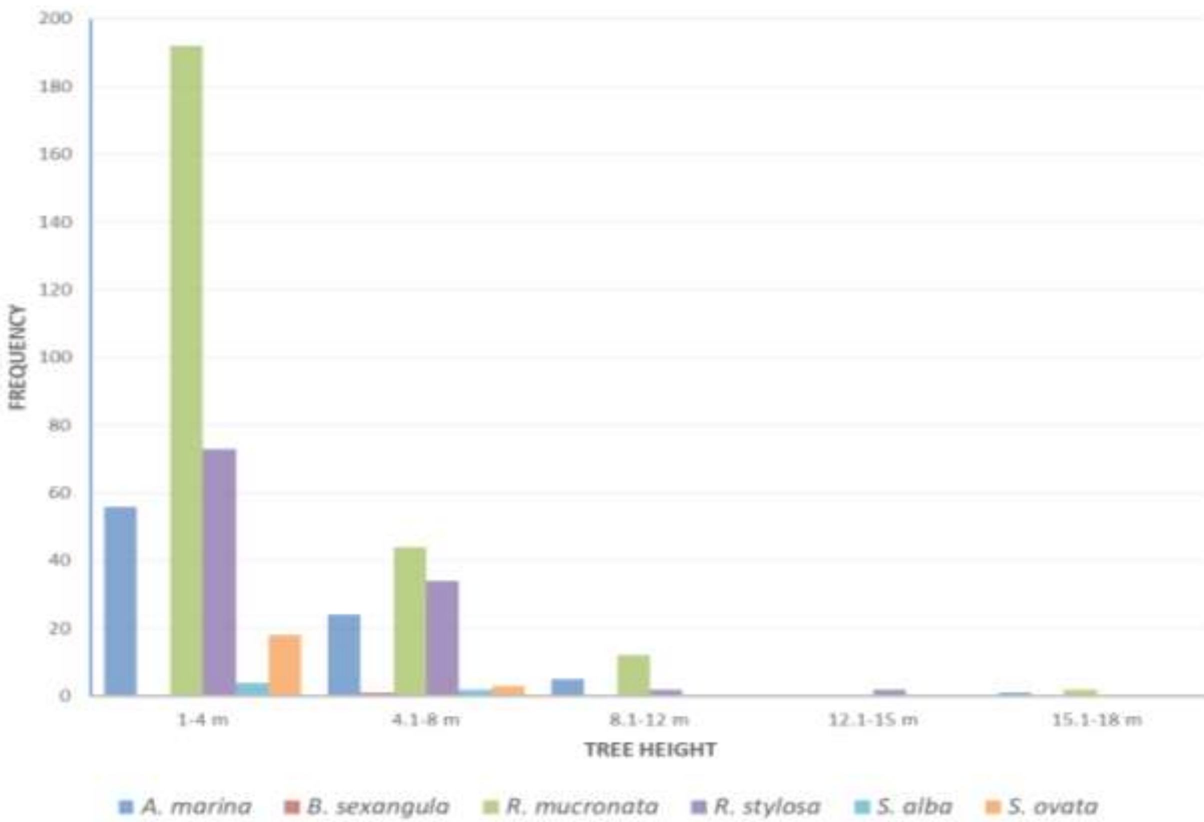


**Figure 2.** Distribution of mangrove species based on tree height

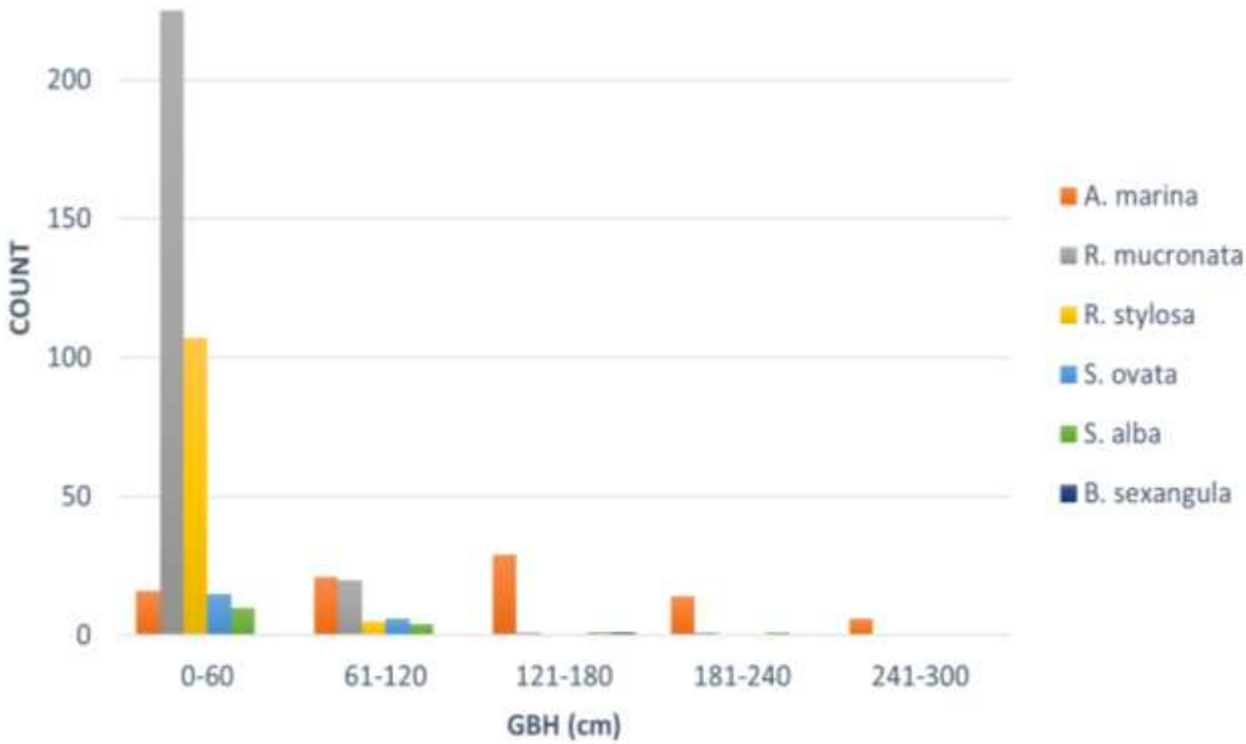


**Figure 3.** Distribution of mangrove species based on girth at breast height (GBH)

**Regenerative Capacity**

In mangrove forests, where no site degradation has taken place, mangrove species can naturally regenerate (Hussain, 1994). In the case of Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines, all zones have a very high regenerative capacity, as shown in Table 2, with the Transect 4 at 576.47% and Transect 6 at 110.78%. The species of *Rhizophora*, *Bruguiera*, and *Nypa* are viviparous plants that develop seedlings while the seeds are still attached to the mother tree. *Avicennia*, on the other hand, is cryptoviviparous as its seedlings do not grow large enough to rapture its pericarp. *Sonneratia* is an exception as it is not a viviparous (Hussain, 1994). High regenerative capacity in the site is attributed to these species as they produce light-weight seeds that are easily carried by water and are dispersed in the forest area.

**Table 2.** The regenerative capacity of each transect and the entire mangrove cover of Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines.

| Transect | Seedlings and Saplings | Mature | Regenerative Capacity |
|---|---|---|---|
| 1 | 32 | 22 | 145.45% |
| 2 | 467 | 111 | 420.72% |
| 3 | 99 | 46 | 215.22% |
| 4 | 392 | 68 | 576.47% |
| 5 | 294 | 76 | 386.84% |
| 6 | 185 | 167 | 110.78% |
| ***Total*** | ***1469*** | ***490*** | ***299.80%*** |

**Community Structure Analysis**

*R. mucronata* obtained the highest relative density (51.43%) and relative frequency (38.43%) values (Table 3). Frequency is often studied as it reflects the pattern of distribution and heterogeneity in a mangrove forest. Obtaining a high value implies that *R. mucronata* was observed to be more distributed all throughout the six transect lines as compared to other tree species which had relatively low occurrence. Its high relative density value also highlights *R. mucronata* as the largest contributor to the mangrove biomass of the whole study area. This is supported by Adhikari et al. (2015) which revealed that *Rhizophora* species have developed adaptive mechanisms over time as they are often submerged to saline water. It has a cytological pump mechanism which removes excess salt from the plant cells, making it thrive among others even when exposed to harsh environments.

