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Mangrove Forest Inventory and Estimation of Carbon Storage and Sedimentation in Pagbilao

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Mangrove Forest Inventory and Estimation of Carbon Storage and Sedimentation in Pagbilao

April 2017

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Foreword

The Mangrove Forest Inventory, Estimation of Carbon Storage and Sedimentation in Pagbilao, Quezon Province was a pilot study developed and compiled by the Philippine Statistics Authority (PSA) under the Wealth Accounting and the Valuation of (WAVES) Project of the World Bank.

WAVES is a global initiative launched in 2010 to mainstream natural capital in the development planning and national economic accounts in support of sustainable development. It aims to help countries build accounts for natural capital and this ensure that their significance and benefits are incorporated in development programs and policies.

This pilot study is considered a milestone in the history of PSA, being a pioneering effort towards development of ecosystem accounts since the PSA was established in 2013.

Similar with other initiatives to develop operational frameworks and methodologies, the PSA deemed it important to establish linkages and partner with United Nations agencies, the private sector, civil society organizations, academe, and stakeholders. The call to support the operationalization and institutionalization of the framework on environmental accounting has been a success when participation of various stakeholders are engaged from the start project's developmental activities.

The PSA would like to express its appreciation to the Ecosystem Research and Development Bureau (ERDB), National Mapping and Resource Information Agency (NAMRIA), Provincial Environment and Natural Resources Office (PENRO), Community Environment and Natural Resources Office (CENRO), Pagbilao Mangrove Experimental Forest (PMEF) of the Department of Environment and Natural Resources (DENR), and Local Government Unit of the Municipality of Pagbilao, Quezon for providing assistance and relevant information on the Pagbilao Mangrove Forest. It wishes to acknowledge the support extended by the members of the Task Force on Mangrove Ecosystem Accounts for their support and cooperation.

The PSA is also grateful for the dedicated support of Dr. Stefanie Sieber-Onder, Senior Environmental Economist and Dr. Maya Gabriela Villaluz, Senior Environmental Engineer, of the World Bank; the technical guidance of the team of Mr. Pastor L. Malabrigo, consultant on Mangrove; and Dr. Glenn-Marie Lange, an international consultant on environmental accounting.

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Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

The changing global climatic condition has led to the adoption of environmental programs designed to increase carbon (C) sequestration or promote carbon storage retention for mitigating climate change impacts. One such program is the carbon market and trade system, where C from a forested area is measured and sold for carbon credits. Mangrove forests, which are known to store huge C, have a huge potential to benefit poor communities under a carbon trade, as it is known to store huge C. The mangrove forest in the coastal municipality of Pagbilao, Quezon, located in Luzon island[1] and known for its highly diverse tropical forest ecosystem, holds such vast potential.

One of the objectives of this study is to measure the C storage in Pagbilao, considered a pioneering effort in the area and the rest of the country.

This study is part of the Philippine Wealth Accounting and the Valuation of Ecosystem Services (Phil-WAVES) project of the National Economic and Development Authority and Philippine Statistics Authority, which aims to account for the ecosystem services provided by the Pagbilao mangrove forest (PMF). It covers three major areas: a) mangrove characterization, which includes inventory of flora and fauna; b) estimation of carbon storage, both in the mangroves biomass and the sediments; and c) estimation of sedimentation rate in Pagbilao mangrove forest.

Mangrove characterization. The study team employed a stratified quadrat-based sampling technique for the inventory of mangrove flora. Three levels of stratification were used to proportionately represent the different mangrove stands in Pagbilao.

A total of 30 sampling quadrats (10 meters x 10 meters) were surveyed for the inventory with a minimum distance of 250 m, between quadrats. An opportunistic flora survey was also carried out to account for the maximum possible number of species in the area. A similar research methodology was likewise employed for the fauna inventory as amphibians and reptiles (herpetofauna) were surveyed within the study areas. Herping at night was the primary method employed to to search for herpetofauna, or reptiles and amphibians. Transect survey, mist net trapping, and general observation were applied to survey avian (birds) species. To search for mammals, mist nets and a combination of live traps and victor snap traps were used.

Mangrove biomass estimation. The same sampling quadrats for tree inventory were used to estimate the mangrove biomass in Pagbilao. The allometric equations developed by Komiyama et al. (2005) for Southeast Asian mangroves were used to determine the root and aboveground biomass of the Pagbilao mangrove forest (PMF). To measure the carbon stored in the biomass, carbon content analysis of the wood of each species was

[1]The Philippines is divided into three major island groups, the biggest of which is Luzon, located in the northern part of the archipelago. The others are Visayas and Mindanao, which also host diverse and extreme valuable ecosystems.

conducted. The total biomass of each species was multiplied by their carbon fraction (dry biomass) to obtain the total carbon stock in the mangrove biomass.

Composite soil samples with a 0-30 centimeter depth were collected in the landward, midward, and seaward zones of Pagbilao's mangrove forest. Likewise, intact soil core samples were taken at the same depth to determine the weight of soil on a per hectare basis. The composite soil samples were taken to the International Rice Research Institute Analytical Service Laboratory (IRRI-ASL) for total C analysis. The soil core samples were analyzed for bulk density at the Institute of Renewable Natural Resources Soils Laboratory.

Calculation of sedimentation rate. A watershed approach was used to calculate the sedimentation rate. The potential soil loss in the watershed was determined using the Revised Universal Soil Loss Equation (RUSLE). The resulting data was subsequently multiplied by its corresponding sediment delivery ratio to estimate the rate of sedimentation in the mangrove forest of Pagbilao.

Findings validate Pagbilao's reputation as having one of the largest and most diverse mangrove forests in the Philippines. However, like other mangrove forests in the country, PMF is not spared from mangrove degradation, primarily due to aquaculture. A total area of 534.55 hectares had already been converted to fishpond operations as of 1996. At the time most of the black mangroves were already gone and much of what remain today are seaward scrub forests.

Ibabang Palsabangon, one of the barangays[2] in the municipality of Pagbilao, has the largest mangrove extent and the most diverse mangrove among the town's barangays. The seaward zone (202.04 ha) has the largest coverage, followed by the landward zone (165.75), and the midward zone (159.62). A total of 30 true mangrove taxa belonging to 11 families and 15 genera were observed homing in the municipality's estuarine areas. Among these are threatened ones including gapas-gapas (Camptostemon philippinensis) and piapi (Avicennia marina var. rumphiana), which have been classified in the International Union for Conservation of Nature's (IUCN) Red List as endangered and vulnerable species, respectively.

There is a significant difference between species composition among the different mangrove zones. The seaward zone is dominated by Pagatpat (Sonneratia alba), Bungalon (Avicennia marina), and Bakauans (Rhizophora spp.). Tangal (Ceriops tagal), Malatangal (C. zippeliana), and Tindik-tindukan (Aegiceras floridum) dominate the midward zone. While the most abundant species in the landward zone are Tabigi (Xylocarpus granatum), Api-api (Avicennia officinalis), and Piapi.

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[2]A barangay is the smallest administrative division in the Philippines and is the Filipino term for village, district, or ward.

A total of 22 tree species were recorded at the 30 quadrats surveyed. The landward zone is the most diverse among the mangrove zones, accounting for 16 of the 22 species found across sites. Among the different types of mangrove forests, the riverine and the hammock appeared to be the most diverse. Of the 526 individual stems recorded at the 30 quadrats, 95 exhibited forking that resulted in 706 individuals. Among the three mangrove zones, the midward zone is the most densely stocked, with an average density of 2,890 stems per hectare (ha). In terms of density per forest type, fringing mangroves have the highest average density at 2,700 stems/ha while hammock mangroves appeared to be the least dense. It has been observed, however, that mangrove density is greatly affected by the age or maturity of the stands rather than the topographic position, or forest types.

More than 81 percent of the mangroves surveyed are small-diameter trees, 16 percent medium-sized diameter while only 2.6 percent belong to the large-diameter class. The average diameter at breast height (DBH) for all trees across sites is 11.19 cm while the average height is 8.8 m. The seaward zone has the largest average DBH, followed by the landward, then the midward, zones. This is understandable since trees in the midward zone (i.e., tangal, malatangal, saging-saging, etc.) are naturally small-diameter species.

The overwash mangrove in Patayan island, which is part of Pagbilao Grande Islands, a group of islands that is a popular tourist attraction in the province of Quezon, far exceeds the rest of the forest types in diameter, but has the lowest average height. This is not surprising since pagatpat, the only species found in the quadrat, is a large-diameter tree that rarely grows to a height of 10 m.

The three most important species that obtained the highest importance value are bakauan lalaki, tabigi, and api-api. Bakauan lalaki got the highest rank across all three values — relative frequency, relative density, and relative dominance. All the 30 quadrats recorded very low Shannon diversity index. The very low diversity for a 10 m x 10 m quadrat is expected in any mangrove forest due to a strictly defined mangrove zonation pattern, where each species has its own specialized niche.

Home to a variety of wildlife species, the Pagbilao mangrove forest boasts at least 71 species of terrestrial vertebrates, comprising 55 species of birds, nine species of herpetofauna, and seven species of mammals, which were recorded from the wildlife survey. At least 15 species were found endemic to the Philippines. Four threatened and near-threatened species were found at the study sites.

Nine species of herpetofauna consisting of one toad and three true frogs, two gekkonid and one varanid lizards, one python, and one elapid snake, were found at the study sites. Philippine monitor lizard and Philippine cobra are both endemic to the country. The latter has been categorized as a near-threatened species by the IUCN.

A total of 55 avian species recorded across study sites belong to at least 27 families and 48 genera. Thirteen of these are Philippine endemic species while three are listed as vulnerable by the IUCN, including the Philippine duck, Philippine eagle-owl, and Java sparrow. The majority (32/55) of the bird species are residents. In contrast, endemic species comprised only 23 percent (13/55), while migrants species constituted four, or 7.2 percent. Among mammals, seven species were found in the Pagbilao mangrove, six of which are pteropid bats. Only one species, the greater Musky fruit bat (Ptenochirus jagori), is endemic to the country.

The computed biomass for all the quadrats ranged from 0.17 to 365.28 ton ha^{-1} with mean biomass stock of 132.51 ton ha^{-1}. The midward zone of the mangrove forest has the highest average aboveground and root biomass, closely followed by the seaward zone. The landward zone has significantly lower biomass, which is not even half of the midward zone. The lone overwash mangrove forest in Patayan island, which is a remnant of an old-growth forest composed of large-diameter pagatpat (Sonneratia alba) trees, far exceeds the rest of the forest types in terms of biomass. The wide variation in the computed biomass is attributed to the difference in the stand density and maturity of trees within each plot and forest type.

Results of the carbon analysis showed that carbon fraction varies among mangrove species, ranging from 44.6 percent to 49.7 percent. The top four species (kulasi, malatangal, nilad, tangal) with the highest carbon fraction are small-diameter trees commonly found at the midward or landward position. The commonly used reforestation species (Rhizophora spp.), along with other large-diameter mangroves, (Avicennia spp.), are among the lowest in terms of carbon fraction.

The biomass C-stock varied across quadrats, from 0.08 t C ha^{-1} to 172.42 t C ha^{-1} with a mean value of 61.34 tons C ha^{-1}. The carbon stored from the aboveground biomass accounts for about 58 percent of the total biomass carbon stock. When it comes to sediment/soil carbon, the landward position from Barangay Ibabang Palsabangon registered the lowest value of 40.9 t C ha^{-1}. The highest value, 190.5 t C ha^{-1}, came from the seaward location taken at Barangay Pinagbayanan. In sum, the Pagbilao mangrove forest stores an average of 184.84 t C ha^{-1}; 35.54 t C ha^{-1} from the aboveground biomass; 25.8 t C ha^{-1} from the root biomass; and 123.5 t C ha^{-1} from the soil. Occupying a total area size of 646 hectares, the whole mangrove forest stores 119,406.6 t C. The same area receives an estimated amount of 137.6 to 237.7 tons of sediments per year.

Data generated through study are expected to help the stakeholders in their research and conservation (e.g., production of information, education and communication materials) efforts for the PMF. For instance, data on wildlife census can be used to promote wildlife and bird tourism in the area. More importantly, these data will not only be useful in the determination of the total C storage in the mangrove forest of Pagbilao but also in the overall assessment of its ecosystem services.

1 | Introduction

The Pagbilao mangrove forest (PMF) is one of the last remaining mangrove forests in Southern Luzon. It also boasts one of the most diverse ecosystems in the country, having a considerably large number of true mangrove species (Bravo, 1996). Back in 1984, the total area of PMF was around 693 hectares (Jansen & Padilla, 1996). Of these, 396 hectares were on public lands while 297 hectares were privately owned.

According to the 2015 Comprehensive Land Use Plan (CLUP) of Pagbilao, the total area of mangrove forests of the whole municipality, sub-categorized under the water use zone, is 1,739 ha. These most likely include the areas that have been converted to fishponds and other agricultural uses. According to the 2010 National Mapping and Resource Information Authority (NAMRIA), the Philippine government's central mapping agency, the total mangrove cover of the municipality of Pagbilao is 645.98 hectares, distributed over 12 coastal barangays (see Table 1).

Table 1. Extent of mangroves in the different barangays of Pagbilao

Barangay	Mangrove Area (hectares)
Alupaye	5.13
Bantigue	20.42
Barangay 2 Daungan	0.66
Binahaan	79.21
Ibabang Palsabangon	348.44
Ibabang Polo	39.42
Ilayang Palsabangon	6.22
Ilayang Polo	30.01
Kanluran Malicboy	60.51
Mapagong	8.71
Pinagbayanan	11.67
Silangan Malicboy	35.60
TOTAL	**645.98**

Pagbilao Mangrove Experimental Forest

Barangay Ibabang Palsabangon has the largest mangrove forest cover in Pagbilao, comprising about 54 percent of the total across the municipality. Bureau of Forest Development (BFD) Administrative Order No. 7 (s. 1975) declared 145 hectares in Ibabang Palsabangon the Pagbilao Mangrove Experimental Forest (PMEF) under the Department of Environment and

Natural Resources (DENR). This policy provided the necessary protection (and funding) to prevent further degradation of this vital ecosystem (Slootweg et al., 2010).

The PMEF, located in Pagbilao Bay, is generally a second-growth forest with an average age of 20 years (NRMC 1980). It is acclaimed as the world's second largest mangrove in terms of species richness (Pagbilao CLUP, 2015). Hence, the area has drawn considerable interest from environmental groups and the academe (Almazol et al., 2013). It has also become a showcase for training and research, having been declared a Genetic Resource Area, and a National Centre for Mangroves (Jansen & Padilla, 1996). To date, however, no comprehensive survey has been undertaken in the PMEF to determine the total number of species inhabiting the area.

Pagbilao mangrove forest as carbon sink

The changing climatic pattern resulting from higher greenhouse gas (GHG) concentrations in the atmosphere, which are anthropogenic or human-induced, is increasingly causing environmental disasters in the world, most especially in the tropics, where the brunt of stronger typhoons is felt by poor communities. Various programs have been in place to increase carbon sequestration or promote carbon storage retention, thus mitigating climate change impacts. Some of these projects have called for carbon accounting in different systems, from natural to artificial, with the overall aim of valuing its benefits economically. Carbon market and trade system were established for this purpose.

Forests play a major role in the global carbon cycle since they store huge amounts of carbon (FAO, 2006). About 283 gigatons (Gt) of carbon is stored in the world's forests' biomass alone. Soil, litter, deadwood, and forest biomass comprise 50 percent more than the amount of carbon present in the atmosphere (FAO, 2005).

In the Philippines, a 2003 estimate showed that the Philippine forests sequester 107 million tons (Mt) yr^{-1} of carbon dioxide (CO_2) (Lasco and Pullman, 2003). This amount is almost equal to the total GHG emissions of the country. According to the Food and Agriculture Organization (2015) the Philippines' total forest carbon stock is 1,290 MT. This value is broken down as follows: aboveground biomass, 545 MT; below-ground biomass, 131 MT; deadwood, 74 MT; litter, 17 MT; and soil, 523 MT (FAO, 2015).