*A. marina*, on the other hand, garnered the highest relative dominance (69.76%) and importance value index (118.6). Importance values (IV) portray the ecological importance of a species in a given ecosystem and are a basis for prioritizing species conservation (Kacholi, 2014). The high IV index exhibited by *A. marina* categorizes it as a low conservation priority mainly due to its high relative dominance among the species. It is also very acclimated in its environment as evidenced by *A. marina* being the tallest tree recorded (18.3 m) in the whole study site.

*B. sexangula* tallied the lowest values on all categories. Its low dominance and frequency reflect the single tree that was recorded and sighted in only one transect (Transect 5). Its low IV index further classifies *B. sexangula* as rare rather than common, making it a high priority for conservation efforts, along with the near-threatened species *S. ovata*.

**Mangrove diversity analysis**

The sample mangrove population from Barangays Sta. Fe and Cahagnaan were found to have a low evenness index of 0.176 (Table 4). Evenness refers to how evenly distributed the individuals are among the species (Dronkers, 2020). Its value ranges from 0 to 1, where a lower value means lower evenness. The site's low evenness index implies that some species are dominating the area, and this could pose problems to the community's diversity and species composition.

**Table 3.** Mangrove species of Barangays Sta. Fe and Cahagnaan, Matalom, Leyte and their corresponding frequency (Freq), dominance (Dom), density (Den), relative frequency (Rfreq), relative density (Rden), relative dominance (Rdom), and importance value (IV) index.

| Species | Freq | Den | Dom | Rfreq | Rden | Rdom | IV | Remarks |
|---|---|---|---|---|---|---|---|---|
| *A. marina* (Forssk.) Vierh. | 42.49 | 0.01062 | 0.1891 | 31.29 | 17.55 | 69.76 | 118.60 | 1 |
| *R. mucronata* Lam. | 52.47 | 0.03111 | 0.0398 | 38.43 | 51.43 | 15.80 | 105.66 | 2 |
| *R. stylosa* Griff. | 19.98 | 0.01407 | 0.0078 | 14.83 | 23.27 | 8.35 | 46.45 | 3 |
| *B. sexangula* (Lour.) Poir | 1.04 | 0.00012 | 0.0015 | 0.64 | 0.20 | 0.40 | 1.24 | 6 |
| *S. ovata* Backer | 13.89 | 0.00259 | 0.0061 | 9.22 | 4.29 | 2.38 | 15.89 | 4 |
| *S. alba* Sm. | 8.13 | 0.00198 | 0.0085 | 5.60 | 3.27 | 3.31 | 12.18 | 5 |

On the other hand, Simpson's Index (D) of the whole mangrove area was relatively low with a value of 0.351. Simpson's Index is a measure of dominance which indicates the probability that two individuals randomly selected from a sample will belong to the same species (Dronkers, 2020). The value of D ranges from 0, where all species are equally distributed throughout the area, to 1, where one taxon completely dominates the area. The site's low D value suggests a low dominance in the area. This finding contradicts the results for evenness which implied an uneven distribution in the area. Similar results were seen in the study of Cardillo, et al. (2018) in Davao, where their site obtained low evenness and dominance values of 0.535 and 0.159, respectively. Such results suggest that minimal species contribute to the uneven distribution in the area; yet, they are not completely dominant.

Lastly, the resulting Shannon-Wiener Index from the study site was 1.2456. This is considered very low in the Shannon Diversity Index scale developed by Fernando (1998) as cited by Dimalen & Rojo (2018). Jost (2006) as cited by Cardillo, et al. (2018), presents a more effective way of using this index as a biodiversity tool by converting it to its equivalent number of species (ENS). This is done by raising Euler’s number (e) with the Shannon index value. As such, the ENS obtained is 3, which implies that the area has an equivalent diversity with a community having three equally common species.

The Shannon-Wiener index of the site is comparatively higher than that of Patindol & Casas (2019), which yielded an average of 0.914 for Tacloban mangroves. This is despite using the same protocol in 125 plots, while this study only had 81 plots. This suggests a higher status of diversity in Matalom than Tacloban. Such might have been observed since the latter assessment was conducted in a disaster-prone area open to both anthropogenic and natural disturbances. On the other hand, this study’s Shannon index was relatively lower than that of Abino, et al (2014) which had a value of 1.6 for Samar mangroves, and that of Cardillo, et al. (2018) which yielded a value of 2.2 for Davao mangroves. Both studies, however, only covered 12 and 6 plots, respectively. This suggests a lower status of diversity in Matalom than in the mentioned areas.

One of the specific implications of high biodiversity is that it ensures a stable supply of ecosystem goods and services (Cardillo et al., 2018). Therefore, the low biodiversity status in Matalom, Leyte implies that the site has a less stable ecosystem supply. The conduct of conservation and appropriate mangrove-planting programs within the area is vital for the survival of the mangrove site amidst the increasing spatial and temporal variability in today's climate crisis.

**Table 4.** Diversity analyses for sampled mangrove forest in Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines

| **Diversity indices** | **Value** |
|---|---|
| Shannon-Wiener Index of Diversity (H’) | 1.246 |
| Simpson’s Index of Diversity (D) | 0.351 |
| Effective Number of Species (ENS) | 3.476 |
| Evenness Index | 0.176 |

## Geospatial Mapping

The generated spatial map (Figure 4) shows the boundaries of the study site from each barangay and the total transect lines covered. GPS was used to ensure that each transect line had a uniform interval of 250 meters. The spatial map was then generated using QGIS software.

Effective mangrove monitoring and management is essential to protect and enhance this mangrove forest found in Barangay Sta. Fe and Cahagnaan, Matalom, Leyte. This GIS generated map will then serve as the base map for future actions. Changes in the mangrove ecosystem, both positive and negative, can be compared to this 2020 map and thereby evaluate the effect of the management efforts that the local government and the community would possibly adopt.