Mangrove forests, one of the unique forest ecosystems in the tropics, have been proven to store relatively huge amounts of carbon (Abino et al., 2014).

Mangroves, along with salt marshes and seagrass, are among the most efficient carbon sinks in the world (Donato et al., 2011). Several studies have shown that carbon storage by mangrove forests is two to three times higher than that of terrestrial forests (Donato et. al., 2011; Kauffman, et al., 2011; Lunstrum and Chen, 2014). However, mangroves also have the potential to release a high amount of carbon to the atmosphere when converted to other land uses. In a mangrove forest, carbon is stored in the biomass and more so in the soil, where organic matter accumulates due to soil waterlogging. Converting these areas into other land uses (e.g., fish ponds) not only removes the forest vegetation that holds carbon but also eliminates soil carbon accumulation from litter fall.

The growth and development of mangrove forests depend on the amount of sedimentation coming from their headwaters. Sediments and nutrients from the uplands that flow through the tributaries are absorbed by the mangroves (Abino et al., 2014). The acceleration of soil erosion increases the sediment inflow into the streams (Zhou, 2008). Given the effects of upland activities on the acceleration of soil erosion, there is a need to understand the dynamics within the watershed. The relationship between watershed disturbances and sediment yield requires basin-wide information on the rates of sedimentation (Mattheus, 2013). Sediments transported to the watershed outlet contribute to land accretion, which is facilitated by the trapping features of mangrove forests. These sediments are rich in nutrients as they are typically the topsoil material from the watershed. The sediments trapped by mangrove forests produce a reciprocating effect by providing a nutritious substrate for mangrove trees to grow on.

The mangrove forest in Pagbilao is one of the relatively intact mangrove forest ecosystems in the Philippine island of Luzon. It has been recorded to have a higher diversity, being home to the PMEF. As the PMEF exemplifies a good mangrove forest ecosystem, it is important to determine how much carbon is stored in this area, which could be used as a barometer by which carbon stored in other mangroves in the region can be measured.

This report tackles the carbon storage (both in biomass and soil) and sedimentation rate in the mangrove forest of Pagbilao, as part of the overall economic valuation of the benefits of this ecosystem.

2 | Methodology

Mangrove Flora

Assessment of mangrove flora followed a standard sampling technique. Important parameters such as importance values and diversity índices were also measured for a more thorough analysis of the extent of mangroves in Pagbilao.

Vegetation Survey

The study team employed a stratified quadrat sampling technique for the conduct of an inventory of mangrove flora. Three levels of stratification were used to proportionately represent the different mangrove stands in the coastal municipality of Pagbilao, namely, a) location (i.e., barangay) of the mangroves; b) topographic position of the mangroves (seaward, midward, landward); and c) mangrove forest types (scrub, fringing, hammock, riverine, basin, overwash). Since a large portion of the Pagbilao mangrove forest are classified as seaward and scrub mangroves, more sampling points belonging to these forest types were surveyed (see Table 2).

Table 2. Location, position, and forest type of sampling quadrats

Quadrat No.	Coordinates	Barangay	Position	Forest Type
1	N13°57′42.5″ E121°42′14.8″	Pinagbayanan	Seaward	Scrub
2	N13°57′59.23″ E121°42′30.9″	Pinagbayanan	Seaward	Plantation
3	N13°58′28.1″ E121°42′49.1″	Pinagbayanan	Midward	Riverine
4	N13°58′11.9″ E121°42′49.2″	Pinagbayanan	Seaward	Scrub
5	N13°57′05.8″ E121°42′57.7″	Patayan Island	Seaward	Overwash
6	N13°56′57.5″ E121°43′02.3″	Patayan Island	Seaward	Scrub
7	N13°58′08.6″ E121°43′20.1″	Ibabang Palsabangon	Seaward	Scrub
8	N 13°58′32.5″ E121°43′22.3″	Ibabang Palsabangon	Midward	Basin
9	N13°58′11.8″ E121°43′26.5″	Ibabang Palsabangon	Midward	Riverine
10	N13°58′19.3″ E121°43′27.9″	Ibabang Palsabangon	Midward	Hammock
11	N13°58′34.5″ E121°43′31.6″	Ibabang Palsabangon	Landward	Riverine
12	N13°58′31.2″ E121°43′33.9″	Ibabang Palsabangon	Midward	Plantation
13	N13°58′32.8″ E121°43′34.3″	Ibabang Palsabangon	Landward	Basin
14	N 13°58′29.3″ E121°43′41.5″	Ibabang Palsabangon	Landward	Hammock

Quadrat No.	Coordinates	Barangay	Position	Forest Type
15	N13°58'12.1" E121°43'44.4"	Ibabang Palsabangon	Midward	Riverine
16	N13°58'03.3" E121°43'49.1"	Ibabang Palsabangon	Seaward	Riverine
17	N13°58'19.6" E121°43'51.0"	Ibabang Palsabangon	Midward	Hammock
18	N13°58'13.3" E121°44'05.6"	Ibabang Palsabangon	Landward	Riverine
19	N13°58'03.3" E121°44'11.9"	Ibabang Palsabangon	Seaward	Scrub
20	N13°58'38.6" E121°44'12.5"	Ibabang Palsabangon	Landward	Basin
21	N13°58'13.5" E121°44'19.0"	Ibabang Palsabangon	Midward	Riverine
22	N13°58'58.4" E121°44'20.7"	Ibabang Palsabangon	Seaward	Riverine
23	N13°58'24.2" E121°44'29.2"	Ibabang Palsabangon	Midward	Riverine
24	N13°58'01.6" E121°44'47.9"	Binahaan	Seaward	Riverine
25	N13°57'45.3" E121°45'42.3"	Binahaan	Midward	Basin
26	N13°57'53.4" E121°45'44.0"	Binahaan	Landward	Hammock
27	N13°56'55.3" E121°46'09.5"	Kanlurang Malicboy	Seaward	Scrub
28	N13°56'42.7" E121°46'25.6"	Kanlurang Malicboy	Seaward	Scrub
29	N13°56'36.4" E121°46'43.4"	Kanlurang Malicboy	Seaward	Scrub
30	N13°56'25.8" E121°46'59.9"	Kanlurang Malicboy	Seaward	Fringing

A total of 30 sampling quadrats (10 m x 10 m) were surveyed for the inventory (see Figure 1), using a minimum distance of 250 m between quadrats. Identification of all species within the sampling quadrats was made. In addition, diameter at breast height (DBH) and total height (TH) of all individual species with ≥ 5 cm DBH were measured. Tree diameter was measured at 1.3 m aboveground or 10 cm above the tallest buttress/prop roots if taller than 1.3 m. In case a tree forks below 1.3 m from the ground, all stems with ≥ 5 cm DBH were measured separately.

An opportunistic flora survey, involving listing and photo documentation of the different mangrove species encountered (inside and outside the quadrats), was also carried out to account for the maximum possible number of species in the area. This survey also documented and somehow estimated the extent of mangrove forests in the different coastal barangays of Pagbilao.

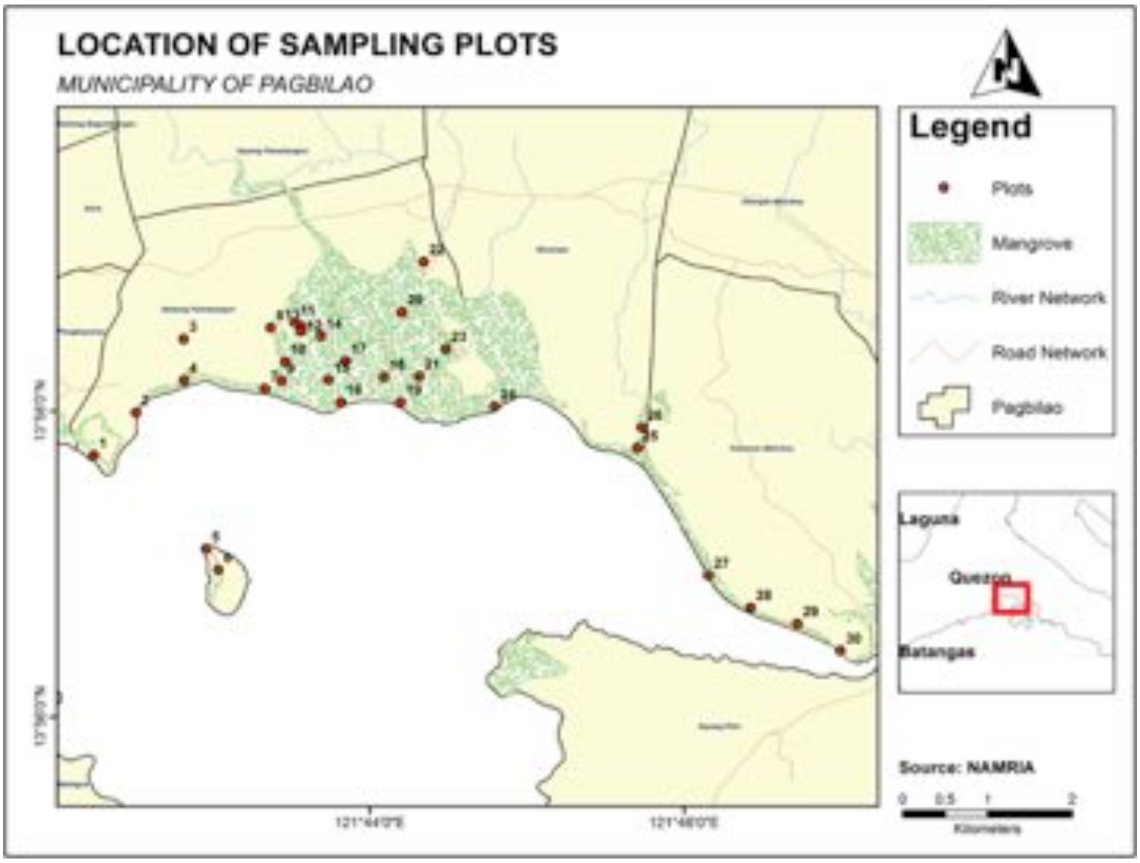

Figure 1. Location of different sampling points of the mangrove inventory

Data Analysis

Information gathered from the field was tabulated and analyzed to characterize floral composition within the study area.

The relative density, relative dominance, and relative frequency values of each tree species were determined to obtain its importance value (IV), which is the standard measurement in forest ecology to determine the rank relationships among species. Also, the relative frequency, relative density, and relative dominance indicate different aspects of the species' importance in a community. IVs were determined using the following formula:

$$\text{Density} = \frac{\text{number of individuals}}{\text{area sampled}}$$

$$\text{Relative Density} = \frac{\text{density for a species}}{\text{total density for all species}} \times 100$$

$$\text{Frequency} = \frac{\text{number of plots in which species occur}}{\text{total number of plots sampled}}$$

$$\text{Relative Frequency} = \frac{\text{frequency value for a species}}{\text{total frequency for all species}} \times 100$$

$$\text{Dominance} = \frac{\text{basal area or volume for a species}}{\text{area sampled}}$$

$$\text{Relative Dominance} = \frac{\text{dominance for a species}}{\text{total dominance for all species}} \times 100$$

$$\text{Importance Value} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Dominance}$$

Diversity indices (Shannon, Simpson's and Evenness) for each sampling quadrat were generated using Paleontological Statistical software package for education and data analysis (PAST version 3.12). Endemism and the ecological status of the different species were assessed to determine the ecological importance of the vegetation in the area. Plant classification followed the latest Angiosperm Phylogeny Group classification (APG IV, 2016) while the common names adapted that of Rojo (1998).

Mangrove Fauna Inventory

Amphibians and Reptiles

Principally, opportunistic search was employed to survey amphibians and reptiles (collectively called herpetofauna) within the study areas. Herping at night was the primary method used to survey this group. Night observation was carried out using torches and head lamps between 1730hrs and 2100hrs.

Surveys were made during the day, simultaneous with bird observations and setting of survey traps and nets for mammals, and other chance field activities to augment data. Search for herpetofauna was made by examining microhabitats such as the remaining patches of vegetation, vegetated floor litter, ponds, creeks, and pools, whenever these were available at the site.

In addition the study team's record of species also considered data from recent reliable accounts from local guides. Species handling included catching frogs, small lizards, and small- to medium-size non-poisonous snakes (when found) using bare hands and having them placed in transparent plastic bags filled with air. All captured species were handled with care not only during the process of catching them but also while they were being measured and photographed, after which they were promptly released close to the site where they were originally found.

Birds

At the study site, setting up a long and continuous trail for bird transects was a challenge. Similarly, mobility and access were difficult within the mangrove forest. Thus, to facilitate observations of birds, the following strategies were applied:

Use of transect lines. These are arbitrary lines that serve as a guide route to the observer. They could be an existing road, trail or any passage way (including route of creeks and rivers) that would allow the observer to spot bird species in their natural habitats. Transect lines were established in areas that best represented the vegetation and habitats of the study area.

A standard 2-kilometer transect line is considered ideal. In reality, however, the length of the transect/s is influenced, or limited, mainly by the type of terrain, accessibility, type of habitat (diversity and or homogeneity), and, more importantly, the survey site boundary. Transects were run in the morning only (usually from 0700hrs to 1000hrs), considered the best time to observe birds. Encounters with species (which were heard or seen) along the transect line were recorded at the species level, including the number of individuals belonging to each species that were encountered.

In case of doubtful records, a "cf." status was indicated across a species' scientific name to suggest the need for further investigation and confirmation of such entries. Off-transect encounters with birds were recorded as general observations. A total of two transect lines (800 m to 1,000 m long) were established within the study site.

Use of mist nets. For cryptic, shy, and nocturnal species, 6-, 9-, and 12-m long monofilaments nets with four pouches, 20-mm mesh were used. Mist nets were used to augment the data while capturing and/or recording species, especially the nocturnal ones, which were difficult to observe or encounter during transect observations. Nets were left open at night from dusk (1830 hrs) until morning (0530 hrs) for nocturnal species.

General observations. These covered species whose records for this study were based on encounters at the site traversed by the team during off-transect periods (i.e., during breaks at the camp, or while mist nets and traps were being set up, or netwatch and herping observations were underway). The study team found the use of motorized boats extremely helpful during observations along rivers, beach sites, islands, and inundated areas of the mangrove forests.

Bird identification and documentation during fieldwork. While on-site identification of species was practiced during transect and general observations, the study team used a digital camera (Sony-Cybershot HX200V) to document the bird species found in the field. Birds were photographed whenever possible during transect walks, general observations, and other field activities. Similarly, captured individuals (on mist nets) were photographed and released. Identification of species at a distance was made using a pair of 10x40 binoculars. Species identification and distribution were based on Kennedy et al. (2000) and other references.

Mammals

Mist nets and the combination of live traps and victor snap traps were used to sample species of volant and small non-volant mammals at the study sites. Netwatch (an activity which tends the nets at dusk, usually around 18:00-1900 hrs, when insect bats are most active) was made to boost data for this group. Likewise, observing for possible tracks/fecal droppings was also made during fieldwork. Identification of mammals was referred to Ingle and Heaney 1992 and Heaney et al. 1998.

Volant mammals (bats). Mist nets (made of monofilaments fiber; 6-, 9- and 12-m length, with four pouches and 20-mm mesh) was used to sample species belonging to this group. Nets were set along pathways, across and parallel to trails, across forest/vegetated gaps or openings, and across rivers and creeks and other potential bat flyways.

Murids (rats and mice). These were sampled using a combination of live traps (consisting of roasted coconut with peanut butter) and victor snap traps using the same bait. Traps were set along suspected murid passageways, under fallen logs and root tangles, along the sides of suspected murid holes, near holes/openings adjacent to rocks and other sites where murid rats are believed to be present. The sketch shows the study team's preferred layout for nets and traps in the field.

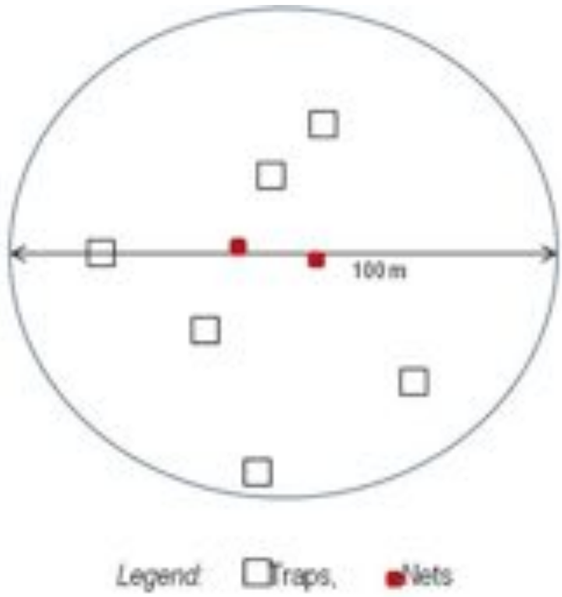

Figure 2. The diagram above illustrates the field deployment of live traps and nets laid at the study sites of the Pagbilao mangroves. The setup shows that net/s was/were placed at the center of an arbitrary circle where live traps and victor snap traps are set and dispersed within a 50-m radius from the point (usually an erected net/s) within the trapping site.

Ethnobiology

Using photographic field guides and the known local names of animals such as birds, mammals (especially medium to large ones), amphibians and reptiles, local residents/guides were interviewed about the presence of potential species that may be occurring at the site.

Desk review

The study team also reviewed and considered supplementary records/data from previous studies on terrestrial vertebrates inhabiting the PMEF and the adjacent areas of the project.

Estimation of Mangrove Biomass Carbon Storage

Calculation of Mangrove Biomass

The same sampling quadrats for tree inventory were used to determine the mangroves biomass in the Pagbilao mangrove forest. Apart from measuring the diameter and height, the survey teams also collected wood specimens from all the species surveyed inside the quadrats. For each species, wood samples were collected from the different parts of the plant, i.e., lower branch, upper branch, and roots (for the pro roots-producing species such as Rhizophora spp).

The allometric equations developed by Komiyama et al. (2005) for Southeast Asian mangroves were used to estimate the biomass of the Pagbilao mangrove forests. The equations use diameter and wood density as predictive variables to estimate both the aboveground and root biomass of each species. These equations have proven to have high coefficient of determination comparable with allometric equations derived for natural stands (Abino et al., 2014). The following allometric equations were used to estimate the aboveground and root biomass:

(1) Aboveground biomass ($\mathbf{BM}_{AG}$) = $0.251\rho D^{2.46}$

(2) Root biomass ($\mathbf{BM}_{R}$) = $0.199 \rho^{0.899} D^{2.22}$

Where ρ = the wood density of each species; and
D = the total diameter of each species

The total diameter at breast height obtained from the tree inventory was used in this report. Wood density for each mangrove species was derived mainly from the Global Wood Density Database (Zanne et al., 2009) and other available literature (see Table 3).

Table 3. Wood density values for each mangrove species

Common Name	Scientific Name	Family	Wood Density
Saging-Saging	Aegiceras corniculatum (L.) Blanco	Mysrinaceae	0.510
Tinduk-Tindukan	Aegiceras floridum Roem & Schult.	Mysrinaceae	0.680
Bungalon	Avicennia marina (Forsk.) Vierh.	Acanthaceae	0.650
Pi-api	Avicennia marina (Forsk.) Vierh. var. rumphiana (Hallier) Bakh.	Acanthaceae	0.605[1]
Api-api	Avicennia officinalis L.	Acanthaceae	0.720
Pototan lalake	Bruguiera cylindrica (L.) Blume	Rhizophoraceae	0.710
Busain	Bruguiera gymnorrhiza (L.) Lamk.	Rhizophoraceae	0.770
Tangal	Ceriops tagal (perr.) C.B. Rob.	Rhizophoraceae	0.780
Malatangal	Ceriops zippeliana Blume	Rhizophoraceae	0.758
Tui	Dolichandrone spathacea (L.f.) K. Schum.	Bignoniaceae	0.410
Buta-buta	Excoecaria agallocha L.	Euphorbiaceae	0.320
Dungon	Heritiera littoralis Ait.	Malvaceae	0.430
Kulasi	Lumnitzera racemosa Willd.	Combretaceae	0.870
Alai	Mallotus tiliifolius (Lamk) Muell.-Arg.	Euphorbiaceae	0.698[2]
Tawalis	Osbornia octodonta F. Muell.	Myrtaceae	0.820
Bakauan Lalaki	Rhizophora apiculata Blume	Rhizophoraceae	0.850
Bakauan Babae	Rhizophora mucronata Lamk.	Rhizophoraceae	0.820
Bakauan Bato	Rhizophora stylosa Griff.	Rhizophoraceae	0.840
Nilad	Scyphiphora hydrophyllacea Gaertn. f.	Rubiaceae	0.685
Pagatpat	Sonneratia alba (L.) Smith	Lythraceae	0.510
Tabigi	Xylocarpus granatum Koen.	Meliaceae	0.700[2]
Piagau	Xylocarpus moluccensis (Lamk.) M. Roem.	Meliaceae	0.571[1]

Note: The wood density values are average wood density for each species (based on studies from Southeast Asia) derived from the Global Wood Density Database (Zanne et al. 2009) unless otherwise stated.
[1]The International Tropical Timber Organization (ITTO) (2013)
[2]Kauffman, J.B. and Donato, D.C. (2012)

Carbon Content Analysis

To measure the carbon stored in the biomass, carbon content analysis of the wood of each species was conducted. Wood samples of each species taken from the different quadrats and from different plant parts were compositely processed, oven-dried, and pulverized before sending them to the IRRI-ASL for carbon content analysis using the automated carbon analysis-mass spectrometry continuous flow technique. The composite sampling was done to obtain a more accurate mean carbon fraction for each species, since it is highly possible that the carbon content of the wood of the same species may vary depending on the area where it is planted and the plant part where the wood sample is obtained.

The carbon storage of the aboveground and root biomass was first computed per species by multiplying the total biomass by the carbon fraction of each species. The values of carbon storage of all species inside each quadrat were totaled to get the total carbon stock per quadrat. Carbon stock per quadrat was then summed up and averaged to get the mean stand carbon pool, which was then converted to tons per hectare.

Estimation of Mangrove Sediment Carbon Storage

Soil Characterization

The identification of the soil found in the town of Pagbilao was determined using the soil shapefiles of the Bureau of Soil and Water Management under the Department of Agriculture (BSWM-DA). Thereafter, the general characterization was done using existing literature.

Soil sampling and analysis

The location of the sampling plots for soil sampling followed the protocol established by the tree inventory team. However, not all sampling plots were subjected to soil sampling as a review of the mangrove forest distribution and corresponding soil map revealed that only one soil type was present in the forest ecosystem of Pagbilao. As such, only representative samples from the three mangrove zones (seaward, midward, and landward) were taken (see Table 4). Overall, five samples were taken from each zonation.

Table 4. Soil sampling location for total soil C measurement at the Pagbilao mangrove forest

Sample	Plot Number	Position	Forest Type	Barangay
1	7	Seaward	Scrub	Ibabang Palsabangon
2	8	Midward	Basin	Ibabang Palsabangon
3	14	Landward	Hammock	Ibabang Palsabangon
4	13	Landward	Basin	Ibabang Palsabangon
5	12	Midward	Plantation	Ibabang Palsabangon
6	4	Seaward	Scrub	Pinagbayanan
7	3	Midward	Riverine	Pinagbayanan
8	2	Seaward	Plantation	Pinagbayanan
9	1	Seaward	Scrub	Pinagbayanan
10	5	Seaward	Overwash	Patayan Island
11	23	Midward	Riverine	Ibabang Palsabangon
12	20	Landward	Basin	Ibabang Palsabangon
13	18	Landward	Riverine	Ibabang Palsabangon
14	9	Midward	Riverine	Ibabang Palsabangon
15	11	Landward	Riverine	Ibabang Palsabangon

Soil samples were collected two ways. First, intact soil core samples were taken using a pre-fabricated steel tubing with a dimension of 5 cm diameter and 30 cm length for bulk density measurement. One soil core sample was collected at each of the 15 sampling plots. The other soil sample was collected using a soil auger following a depth of 30 cm. Ten auger soil samples were obtained at each plot, which were then placed and mixed in a plastic bag and treated as one composite sample.

The intact soil core samples were brought to the Institute of Renewable Natural Resources Soils Laboratory for oven-drying. The composite soil samples were taken to this same facility for air-drying and sieving using a 2-mm wire mesh, and later to the International Rice Research Institute Analytical Service Laboratory (IRRI-ASL) for total soil C analysis.

Soil C Storage

The stored soil C in the mangrove forest was calculated using the following formula:

$$Soil\ C\ (tons\ ha^{-1}) = Weight\ of\ soil\ (kg\ ha^{-1})\ x\ soil\ C\ content\ (weight\ kg^{-1})$$

whereas,

$$Weight\ of\ soil\ (tons\ ha^{-1}) = Bulk\ density\ (Mg\ m^{-3})\ x\ 3000\ m^3\ ha^{-1})$$

$$Bulk\ density\ (BD) = \frac{Ovendry\ weight\ (odw)}{Volume\ of\ soil\ (soil\ solids + pore\ space)}$$

The total soil C storage in the entire mangrove forest of Pagbilao was determined using this formula:

$$Total\ Soil\ C\ (tons) = Average\ Soil\ C\ (tons\ ha^{-1})\ x\ Total\ area\ of\ mangrove\ forest\ (ha)$$

Estimation of sedimentation rate

The sedimentation rate in the mangrove forest of Pagbilao was estimated indirectly through modelling using a Geographic Information System (GIS) platform and on a watershed scale. This mode was based on the fact that the sediments deposited in the coastal area comes from the whole watershed and are channeled to the coastal region through its tributaries. The same approach was used in numerous studies (e.g., Ferro and Minacapilli, 1995; Alatorre et al., 2012). For this purpose, four watersheds, namely, Palsabangon, Pagbilao, Malicboy, and Locohin, were delineated. These watersheds drain into the mangrove forest of Pagbilao.

The sedimentation rate was estimated using the formula:

$$\begin{aligned} &\textit{Estimated sedimentation rate } (tons\ ha^{-1} yr^{-1}) \\ &\qquad = \textit{Soil loss potential } (tons\ ha^{-1} yr^{-1}) x \textit{ Sediment Delivery Ratio} \end{aligned}$$

The soil loss potential was determined using the Revised Universal Soil Loss Equation (RUSLE), an improved model of the USLE developed by Wischmeier and Smith (1960). The USLE follows the equation below:

$$A = R \bullet K \bullet L \bullet S \bullet C \bullet P$$

Where A = Soil loss potential
R = Rainfall erosivity factor
K = Soil erodibility factor
LS = Topographic factor
C = Cover and management factor
P = Erosion Control Practice

Each of the factors was derived as follows:

Rainfall erosivity factor (R)

The rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}) reflects the effect of rainfall intensity on soil erosion (Ganasri, 2015). The monthly rainfall (mm) based on the 1990-2012 data for the watershed was obtained from the rain gauge station of the Philippine Atmospheric, Geophysical and Astronomic Services Administration (PAGASA) in Tayabas, Quezon (see Figure 3). The watershed was assigned a single R value based on a uniform rainfall value. The rainfall erosion index developed by David (1988) was used to estimate the rainfall erosivity value.

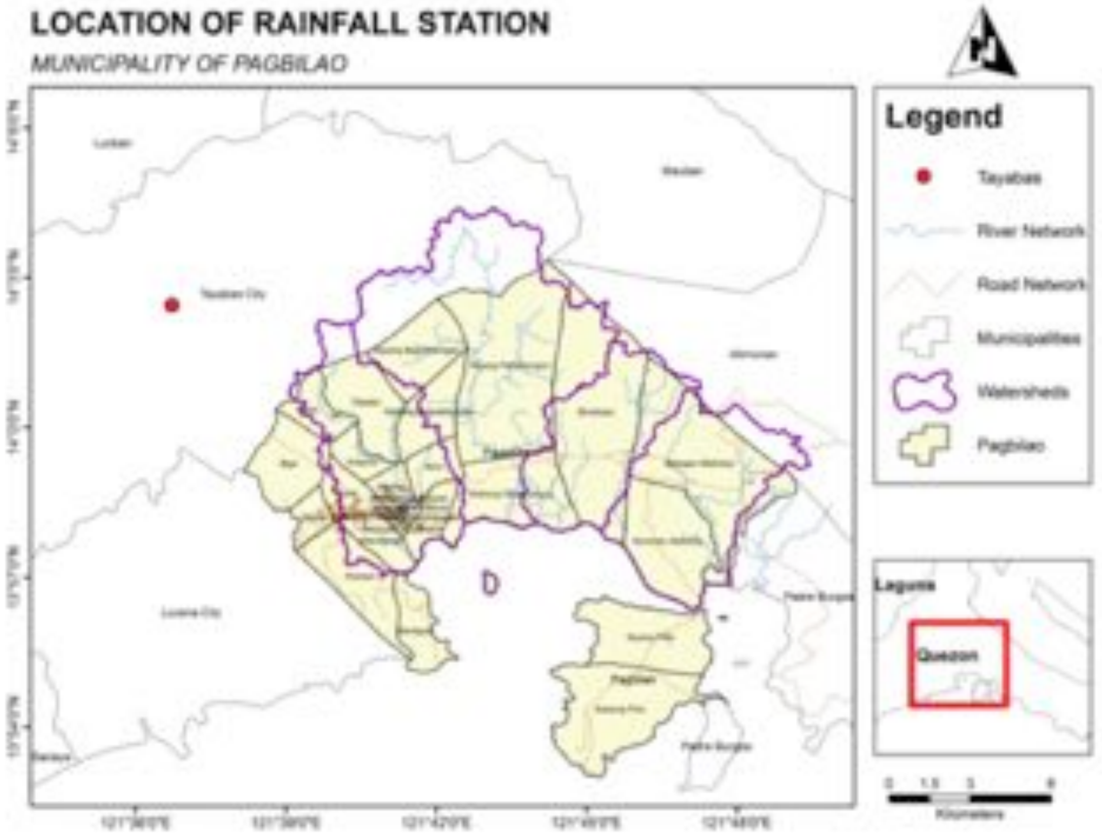

Figure 3. The PAGASA weather station to Tayabasm Quezonm the nearest weather station in Pagbilao, Quezon, where the rain data was sourced for the calculation of rainfall erosivity factor (R)

Soil erodibility factor (K)

The soil erodibility factor (K) is an empirical measure affected by soil texture, organic matter, structure, and permeability of the soil profile. The Philippine soil series data on the watershed in Pagbilao was obtained from the Department of Agriculture's Bureau of Soil and Water Management (see Figure 4). K values were assigned to each soil series following the procedure developed by David (1988), as cited by De Asis (2006) relative to Philippine soils (see Table 5).