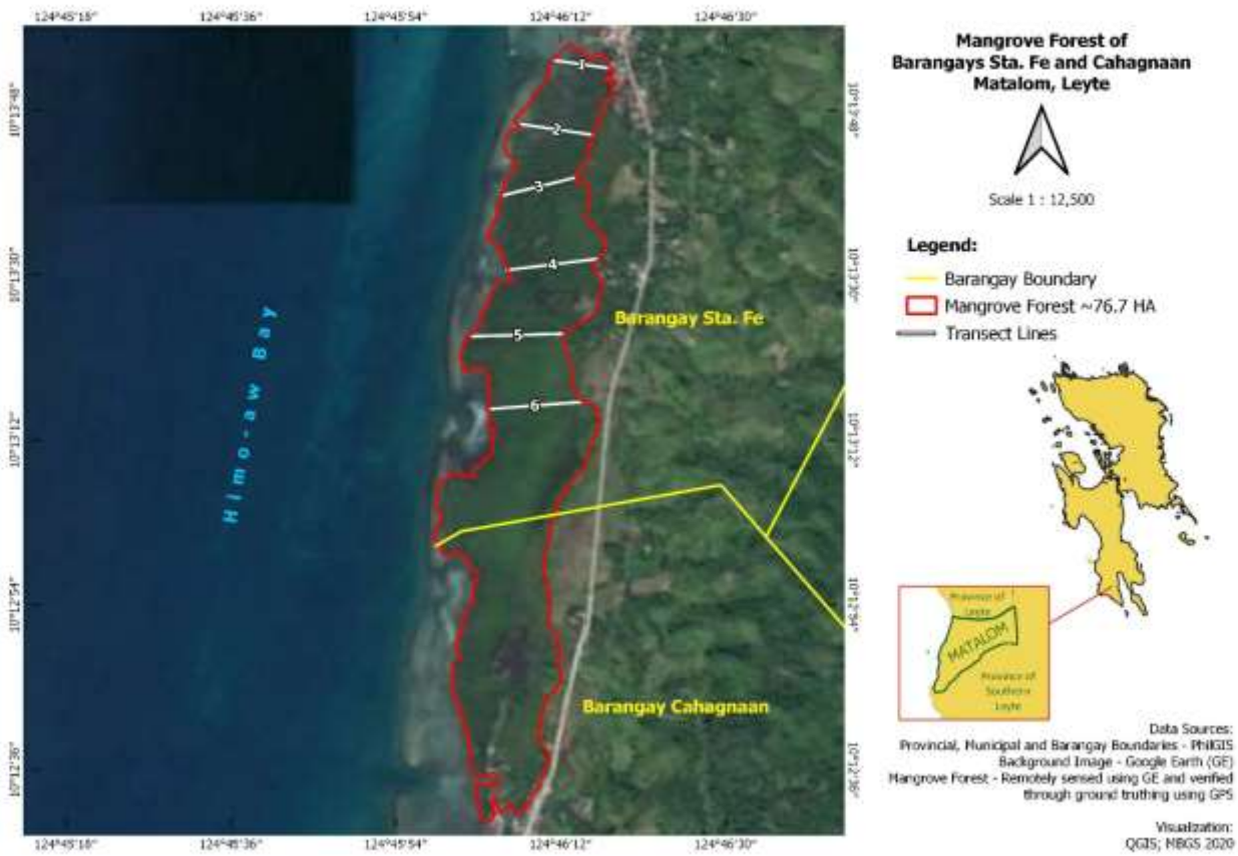


**Figure 4.** GIS generated location and mangrove cover map in Barangay Sta. Fe and Cahagnaan, Matalom, Leyte.

## 4. Conclusion

In conclusion, the mangrove forest between Barangays Sta. Fe and Cahagnaan, Matalom, Leyte, Philippines housed a total of seven mangrove species belonging to four families. Among these, only *Sonneratia ovata* was recognized as Near Threatened by the IUCN. The species composition of the mangrove forest was predominated by the Rhizophoraceae family, which constituted three of the seven species. In general, there was no distinct zonation pattern in the site, consequently implying a potentially low environmental gradient in the area. *Rhizophora mucronata* had the highest relative dominance and relative frequency values, while *Avicennia marina* had the highest relative dominance value. In addition, *A. marina* garnered the highest importance value, thus implying that it was relatively the most acclimated species in the site. On the other hand, *Bruguiera sexangula* had the lowest values for all four fields. These findings indicate that increased attention should be given to *S. ovata* and *B. sexangula* in mangrove conservation programs in order to preserve the site's diversity, while *A. marina* could be of least priority. Results of the diversity indices show that the site has a very low diversity (H'=1.246) and low evenness (E=0.176), but with a fair distribution of dominant species. In addition, it's high regenerative capacity implies that the mangrove forest has a high potential of sustaining itself in face of destructive events such as fires, diseases, or calamities. If given more time and resources, it is recommended to cover the whole area to achieve a more accurate representation. There is also a need for conservation programs not only for maintaining its good forest condition but also in alleviating the community's low diversity level for a more stable mangrove ecosystem in the long run.

## 5. Acknowledgments

This study was funded by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department and Science Technology (DOST-PCAARRD) under the Biodiversity and Vulnerable Ecosystems Research (BiVER) implemented by Philippine Science High School - Eastern Visayas Campus. We are also grateful for the support of the local government of Matalom headed by Mayor Eric Pajulio. Assistance from Matalom citizens during fieldwork is highly appreciated.

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