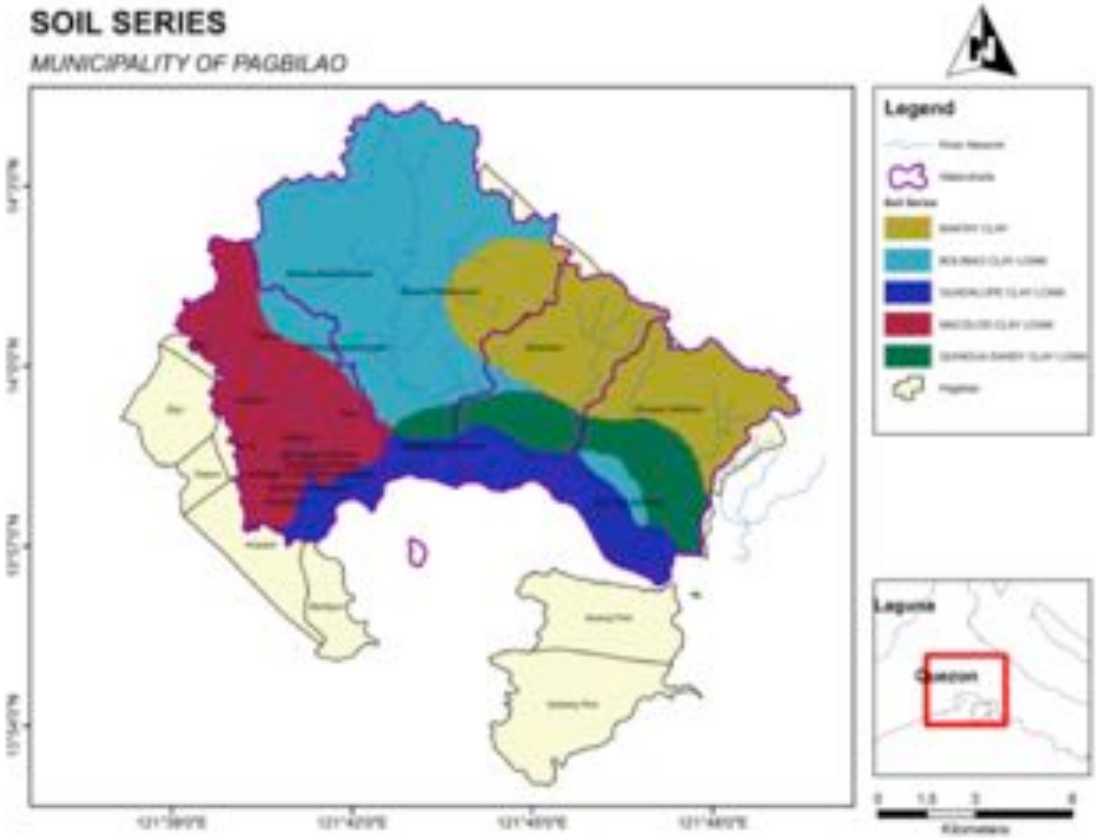

Figure 4. Soil map of the sub-watersheds covering the mangrove forest of Pagbilao

Table 5. Soil texture and corresponding K values

Soil Texture	K Value
Bolinao clay loam	0.25
Guadalupe clay loam	0.25
Quingua sandy clay loam	0.145
Macolod clay loam	0.55
Bantay clay	0.18

Topographic factor (LS)

The topographic factor includes the slope length factor (L) and the slope steepness factor (S), both calculated by determining the slope length and angle. This factor represents a ratio of soil loss under a given condition of a site with the standard slope steepness of 9 percent and slope length of 22.6 m (Wischmeier and Smith,1960). A digital elevation model (DEM) with 5-m resolution covering the areas of Pagbilao was used to derive the slope map (see Figure 5). A corresponding LS value was used based on the slope class (see Table 6).

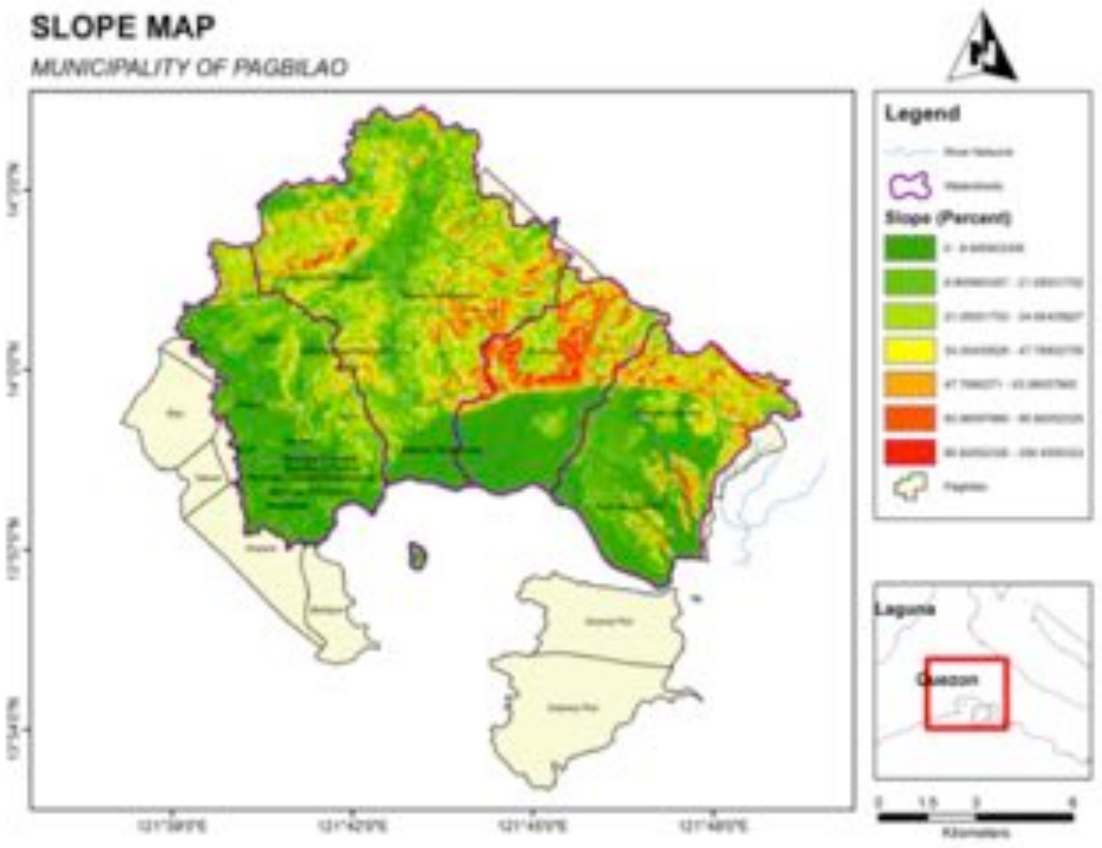

Figure 5. Slope classification of the sub-watersheds covering the mangrove forest of Pagbilao

Table 6. Slope class and corresponding LS-values

Slope Class	K Value
0-3%	0.01306
3-8%	0.01336
8-18%	0.04583
18-30%	0.12805
30-50%	0.32106
Above 50%	1.04667

Cover and management factor (C)

The cover and management factor reflects the effect of cropping and management practice on erosion rate (Fu, 2006). It is used most often to compare the relative impacts of management options on conservation plans. The 2015 land cover of Pagbilao obtained from NAMRIA was used in the study (see Figure 6). The C values were derived following the major land use group by Bantayan (2006) for Mt. Makiling and Dumas (2010) for coastal zone (see Table 7).

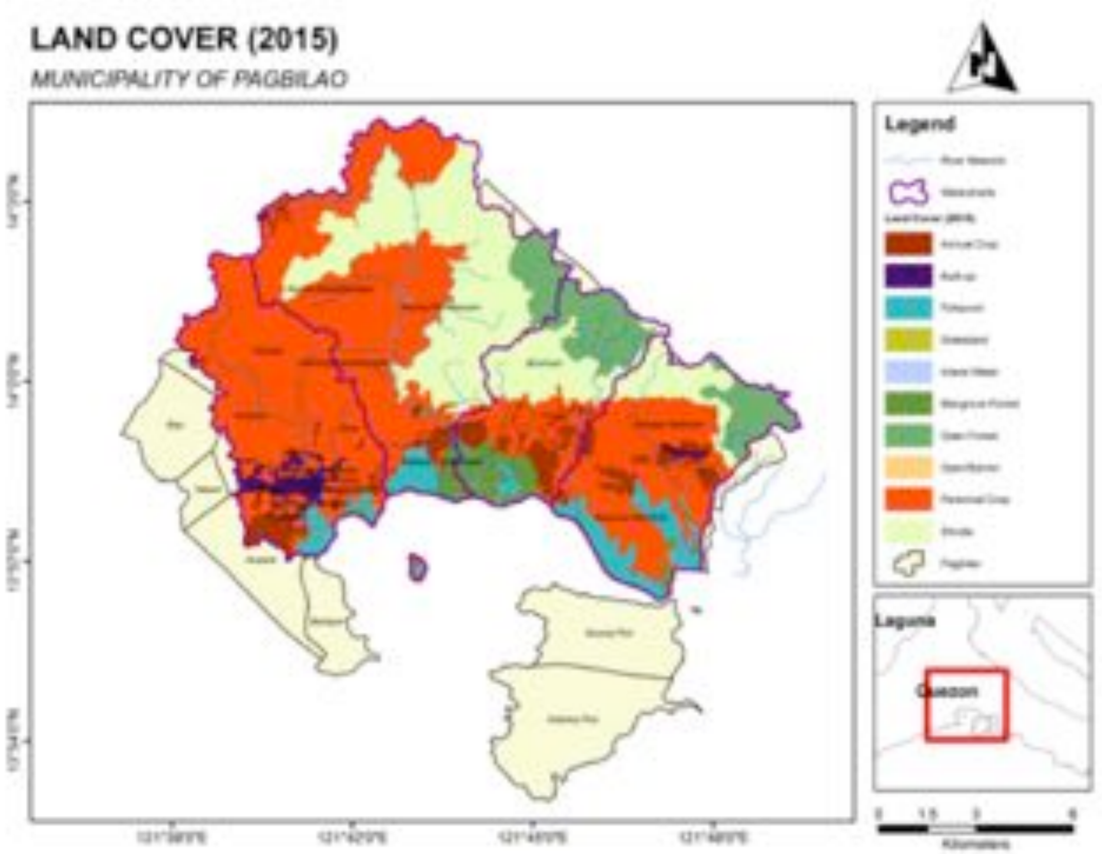

Figure 6. Land cover map of the sub-watersheds covering Pagbilao, Quezon

Table 7. Land cover and corresponding C values

Land Cover	C Value
Annual Crop	0.16
Built-Up	0.2
Fishpond	0.4
Grassland	0.013
Inland Water	0.28
Mangrove Forest	0.001
Open Forest	0.001
Open/Barren	0.45
Perennial Crop	0.16
Shrubs	0.013

Conservation support practice factor (P)

The practice factor is the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to soil loss with straight-row farming up and down the slope. For lack of data on the support practice factor in the study area, a P value of 1 was assumed throughout the study.

Sediment delivery ratio (SDR) is the fraction of gross erosion that is transported from a given area in a given time interval (Zhou, 2008). It is dependent on the drainage area and other basin characteristics as indicated by (stream?) relief, stream length, bifurcation ratio, the proximity of the sediment source to the stream, and the texture of the eroded material (Ferro, 1995). SDR ratio is needed to estimate the sedimentation rate of a watershed. It was calculated based on the size of the watershed following the formula developed by Vanoni (1975), as cited by Ouyang (1997):

$$SDR = 0.42 * A^{-0.125}$$

A = drainage area in square miles

In the application of the SDR formula, two approaches were used.

First, a sequential delivery process was employed. For this purpose, the four watersheds in Pagbilao were divided into three units or zones based on elevation values (see Figure 7). The division of basin into morphological units allows the processing of sediment delivery at a basin scale (Ferro, 1995). The zone classifications ranging from low (below 100 meters above sea level), mid (100 - 300 masl), to high (above 300 m) were established. The average potential soil loss values (t ha^{-1} yr^{-1}) of the high zones per watershed were multiplied by the sediment delivery ratio of the high zones. The product was added to the average potential soil loss of the mid zones then multiplied by the sediment delivery ratio of the mid zones. Finally, the values were added to the soil loss values of the low zones and multiplied by the sediment delivery ratio.

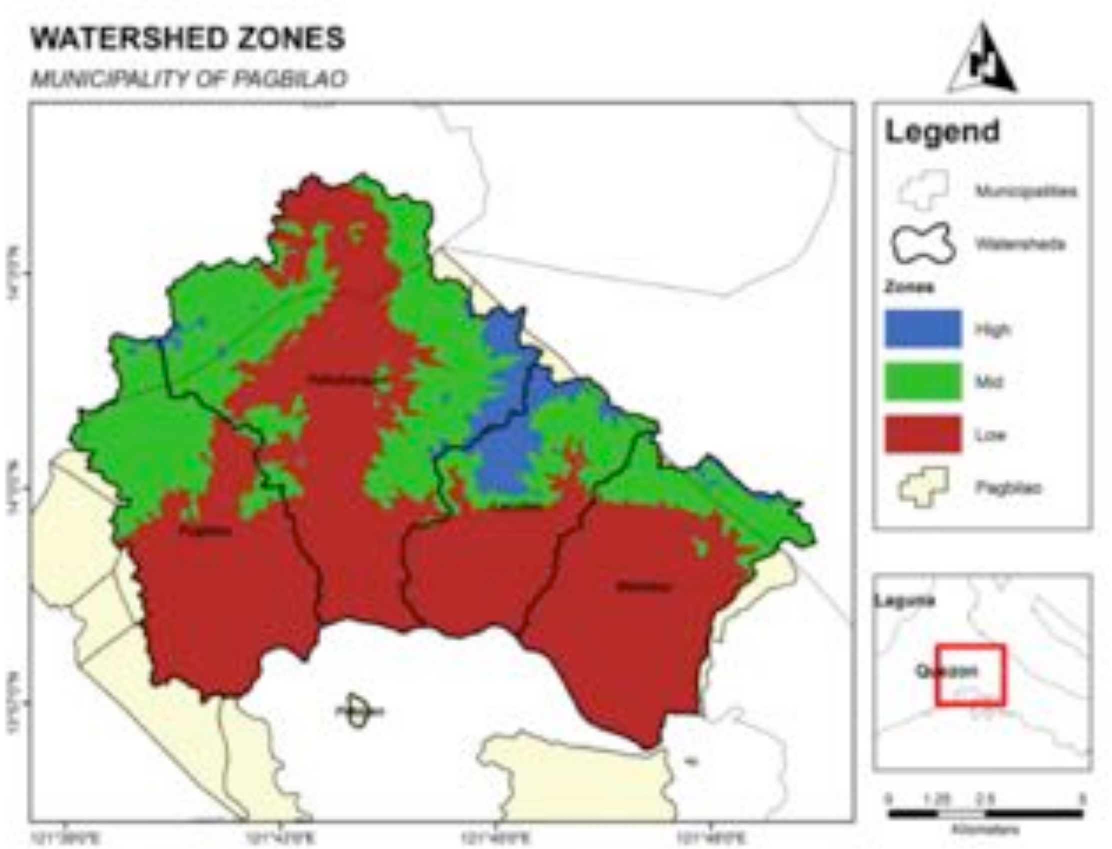

Figure 7. The watersheds covering the mangrove forest of Pagbilao divided into three zones: low, mid, and high elevations

Second, instead of dividing the watersheds into zones and doing a sequential sediment delivery, a simplified estimation of the sedimentation rate was estimated by simply multiplying the average potential soil loss values for each watershed by its corresponding sediment delivery ratio.

3 | Results and Discussion

Pagbilao Mangrove Flora

General vegetation. Like many mangrove forests in the country, PMF is not spared from degradation. Except for PMEF, the remaining mangroves are mostly scrub forests characterized by a narrow strip zone along the coastal shore, and a thin strip of riverine mangroves along the tributaries (see Figure 8). Fishpond conversion is the single biggest cause of mangrove decline in the province. In many areas, the midward and landward mangroves are already gone and only a single layer of mangrove trees that serves as biological fence for the fishponds is left (see Plate 1).

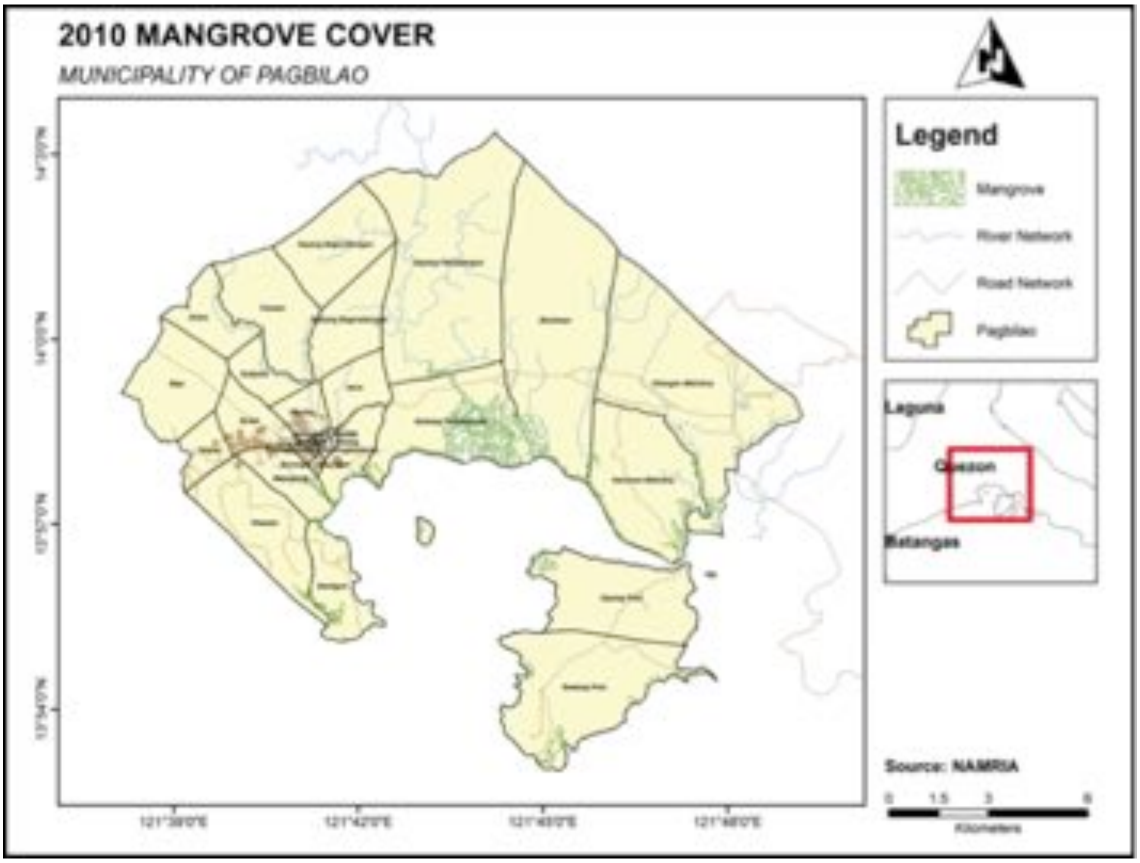

Figure 8. Map showing the remaining mangroves in the municipality of Pagbilao

The 2016 NAMRIA map shows that fishponds in the whole municipality of Pagbilao have a total area of 534.55 hectares. Based on the 2009 Google map (the earliest available with the fishpond cover), the area covered by the fishponds increased by 9.34 ha in just a span of about seven years (see Figure 9). Assuming that all the fishpond areas were originally mangrove forests, this figure suggests that more than 500 ha of mangroves have been lost to fishpond conversion alone. A comparison of the 2010 and 1996 (based on 1990 data) mangrove cover maps of NAMRIA suggests a reduction of more than 241 hectares of mangroves in 20 years (see Figure 10).

In terms of the extent of mangroves by topographic position, the classification developed by Ong and Gong (2013) was applied, that is: a) seaward zone (0 m to 100 m from the shore); b) midward zone (101 m to 300 m from the shore); and c) landward zone (beyond 300 m from the shore). Using the 2010 NAMRIA map, the total mangrove area for each zone (see Table 8) we estimated. It appears that the seaward zone (202.04 ha) has the largest extent, followed by the landward (165.75) zone, and the midward zone (159.62). It is worth mentioning that in a pristine, undisturbed mangrove forest, the seaward zone has the lowest mangrove cover. Midward and landward zones have significantly larger coverages than the seaward zone, which is limited to the first 100 m distance from the shore.

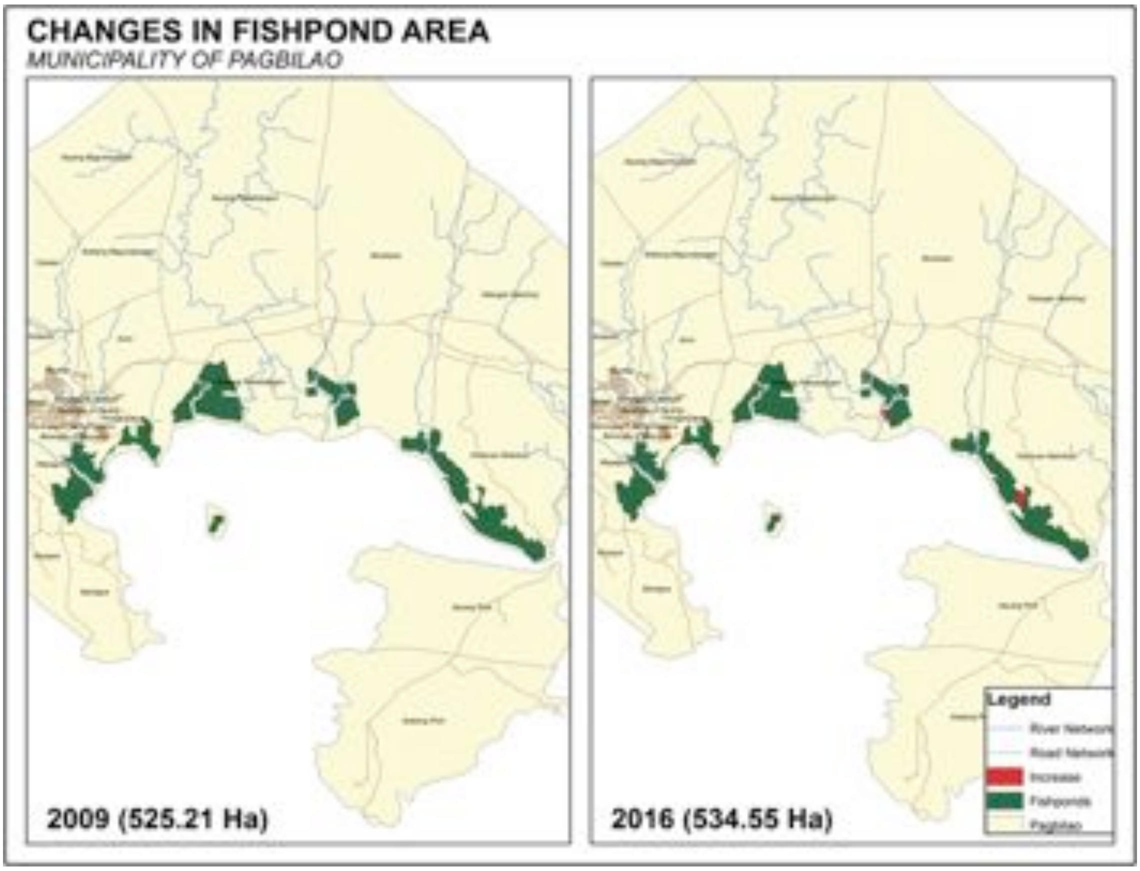

Figure 9. Extent of fishpond area in Pagbilao from 2009 to 2016

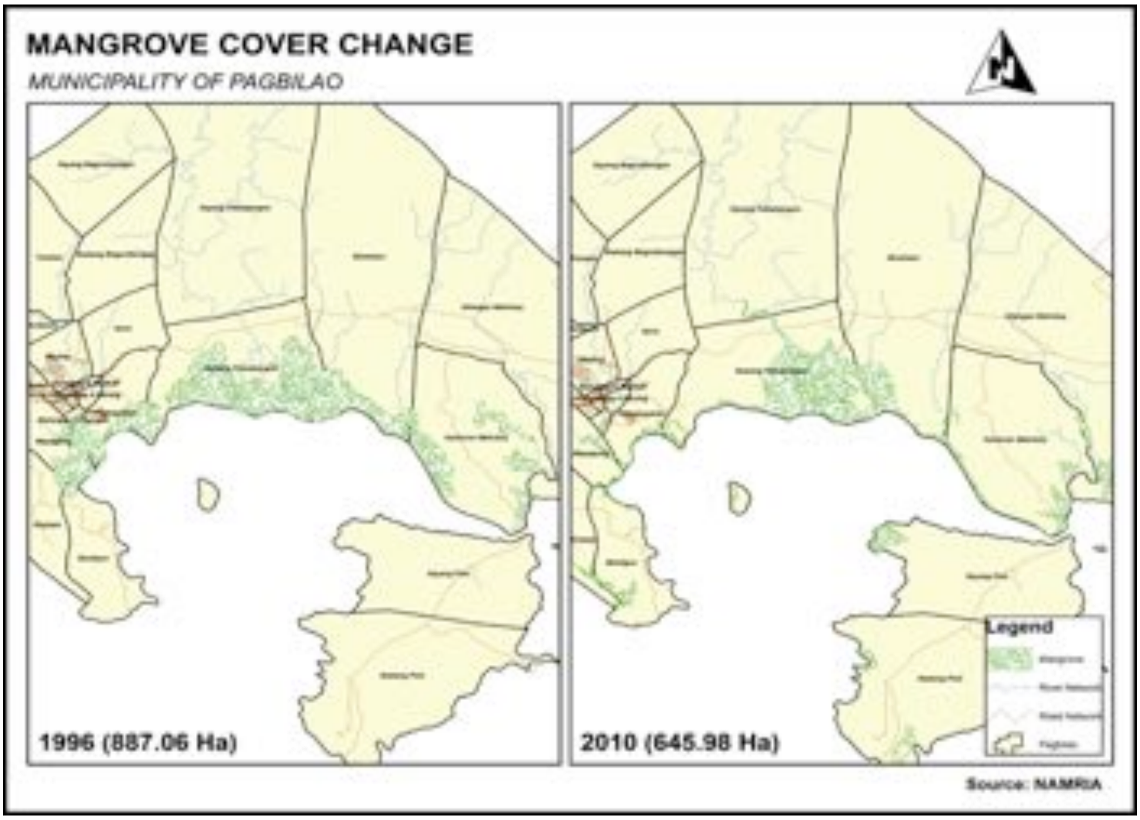

Figure 10. Extent of mangrove forest cover in Pagbilao from 1996 to 2010

Mangrove species diversity. The results of the survey lend credence to the claims of the DENR and the municipality that PMF is one of the most diverse mangrove forests in the country. A total of 30 true mangrove taxa (see Table 9) belonging to 11 families and 15 genera were observed during the study. This taxonomic survey is a major contribution to the existing stock of knowledge on mangrove diversity in the area. Prior to this study, the exact number of mangrove taxa in the municipality was unknown. In fact, the 2015 CLUP of Pagbilao states that PMF has only 19 true mangrove species but declares that it is the world's second largest mangrove based on the number of species.

It is worth noting that the list covers threatened species such as gapas-gapas (Camptostemon philippinensis) and piapi (Avicennia marina var. rumphiana), which have been categorized in the IUCN Red List as endangered and vulnerable species, respectively. The list also includes two near-threatened species while the rest are of least concern. The bakauan baler (Kandelia candel) species, which is naturally distributed only in the province of Aurora, was planted in PMEF to see if it could survive in the area. Accordingly, more than 100 seedlings were introduced in the area but only six saplings were found during the survey.

Out of a total of 37 true mangrove taxa found in the Philippines, only seven species are not present in Pagbilao. Of the 30 taxa recorded from the survey, 20 species were observed from the quadrat sampling while the rest were documented from the opportunistic survey.

Table 8. Extent of coverage of the different mangrove zones (2010)

Topographic Position	Barangay	Area
Seaward	Alupaya	4.70
	Bantigua	20.42
	Binahaan	12.22
	Ibabang Palsabangon	160.20
	Ibabang Polo	39.42
	Ilayang Polo	30.01
	Kanluran Malicboy	35.20
	Mapagong	6.10
	Pinagbayanan	10.65
	Silangan Malichoy	1.72
Total		320.62
Midward	Binahaan	11.18
	Ibabang Palsabangon	127.38
	Kanluran Malicboy	16.10
	Mapagong	0.88
	Pinagbayanan	1.02
	Silangan Malichoy	3.06
Total		159.62
Landward	Alupaya	0.43
	Barangay 2 Daungan	0.66
	Binahaan	55.81
	Ibabang Palsabangon	60.86
	Ilayang Palsabangon	6.22
	Kanluran Malicboy	9.21

Topographic Position	Barangay	Area
	Mapagong	1.74
	Silangan Malichoy	30.82
Total		165.75

A total of 22 species were recorded from the 30 quadrats surveyed, two of which (Dungon late (Heritiera littoralis) and Alai (Mallotus tiliifolius)) were not true mangroves but were mangrove associates. In terms of species diversity and abundance per barangay, Ibabang Palsabangon, where PMEF is located, has the most diverse species, numbering 22 (see Table 10). This is understandable since, it has the largest extent of mangrove cover and the most number of quadrats (17) surveyed. More than 65 percent (346/527) of the total number of individuals inventoried were also found in Ibabang Palsabangon. Patayan island, a small island which is becoming a favorite attraction in the province because of its mesmirizing sand bar, is the least diverse with only four species recorded. The overwash mangrove in Patayan island is dominated by large pagatpat (Sonneratia alba) trees.

Survey findings reinforced the general trend that the landward zone of the mangrove forests is the most diverse (see Table 11). Despite having the least number of quadrats (6) surveyed and the least number of individuals (96) recorded, the landward zone is nonetheless home to the highest number of species (16). In terms of diversity of the different mangrove forest types, the riverine and the hammock appeared to be the most diverse. Two of the quadrats surveyed contain only one species — the bakauan babae plantation in Pinagbayanan and the overwash mangrove forest in Patayan island, where only the pagatpat species was found.

Table 9. Taxonomic list of true mangrove species documented in Pagbilao mangrove forest

Family	Species	Conservation Status
ACANTHACEAE	Acanthus ebracteatus Vahl.	LC
ACANTHACEAE	Acanthus ilicifolius L.	LC
ACANTHACEAE	Avicennia marina (Forsk.) Vierh. ssp. marina	LC
ACANTHACEAE	Avicennia marina var. rumphiana (Hallier f.) Bakh.	VU
ACANTHACEAE	Avicennia officinalis L.	LC
COMBRETACEAE	Lumnitzera littorea (Jack) Voigt.	LC
COMBRETACEAE	Lumnitzera racemosa Willd.	LC
EUPHORBIACEAE	Excoecaria agallocha L.	LC
LYTHRACEAE	Sonneratia alba J. Smith	LC

Family	Species	Conservation Status
LYTHRACEAE	Sonneratia caseolaris (L.) Engler	LC
LYTHRACEAE	Sonneratia ovata Backer	NT
MALVACEAE	Camptostemon philippinensis (Vidal) Becc.	EN
MELIACEAE	Xylocarpus granatum Koen.	LC
MELIACEAE	Xylocarpus moluccensis (Lamk.) Roem.	LC
MYRSINACEAE	Aegiceras corniculatum (L.) Balanco	LC
MYRSINACEAE	Aegiceras floridum Roemer and Schultes	NT
MYRTACEAE	Osbornia octodonta F. Muell.	LC
PTERIDACEAE	Acrostichum aureum L.	LC
PTERIDACEAE	Acrostichum speciosum Willd.	LC
RHIZOPHORACEAE	Bruguiera cylindrica (L.) Bl.	LC
RHIZOPHORACEAE	Bruguiera gymnorrhiza (L.) Lamk.	LC
RHIZOPHORACEAE	Bruguiera parviflora Wight and Arnold ex Griffith	LC
RHIZOPHORACEAE	Bruguiera sexangula (Lour.) Poir.	LC
RHIZOPHORACEAE	Ceriops tagal (Perr.) C.B. Robinson	LC
RHIZOPHORACEAE	Ceriops zippeliana Sheue et al.	LC
RHIZOPHORACEAE	Kandelia candel (L.) Druce.	LC
RHIZOPHORACEAE	Rhizophora apiculata Bl.	LC
RHIZOPHORACEAE	Rhizophora mucronata Poir.	LC
RHIZOPHORACEAE	Rhizophora stylosa Griff.	LC
RUBIACEAE	Scyphiphora hydrophyllacea Gaetn. f.	LC

Table 10. Species diversity and abundance per barangay

Barangay	Number of Quadrats	Number of Species	Number of Individuals
Binahaan	3	8	37
Ibabang Palsabangon	17	22	346
Kanlurang Malichoy	4	6	82
Patayan Island	2	4	20
Pinagbayanan	4	9	42
Total	30	22	527

Table 11. Species diversity and abundance per stratum

Mangrove Zone	Forest Types	Number of Quadrats	Number of Species	Number of Individuals
Seaward	Fringing	1	3	19
	Overwash	1	1	5
	Plantation	1	1	2
	Riverine	3	9	43
	Scrub	8	10	140
Total		14	13	209
Midward	Basin	2	3	37
	Hammock	2	7	25
	Plantation	1	6	58
	Riverine	5	12	102
Total		10	15	222
Landward	Basin	2	6	43
	Hammock	2	10	27
	Riverine	2	5	26
Total		6	16	96

Mangrove Stand Structure

Stand density. Forking or the production of two or more stems (≥ 5 cm DBH) from a point below 1.3 m from the ground is very common among mangrove trees. Of the 526 individuals recorded from the 30 quadrats, 95 exhibited forking. Seventeen of the 22 species have at least one forking individual (see Table 12), many of which have more than three stems. A total of 706 individual stems were counted and measured. To avoid underestimating the density of the area (especially when the density will be used to determine the protective services of the area), the number of stems (instead of number of individuals) was used to compute for the density.

Among the three mangrove zones, the midward zone is the most densely stocked with an average density of 2,890 stems/ha (see Figure 11). This conforms to the general condition of any natural mangrove forest, where the midward zone is mostly composed of small-diameter, closely spaced trees. In terms of density per forest type, fringing mangroves obtained the highest average density of 2,700 stems/ha while hammock mangroves appeared to be the least dense (see Figure 12).

It was observed, however, that the mangrove density has been greatly affected by the age or maturity of the stand rather than the topographic position or forest type. Younger stands with smaller-diameter trees have higher density while more mature stands with larger-diameter trees could only accommodate a few individuals. For instance, the overwash mangrove in Patayan island has the lowest average density of 900 stems/ha, primarily because it is a mature stand of pagatpat, with an average DBH of 31.56 cm.

Table 12. List of species and number of individuals that exhibit forking

Species	No. of forking individuals
Aegiceras floridum Roem & Schult	9
Avicennia marina (Forsk.) Vierh. var. *rumphiana* (Hallier) Bakh.	7
Avicennia marina (Forsk.) Vierh.	8
Avicennia officinalis L.	8
Bruguiera cylindrica (L.) Blume	1
Bruguiera gymnorrhiza (L.) Lamk.	1
Ceriops zippeliana Blume	1
Ceriops tagal (Perr.) C.B. Rob.	2
Dolichandrone spathacea (L.f.) K. Schum.	1
Excoecaria agallocha L.	3
Heritiera littoralis Ait.	1
Osbornia octodonta F. Muell.	7
Rhizophora apiculata Blume	16
Rhizophora mucronata Lamk.	5
Scyphiphora hydrophyllacea Gaernt. F.	6
Sonneratia alba (L.) Smith	9
Xylocarpus granatum Koen.	10

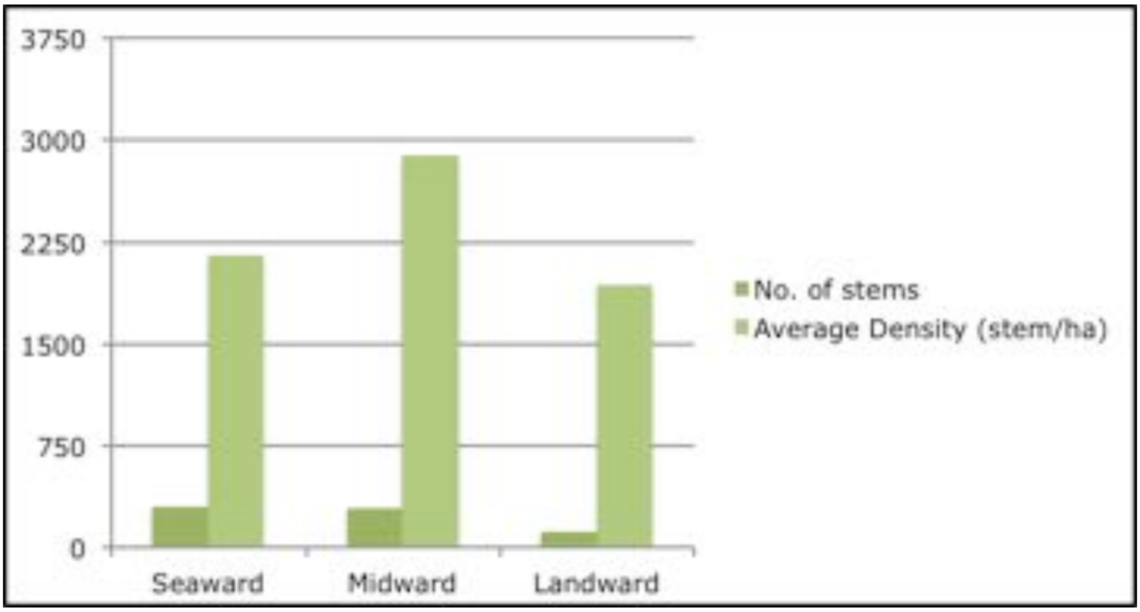

Figure 11. Stand density of different mangrove types

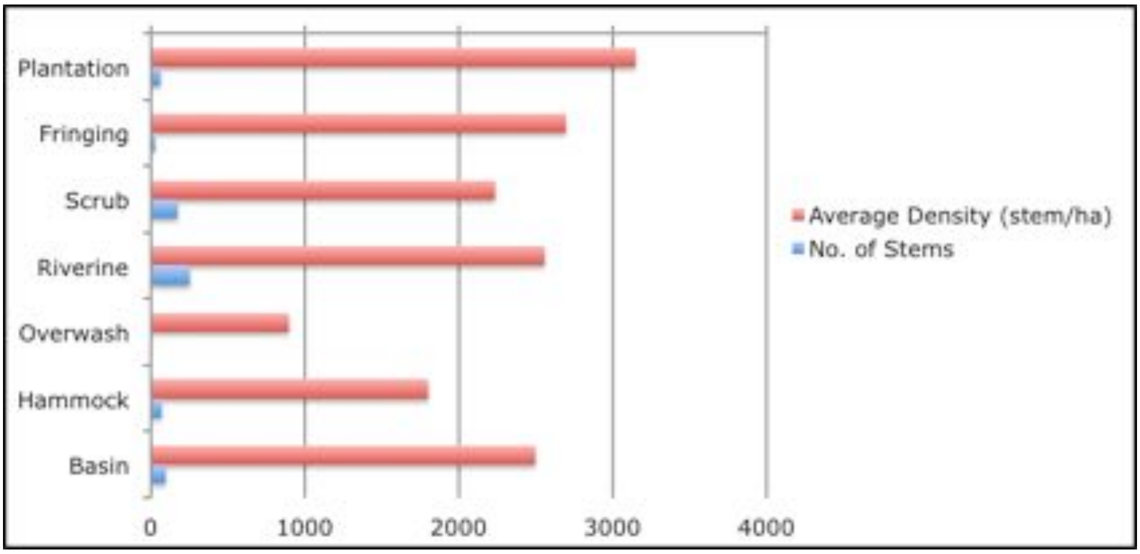

Figure 12. Stand density of different forest types

Diameter class distribution. More than 81 percent (576/706) of the trees/stems surveyed are small-diameter (5-15 cm) trees, 16 percent are of medium diameter (16-30 cm), while only 2.6 percent belong to the large-diameter class (31 cm and above?) (see Table 13). These proportions are almost the same across all the three mangrove zones. This forest structure is common among mangroves. Unlike terrestrial trees, only a few mangrove species can reach a diameter of more than 30 cm. In addition, the Pagbilao mangrove forest is generally a secondary, relatively young, forest, aged about 20 years old (Pagbilao CLUP, 2015). Hence, the mangrove trees have not reached yet their mature size.

Except for a single quadrat in Patayan island, the same proportions were observed across the different forest types (see Table 14). This quadrat is a monotypic overwash mangrove, more likely a remnant of an old-growth forest composed of large-diameter Pagatpat trees. Of the nine individuals recorded from this quadrat, five individuals have more than 30 cm diameter. The two largest trees recorded in the survey came from this quadrat with a diameter of 59 cm and 56.5 cm, respectively.

Table 13. Diameter distribution across mangrove zones

Mangrove Zone	Diameter range (cm)			Total
	5 to 15	16 to 30	31 above	
Landward	88	26	2	116
Midward	248	36	5	289
Seaward	240	49	12	301
Total	**576**	**111**	**19**	**706**

Table 14. Diameter distribution of the different forest types

Forest Type	Diameter range (cm)			Total
	5 to 15	16 to 30	31 above	
Basin	83	15	2	100
Hammock	60	11	1	72
Over wash	3	1	5	9
Riverine	207	45	4	256
Scrub	137	35	7	179
Fringing	26	1	0	27
Plantation	60	3	0	63
Total	**576**	**111**	**19**	**706**

Diameter and height. The average DBH among all trees across the study sites is 11.19 cm. The top three species with the largest average diameter are pagatpat (Sonneratia alba), api-api (Avicennia officinalis), and piapi (Avicennia marina var. rumphiana) (see Table 15). This ranking was quite expected since the three species are among the known large mangrove trees. Piagau (Xylocarpus moluccensis) and alai (Mallotus tiliifolius), a mangrove associate, got the lowest average diameter at 5.5 cm. These two species both have single individuals measured across sites. This does not mean, however, that these two species are small-diameter trees. It just so happened that the single individuals for each species are still saplings. Piagau and alai are both medium-diameter trees that could attain a maximum diameter of at least 30 cm.

The average height of the trees across sites is 8.8 m. The three tallest species are bakauan bato (Rhizophora stylosa), api-api (Avicennia officinalis), and piapi (Avicennia marina var. rumphiana). In terms of average DBH, api-api and piapi also rank second and third, respectively. Bakauan bato is a seaward species, usually located right behind the frontliners, pagatpat and bungalon. It may not be the tallest among the mangroves but it was found to be the tallest among the quadrats sampled. Consequently, because of the dominance in height and abundance of bakauan bato, the seaward zone was found to have the highest average height among the three mangrove zones (see Figure 13).

Table 15. Average DBH and height of the different species surveyed

Species	Common name	Average DBH (cm)	Average height (cm)
Aegiceras corniculatum (L.) Blanco	Saging-saging	6.00	5.00
Aegiceras floridum Roem & Schult	Tinduk-tindukan	7.57	6.27
Aviccenia marina (Forsk.) Vierh. var. rumphiana (Hallier) Bakh.	Piapi	15.62	8.91
Avicennia marina (Forsk.) Vierh.	Bungalon	13.04	11.23
Avicennia officinalis L.	Api-api	16.87	11.74
Bruguiera cylindrica (L.) Blume	Pototan	7.65	8.92
Bruguiera gymnorrhiza (L.) Lamk.	Busain	8.98	6.04
Ceriops zippeliana Blume	Malatangal	5.99	5.28
Ceriops tagal (Perr.) C.B. Rob.	Tangal	7.72	6.67
Dolichandrone spathacea (L.f.) K. Schum.	Tui	13.53	9.00
Excoecaria agallocha L.	Buta-buta	11.53	10.44
Heritiera littoralis Ait.	Dungon late	7.66	5.61
Lumnitzera racemosa Wild.	Kulasi	9.00	10.00
Mallotus tiliifolius (Blume) Muel.-Arg.	Alai	5.50	4.50
Osbornia octodonta F. Muell.	Taualis	11.32	8.88
Rhizophora apiculata Blume	Bakauan lalaki	10.13	8.41
Rhizophora mucronata Lamk.	Bakauan babae	8.86	9.38
Rhizophora stylosa Griff.	Bakauan bato	11.57	11.83
Scyphiphora hydrophyllacea Gaernt. F.	Nilad	7.89	7.32
Sonneratia alba (L.) Smith	Pagatpat	18.04	9.24

Species	Common name	Average DBH (cm)	Average height (cm)
Xylocarpus granatum Koen.	Tabigi	11.42	9.25
Xylocarpus moluccensis (Lamk.) M. Roem.	Piagau	5.50	5.00

The average diameter and height of all trees in each mangrove zone were also computed to better understand the stand structure of the Pagbilao mangrove forest. The seaward zone has the largest average DBH, followed by the landward zone, then the midward zone (see Figure 13). That the midward zone emerged as having the lowest average DBH is understandable. As mentioned earlier, trees in the midward zone (i.e. tangal, malatangal, saging-saging, etc.) are naturally small-diameter species. Dominant trees in the landward zone (i.e., api-api and piapi) and seaward zone (i.e., pagatpat and bungalon) are some of the largest mangrove species. In the case of PMF, the larger average DBH of the seaward zone compared to the landward zone can be attributed to the large pagatpat trees in the overwash mangrove of Patayan island (see Figure 14). In fact, Pagatpat far exceeds other species in terms of average diameter.

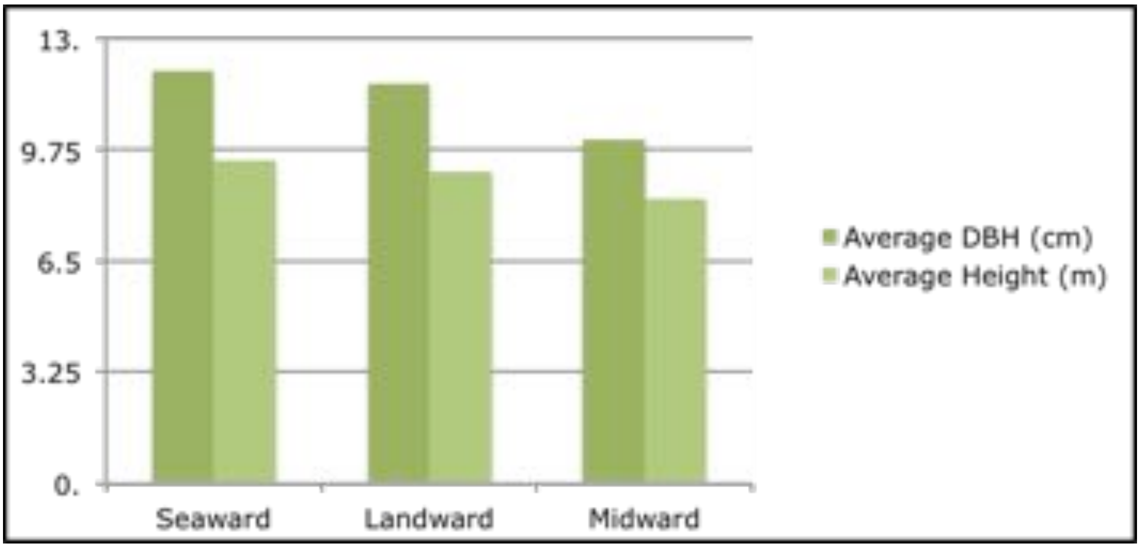

Figure 13. Average DBH and height of the different mangrove zones

Plantation forests were found to have the highest average height of 10.09 m among the different forest types (see Figure 14).

There are two mangrove plantations included in the survey, located in barangays Pinagbayanan and Palsabangon. The young plantation in Pinagbayanan has an average height of only 4.5 m while the plantation in

Ibabang Palsabangon (about 20 years old), which is near the PMEF station, has the highest average height among the quadrats at 10.27 m. The overwash mangrove in Patayan island, which far exceeds the rest of the forest types in terms of average diameter, has the lowest average height. This is not surprising since Pagatpat, the only species in the quadrat, is a large-diameter tree but rarely grows to a height of 10 m.

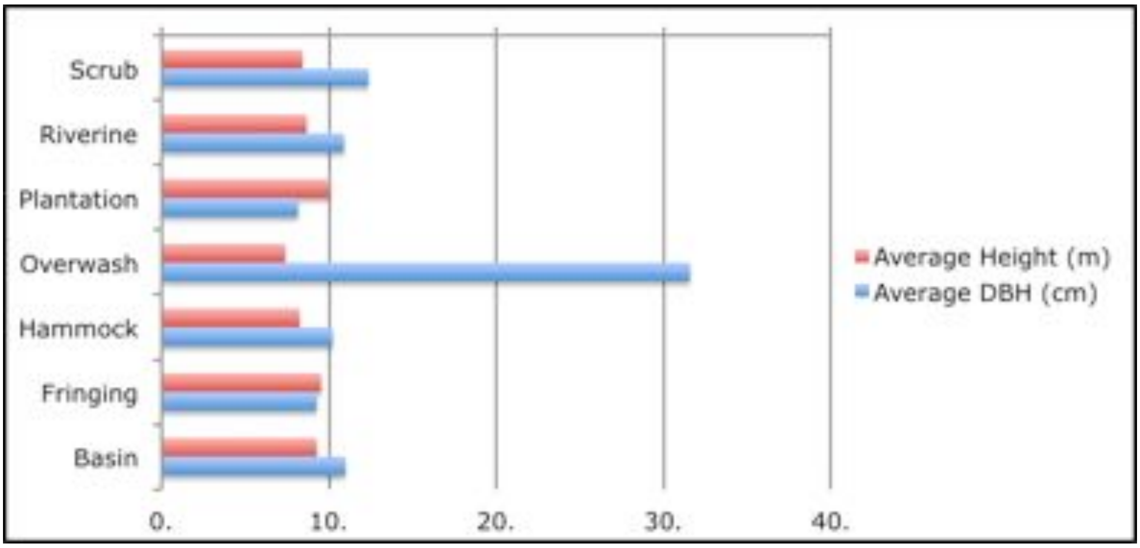

Figure 14. Average DBH and height of the different forest types

Importance value. The relative density (RD), relative dominance (RDom), and relative frequency (RF) values of each mangrove tree species in all the quadrats were determined to calculate their importance value (IV). High IVs among species indicate a composite score for high relative species dominance, density, and frequency. Based on the computed IV (see Table 16), the three most important species, or species with the highest IVs compared to the others, are bakauan lalaki (Rhizophora apiculata), Tabigi (Xylocarpus granatum), and api-api (Avicennia officinalis). Bakauan lalaki obtained more than 20 percent of the total IV of all the species surveyed. It ranked number one based on RD, RDom, RF.

Table 16. Importance value of each mangrove tree species surveyed

Species	RF	RD	RDom	IV
Rhizophora apiculata Blume	11.966	18.980	30.881	61.827
Xylocarpus granatum Koen.	7.692	12.606	17.307	37.606
Avicennia officinalis L.	8.547	7.365	12.897	28.809
Rhizophora mucronata Lamk.	8.547	9.632	6.081	24.259

Species	RF	RD	RDom	IV
Sonneratia alba (L.) Smith	6.838	6.374	11.037	24.249
Avicennia marina (Forsk.) Vierh.	9.402	6.374	5.770	21.545
Avicennia marina (Forsk.) Vierh. var. rumphiana (Hallier) Bakh.	6.838	5.949	7.211	19.998
Ceriops zippeliana Blume	8.547	5.099	0.780	14.427
Osbornia octodonta F. Muell.	2.564	6.374	4.350	13.288
Aegiceras floridum Roem & Schult	5.128	4.533	0.982	10.643
Scyphiphora hydrophyllacea Gaernt. F.	4.274	3.966	0.817	9.056
Ceriops tagal (Perr.) C.B. Rob.	4.274	2.550	0.323	7.146
Excoecaria agallocha L.	3.419	2.550	0.722	6.691
Bruguiera cylindrica (L.) Blume	1.709	3.399	0.564	5.673
Heritiera littoralis Ait.	2.564	1.275	0.080	3.918
Bruguiera gymnorrhiza (L.) Lamk.	1.709	1.133	0.086	2.929
Rhizophora stylosa Griff.	1.709	0.850	0.081	2.640
Dolichandrone spathacea (L.f.) K. Schum.	0.855	0.425	0.028	1.307
Lumnitzera racemosa Wild.	0.855	0.142	0.001	0.998
Aegiceras corniculatum (L.) Blanco	0.855	0.142	0.001	0.997
Mallotus tiliifolius (Blume) Muel.-Arg.	0.855	0.142	0.001	0.997
Xylocarpus moluccensis (Lamk.) M. Roem.	0.855	0.142	0.001	0.997

Note: RF – Relative frequency, RD – Relative density, RDom – Relative dominance

Diversity indices. Based on the number and abundance of all the species, Paleontological Statistical software package for education and data analysis (PAST version 3.12) was used to compute for diversity indices including Shannon (H'), Evenness (J'), and Simpson (D) for all the quadrats. Shannon Index yields an estimate of species richness and distribution. The Evenness index tells us how evenly species and/or individuals are distributed inside a plot or quadrat. Simpson's Index gives the probability of getting different species when two individuals were drawn (with replacement) inside a plot.

Based on the diversity classification range developed by Fernando et al. (1996), all of the quadrats have very low diversity (see Table 17) for a 10 m x 10 m quadrat. This is expected in any mangrove forest due to the very defined mangrove zonation pattern, where each species has its own specialized niche.

Quadrat 14 obtained the highest value (1.796) while quadrat 5, which has a single species, got the lowest Shannon index of zero. The number of species present in each quadrat was primarily the reason for high/low value Shannon index value. Nine species were recorded in quadrat 14 and only one species, Sonneratia alba (L.) Smith, was recorded in quadrat 5. Similarly, quadrat 5 had the lowest Simpson index value. Quadrat 2, a plantation composed of Rizophora mucronata Lamk. and R. apiculata Blume, obtained the second lowest value for the Shannon and Simpson indices. Quadrat 22 obtained the highest value on the Simpson index instead of quadrat 14. The over dominance of Herritiera littoralis Ait. in quadrat 14 lowered its value for the Simpson index. In terms of Evenness index, quadrat 5 had the highest value of 1.00, understandably because it contains a single species.

Table 17. Diversity indices and number of species and individuals for each plot

Quadrat No.	Plot Character	No. of species	No. of individuals	Diversity Indices		
				H'	D'	J'
1	Seaward; Scrub	4	7	1.277	0.694	0.897
2	Seaward; Plantation	3	157	0.258	0.120	0.431
3	Midward; Riverine	9	22	1.763	0.760	0.648
4	Seaward; Scrub	4	21	1.196	0.671	0.827
5	Seaward; Overwash	1	5	0.000	0.000	1.000
6	Seaward; Scrub	4	19	0.734	0.360	0.521
7	Seaward; Scrub	4	19	0.898	0.482	0.613
8	Midward; Basin	2	55	0.500	0.320	0.825
9	Midward; Riverine	7	109	1.166	0.603	0.458
10	Midward; Hammock	4	103	0.891	0.479	0.609
11	Landward; Riverine	4	16	1.103	0.602	0.754
12	Midward; Plantation	6	70	1.187	0.624	0.546
13	Landward; Basin	5	45	0.801	0.378	0.446
14	Landward; Hammock	9	26	1.796	0.778	0.670
15	Midward; Riverine	7	118	1.383	0.709	0.570
16	Seaward; Riverine	6	22	1.577	0.752	0.807
17	Midward; Hammock	5	10	1.557	0.780	0.949
18	Landward; RIverine	5	33	1.458	0.748	0.860
19	Seaward; Scrub	6	23	1.435	0.696	0.700
20	Landward; Basin	6	29	1.461	0.721	0.718
21	Midward; Riverine	6	111	0.886	0.466	0.404
22	Seaward; Riverine	6	19	1.660	0.792	0.876
23	Midward; Riverine	4	40	0.603	0.303	0.457
24	Seaward; Riverine	4	10	1.089	0.580	0.743
25	Midward; Basin	4	23	0.753	0.371	0.531
26	Landward; Hammock	4	15	0.953	0.507	0.649
27	Seaward; Scrub	4	18	1.259	0.685	0.881
28	Seaward; Scrub	3	19	0.537	0.277	0.570
29	Seaward; Scrub	4	30	1.003	0.558	0.681

Quadrat No.	Plot Character	No. of species	No. of individuals	Diversity Indices		
				H'	D'	J'
30	Seaward; Fringing	4	42	0.880	0.541	0.603

Note: H' – Shannon index; D = Simpson index; J – Evenness index
Value interpretation for H': Very High = ≥3.5 above, High = 3.0-3.49, Moderate = 2.5-2.99, Low = 2.0-2.49, Very Low = ≤1.9 and below

Pagbilao Mangrove Fauna

At least 71 species of terrestrial vertebrates comprising 55 species of birds, nine species of herpetofauna, and seven species of mammals were recorded. Fifteen species were found endemic to the Philippines. There were four documented threatened and near-threatened species, namely, the Philippine duck, Philippine eagle-owl, Java sparrow, and Philippine common cobra. The first two species are endemic to the Philippines and are listed as vulnerable on the IUCN Red List. The Java sparrow is an introduced species and is likewise listed as vulnerable while the Philippine common cobra is classified as near threatened on the same global conservation list.

Table 18. Summary of terrestrial vertebrates recorded during a survey of the Pagbilao mangroves[3]

Vertebrate group	Total species	No. of Endemic & NE species	Threatened & NT species	CITES listed	Uncommon/ rare species
Amphibians and reptiles	9	2 (22%)	1 (NT)	3	1
Birds	55	13 (23%)	3 (Vu)	4	4
Mammals	7	1 (14%)	0	1	0
Total	71	16 (22%)	4	8	5

Legend: NE – Near endemic; NT – Near-threatened; Vu –Vulnerable

Hepterofauna (Amphibians and reptiles)

At least nine species of herpetofauna (one toad and three true frogs, two gekkonids, one varanid lizards, one python, and one elapid snake) were

[3] Recorded at Pagbilao Mangrove Experimental Station and vicinities in (?) barangays Pinagbayanan and Palsabangon) from June to July 2016

recorded at the study sites in the Pagbilao mangroves. Endemic accounted to 22 percent (2/9 species). One near-threatened species (the Philippine Common Cobra) was recorded for this group (see Table 19).

Table 19. Amphibians and reptiles recorded during a survey of the Pagbilao mangroves[4]

No.	Family/ Scientific Name	Common Name	Distribution	Conservation status (IUCN)	Encounter
	FROGS AND TOADS				
1	BUFONIDAE Bufo (Rhinella) marinus	Cane Toad	Cosmopolitan; introduced	Least concern	Seen
2	RANIDAE Rana (Fejervarya) cf. cancrivora	Brackish Water Frog/ Asian Brackish Frog	Common all over the country	Least concern	Seen
3	MICROHYLIDAE Kaloula pulchra	Malaysian Narrow mouth Toad	Introduced	Least concern	Seen
4	RHACOPHORIDAE Polypedates leucomystax	White-lipped Tree Frog/ Common Tree Frog	Asia	Least concern	Seen
	LIZARDS				
5	GEKKONIDAE Gekko gecko	Tokay Gecko	Cosmopolitan	Least concern	Heard
6	Hemidactylus cf. frenatus	Common House Gecko	Cosmopolitan	Least concern	Heard/ seen
7	VARANIDAE Varanus cf. marmoratus	Monitor Lizard	Philippines	Least concern; CITES Appendix II	interview (with?)
	SNAKES				
8	BOIDAE (PYHONIDAE) Python (Broghammerus) reticulatus	Reticulated Python	Asia	CITES Appendix II	interview
9	ELAPIDAE Naja cf. philippinensis	Philippine Common Cobra	Philippines	Near threatened CITES Appendix II	interview

No. of Endemic (found only in the Philippines) species: = 2
No. of Threatened/Near-threatened species: = 1
CITES listed species: = 3

Table 20 shows that two species were found to be common in the survey sites. One was Cane toad (Bufo (Rhinella) marinus), which was found in all study sites. This species was introduced to the country in 1930s to control the

[4] Recorded at Pagbilao Mangrove Experimental Station and vicinities in (?) barangays Pinagbayanan and Palsabangon) from June to July 2016. Taxonomy and conservation status follow the IUCN Red List of threatened species (http://www.iucnredlist.org). Distribution were referred to Diesmos, 2010 (unpublished report), Alcala 1986 and IUCN Red List

spread of pests in sugarcane fields. It is also found in all major islands in the country and breeds in ponds and ditches, including those with saline waters (Alcala and Brown, 1998).

The other common species is the brackish water frog Rana (Fejervarya) cf. cancrivora. It exists in ditches, brackish fishponds, rice fields, and upper mangroves. It breeds in brackish waters with salinity of 2.0 parts per thousand (ppt), and can tolerate salinity of up to 2.8 ppt. It is commonly used as food and usually occupy areas near the sea (Alcala and Brown, 1998).

Table 20. Records of herpetofaunal species found in specific or all sampling sites in Pagbilao mangroves[5]

No.	Family/ Scientific Name	1	2	3	4	Remarks
1	BUFONIDAE Bufo (Rhinella) marinus	X	X	X	X	Common in all site especially after the rain
2	RANIDAE Rana (Fejervarya) cf. cancrivora		X		X	Fairly common
3	MICROHYLIDAE Kaloula pulchra	X	X			Introduced
4	RHACOPHORIDAE Polypedates cf. leucomystax			X		
5	GEKKONIDAE Gekko gecko	X				
6	Hemidactylus cf. frenatus	X	X		X	
7	VARANIDAE Varanus cf. marmoratus					Interview
8	BOIDAE (PYHONIDAE) Python (Broghammerus) reticulatus					Interview
9	ELAPIDAE Naja cf. philippinensis					Interview

Legends:
1 – Pagbilao Mangrove Experimental Station compound (PMES),
2 – Herping site 1 (i.e., mangrove pathway/boardwalk)
3 – Herping site 2 (i.e., ricefield going to buri, avicennia site (?) and mammal trapping/netting site 2)
4 – Herping site 3 (i.e., hanging bridge going to nipa-avicennia site/mammal rapping/netting site 3)

Birds

Fifty-five species of birds found in all study sites belong to at least 27 families and 48 genera. Endemic species accounted for 23 percent of the avian species recorded by the research team. Three noteworthy yet threatened species were found at the survey areas, namely, the Philippine duck (endemic — IUCN Vulnerable), Philippine eagle-owl (endemic — IUCN Vulnerable), Java sparrow (introduced — IUCN Vulnerable). These threatened species may well

[5] Conducted in June-July 2016

be indicators of an increased potential value of a birdwatching site. Currently, at least four migratory species exist at the site, and are expected to rise during the peak of migration season (September to January). Table 21 lists the species found during the survey.

Table 21. List of birds recorded during the survey of the Pagbilao mangroves[6]

No.	Family/ Scientific Name	Common Name	Residency status	Conservation status (IUCN)	Encounter
	ARDEIDAE Ardea purpurea	Purple heron	Resident	Least concern	Seen
	Egretta (Ardea) alba	Great egret	Migrant	Least concern	Seen
	Egretta (Ardea) intermedia	Intermediate egret	Migrant	Least concern	Seen
	Egretta garzetta	Little egret	Migrant	Least concern	Seen
	Butorides striatus	Little heron	Resident/ Migrant	Least concern	Seen
	Nycticorax sp.	Night-heron	-	Least concern	Seen
	ANATIDAE Anas luzonica	Philippine duck	Endemic	Vulnerable	Seen
	TURNICIDAE Turnix ocellata	Spotted buttonquail	Endemic	Least concern	Seen
	RAILLIDAE Gallirallus (Hypotaenidia) torquata	Barred rail	Resident	Least concern	heard
	Porzana (Zapornia) cinerea	White-browed crake	Resident	Least concern	Seen
	Amaurornis phoenicurus	White-breasted waterhen	Resident	Least concern	Seen
	Gallicrex cinerea	Watercock	Resident	Least concern	Seen
	SCOLOPACIDAE Numenius cf. phaeopus	Whimbrel	Migrant	Least concern	Seen
	COLUMBIDAE Treron vernans	Pink-necked green pigeon	Resident	Least concern	Seen
	Phapitreron leucotis	White-eared fruit-dove	Endemic	Least concern	Heard
	Streptopelia tranquebarica	Red turtle-dove	Resident	Least concern	Seen
	Streptopelia (Spilopelia) chinensis	Spotted dove	Resident	Least concern	Seen
	Geopelia striata	Zebra dove	Introduce d	Least concern	Seen
	Chalcophaps indica	Common emerald dove	Resident	Least concern	Seen
	CUCULIDAE Eudynamys scolopacea	Common koel	Resident	Least concern	Heard

[6] Recorded at Pagbilao Mangroves Experimental Station (?) and vicinities in (?) barangays Pinagbayanan and Palsabangon in Pagbilao, Quezon between June and July 2016. Taxonomy and conservation status follow IUCN Redlist of Threatened Species (http://www.iucnredlist.org). Residency status follows Kennedy et al., 2000.

No.	Family/ Scientific Name	Common Name	Residency status	Conservation status (IUCN)	Encounter
	Centropus cf. viridis	Philippine coucal	Endemic	Least concern	Heard
	TYTONIDAE Tyto cf. capensis	Grass owl	Resident	Least concern	interview
	STRIGIDAE Otus megalotis	Philippine scops-owl	Endemic	Least concern	Heard
	Bubo philippensis	Philippine eagle-owl	Endemic	Vulnerable	Heard
	CARIMULGIDAE Caprimulgus manillensis	Philippine nightjar	Endemic	Least concern	Seen
	APODIDAE Collocalia cf. vanikorensis	Island swiftlet	Resident	Least concern	Seen
	Collocalia cf. esculenta	Edible-nest swiftlet	Resident	Least concern	Seen
	Collocalia troglodytes	Pygmy swiftlet	Endemic	Least concern	Seen
	ALCEDINIDAE Halcyon chloris	White collared kingfisher	Resident	Least concern	Seen
	MEROPIDAE Merops philippinus	Blue-tailed bee-eater	Resident	Least concern	Seen
	Merops sp.	Bee-eater	Resident	-	Heard
	PICIDAE Dendrocopos maculatus	Philippine pygmy woodpecker	Endemic	Least concern	Seen
	HIRUNDINIDAE Hirundo tahitica	Pacific swallow	Resident	Least concern	Seen
	CAMPEPHAGIDAE Lalage nigra	Pied thriller	Resident	Least concern	Seen
	PYCNONOTIDAE Pycnonotus goiavier	Yellow-vented bulbul	Resident	Least concern	Seen
	Hypsipetes (Ixos) philippinus	Philippine bulbul	Endemic	Least concern	Heard
	ORIOLIDAE Oriolus chinensis	Black-naped oriole	Resident	Least concern	Seen
	CORVIDAE Corvus macrorhynchos	Large-billed crow	Resident	Least concern	Seen
	TURDIDAE Copsychus saularis	Oriental magpie robin	Resident	Least concern	Seen
	SYLVIIDAE Gerygone sulphurea	Golden-bellied fly-eater	Resident	Least concern	Seen
	Megalurus temoriensis	Tawny grassbird	Resident	Least concern	Heard
	Megalurus palustris	Striated grassbird	Resident	Least concern	Heard
	Orthotomus cf. castaneiceps	Philippine tailorbird	Endemic	Least concern	Heard
	Cisticola cf. juncidis	Zittingcisticola	Resident	Least concern	Heard
	MUSCICAPIDAE Cyornis rufigastra	Mangrove blue flycatcher	Resident	Least concern	Seen
	Rhipidura javanica	Pied fantail	Resident	Least concern	Seen
	Hypothymis azurea	Black-naped monarch	Resident	Least concern	Seen
	MOTACILLIDAE Anthus novaeseelandiae	Richard pipit	Resident	Least concern	Seen

No.	Family/ Scientific Name	Common Name	Residency status	Conservation status (IUCN)	Encounter
	STURNIDAE Acridotheres cristatellus	Crested myna	Introduced	Least concern	Seen
	Sarcops cf. calvus	Coleto	Near-endemic	Least concern	Heard
	NECTARINIIDAE Nectarinia cf. jugularis	Olive-backed sunbird	Resident	Least concern	Seen
	ZOSTEROPIDAE Zosterops meyeni	Lowland white-eye	Endemic	Least concern	Seen
	PLOCEIDAE Passer montanus	Eurasian tree sparrow	Introduced	Least concern	Seen
	ESTRILDIDAE Lonchura leucogastra	White-bellied munia	Resident	Least concern	Seen
	Padda oryzivora	Java sparrow	Introduced	Vulnerable	Seen

No. of Endemic (found only in the Philippines) & NE species: = 13
No. of Threatened/NT species: = 3
CITES-listed species: = 4
Introduced species: = 3

Species records and occurence

Based on habitats present within the study sites of the Pagbilao mangroves, birds recorded were grouped into four clustered locations:

A. Mangroves and associate, fishponds and beach sites

Data includes those recorded on transect 1, Pinagbayanan and Patayan island. A total of 34 species were found in these sites (refer to attachments 2.0-2.8 and 3.0-3.8). Noteworthy species include the Philippine duck (recorded in all three sites, generally along fish pond areas) and some of the uncommon species such as night heron (Nycticorax sp.), great egret (Egretta (Ardea) alba), and Oriental magpie robin (Copsychus saularis). Five endemic species were found, namely, Philippine coucal (Centropus viridis), lowland white-eye (Zosterops meyeni), white-eared brown dove (Phapitreron leucotis), Philippine duck and tailorbird Orthotomus sp. (For the species diversity index, a separate discussion is provided in the report).

B. Pure mangrove forest stands

For this site, records from transect 2, which traversed the boardwalk where pure mangrove forests stands are accessible, were considered. A total of 23 species were recorded at this transect. Endemic species totalled six, including the Philippine coucal, yellow-wattled bulbul (Pycnonotus cf. urostictus), Philippine bulbul (Hypsipetes (Ixos) philippinus), Philippine pygmy woodpecker (Dendrocopus maculatus), lowland white-eye, and tailorbird. Uncommon/noteworthy species includes the Oriental magpie robin (Copsychus saularis).

C. Tidal mudflats and rivers adjacent to mangrove forests

Records for this site include a transect/observation site 5, which is a boat transect traversing and observing along the way to Sukol and Palsabangon river in and back to the Pagbilao mangrove experimental station (PMES). At least 28 species (second highest in terms of species diversity, were recorded in the four habitats or sites surveyed. Six endemic species found were the Philippine pygmy woodpecker, Philippine duck, Philippine tailorbird (Orthotomus cf. castaneiceps), Philippine coucal, Pygmy swiflet (Collocalia cf. troglodytes), and lowland white-eye. Rivers, tidal mudflats, and estuaries also offer a unique staging area for water birds such as ducks, egrets, whimbrels, and other resident and migratory species.

D. Ricefields adjacent to buri/coconut and avicennia stands

Rice fields adjacent to mangrove stands and associates also offer unique habitats for many resident and migratory species. At least 22 species were recorded in this type of habitat. Five endemic species were found, namely, Philippine pygmy woodpecker, Philippine coucal, coleto (Sarcops cf. calvus), Spotted buttonquail (Turnix ocellata), and Pygmy swiftlet. Noteworthy and unique species recorded include the Java sparrow (introduced — IUCN Vulnerable) and the uncommon watercock (Gallicrex cinerea).

General Observations

Records generated from general observations covered encounters during off-transect periods such as those that took place at the PMES, during the setup of nets and traps, and interviews with the locals. At least eight noteworthy species were exclusively recorded (highlighted in the table below) from this technique. Refer to the table below.

Table 22. Records of bird species based on general observations during the terrestrial vertebrate fauna survey of the Pagbilao mangroves[7]

Date	Species	ni	Encounter	Location	Coordinates		Elevation (meters)
28 June. 2016	Halcyon chloris	2	netted	PMES	13.97546	121.72581	12

[7] Conducted in June to July 2016

Date	Species	ni	Encounter	Location	Coordinates		Elevation (meters)
	Rhipidura javanica	3	seen/heard	PMES			
	Copsychus saularis	1	heard	PMES			
	Orthotomus sp.	1	heard	PMES			
	Chalcophaps indica	1	netted	PMES			
	Amaurornis phoenicurus	1	heard	ricefields	13.9757	121.72633	10
	Gallirallus (Hypotaenidia) torquatus	2+	heard	Boardwalk			
	Bubo philippensis	2?	heard (11pm)	E-NE of PMES-Buri site			
29 June. 2016	Caprimulgus cf. manillensis	1	heard	PMES			
	Eudynamys scolopacea	1	heard	PMES			
	Bubulcus cf. ibis	3	seen	PMES			
	Lalage nigra	1	heard	PMES			
	Corvus macrorhynchos	1+	heard	PMES			
	Centropus cf. viridis	1	heard	PMES			
	Passer montanus	10+	seen	PMES			
	Lonchura leucogastra	1	Seen	PMES			
29 June. 2016	Caprimulgus manillensis	1	seen	herp transect site 2			
	Otus megalotis	1	heard	PMES			
29 June. 2016	Megalurus palustris	1	heard	PMES			
	Oriolus chinensis	1	heard	PMES			
30. June. 2016	Anas luzonica	3	seen	PMES -in flight			
	Tyto cf. capensis		interview	ricefield			

Use of mist nets

A total of seven net-days and eight net-nights were accumulated in the study using 6, 9 and 12 meters nets for the field sampling (refer to the table below). Total species captures tallied to three (White collared kingfisher =4, Common emerald dove =1, Mangrove blue flycatcher =1).

Table 23. Location of nets and species captures during the terrestrial vertebrate fauna survey of the Pagbilao mangroves June-July 2016

Date	Nets	COORDINATES		Elevation (meters)	Location & net captures	Net-days	Net-nights
		Longitude	Latitude				
6.28.2016	12m	13.97550	121.72616	12	Site 1: near PMES compound White collared kingfisher =2	0.5	1.0
	9m	13.97570	121.72633	10	Site 1: near PMES compound Common emerald dove =1	0.5	1.0
6.29.2016	6m	13.97484	121.72833	17	Site 2: Buri, ferns, Avicennia et al. White collared kingfisher =1	1.0	1.0
	9m	13.97515	121.72820	23	Site 2: Buri, ferns, Avicennia et al. Mangrove blue flycatcher =1	1.0	1.0
6.29-30.2016	12m	13.97577	121.72333	15	Site 3: Nipa, ferns, Avicennia	2.0	2.0
6.30.2016	6m	13.97235	121.73024	10	Site 4: Boardwalk /tower	1.0	1.0
	9m	13.97229	121.73087	6	Site 4: Boardwalk /tower White collared kingfisher =1	1.0	1.0
					TOTAL	7.0	8.0

Parameters that can be used to monitor bird associated biological indicators

Birds are regarded as good indicators of biological diversity, because avian taxonomy is believed to be well known and geographical distributions of individual bird species are sufficiently well documented to permit a comprehensive review and analysis (Mallari & Jensen, 1993, Alviola, 2006). The following section provides an overview of some parameters that can be used for biodiversity analysis or studies.

Diversity Index

Species diversity is a measurable characteristic of natural communities. Shannon index (1949) is by far the most frequently used in both theoretical and applied research in spite of the presence of other formulas for diversity measure (Giavelli et.al. 1986). In the applied work, indices of diversity are used more frequently as bioindicators in the quality control of aquatic (Mason, 1977; Rossi et al., 1979; Dygert, 1981) and terrestrial environments (Menhimick, 1964; Solem, 1979; Giavelli, 1986).

Shannon index or Shannon Weiner index (H') is one of the diversity indices used in this report. This information statistic index assumes that all species are represented in a sample and that they are randomly sampled. Another type of diversity measure used in this report is the dominance index (C). Evenness is another measure of diversity, which focuses on how evenly the individuals in the community are distributed across the different species (Heip et al., 1998).

According to the biodiversity scale used by Fernando et al. (1998), the Shannon Wiener index (H') ranging from 3.5 to 4.0 has very high relative values. Evenness (e) value closer to 1.0 has relatively even distribution. Evenness is a measure of similarity of abundance (ni, or number of individuals) across different species. When there are similar proportions of all species, then the value of evenness is one, but when the level of abundance is very dissimilar (some rare and some common species), then the value decreases.

Table 24. Computed diversity index from bird transects and observation data during the terrestrial vertebrate fauna survey of the Pagbilao mangroves[8]

Observation Lines	Ni	Approximate length of transect	H	C	E
Transect 1	31	1000 meters	3.076886206	0.070412764	0.896009805
Transect 2	23	800+ meters	2.856268211	0.071943599	0.910946733
Observation site 3	13	400 meters	2.335671509	0.120095125	0.91061116
Observation site 4	14	300 meters	2.45570803	0.1015625	0.9305247
Observation site 5	28	≤2500 meters	2.982010588	0.065805914	0.894906234
Observation site 6	22	200+ meters	2.795781521	0.084319527	0.904478526

For details, refer to the diversity index tables in attachments 3.0-3.6.

Legend: Ni – total number of species recorded; H – Shannon Wiener Index; C – dominance index; and e – evenness index

Shannon Weiner index (H) emerged the highest in transect 1 (with a value of 3.076886206), which also indicates the highest number of species recorded (Ni=31). As expected, the diversity measures (H) faithfully correspond to the

[8] Conducted from June – July 2016

total number of species (Ni) for its perceived value (see Table 24). Dominance index (C) was highest in observation site 3 (with value of 0.120095125), which is closely followed by observation site 4. Apparently, this may be explained by the relatively smaller number of species (Ni) recorded compared with the number of individuals (ni) of each species found in these sites.Finally, evenness index (e) was the highest in observation site 4 (with value of 0.9305247).

Residency status

Residency status defines the occurrence of specific species of birds in the country. Kennedy et al. (2000) described in their book the extent of occurrence of Philippine birds. The classifications are as follows:

Endemic — found only in the Philippines
Near endemic — found mainly in the Philippines but also exist on a few islands in neighboring countries, including Banggi, Talaud, Lanyu, and Sangihe Islands in Indonesia
Resident — breed or are suspected breeding in the Philippines normally living there throughout the year
Migrant — breed outside the Philippines and migrate to the country. Migration season in the country starts as early as July and peaks in the month of September to November, migration ends in March. Some migrant may over summer.
Accidental or vagrant — does not normally migrate, travel to or live in the Philippines, usually recorded 1 or 2 times.
Introduced – species that are intentionally introduced in the country and became residents.

Similarly, the residency status among birds is strongly correlated with and dependent on habitat types (i.e., forest, open areas, wetlands, urban areas and others). Furthermore, availability and type of food item and seasonality also coincide with and slightly affect the residency status of birds present in a particular area.

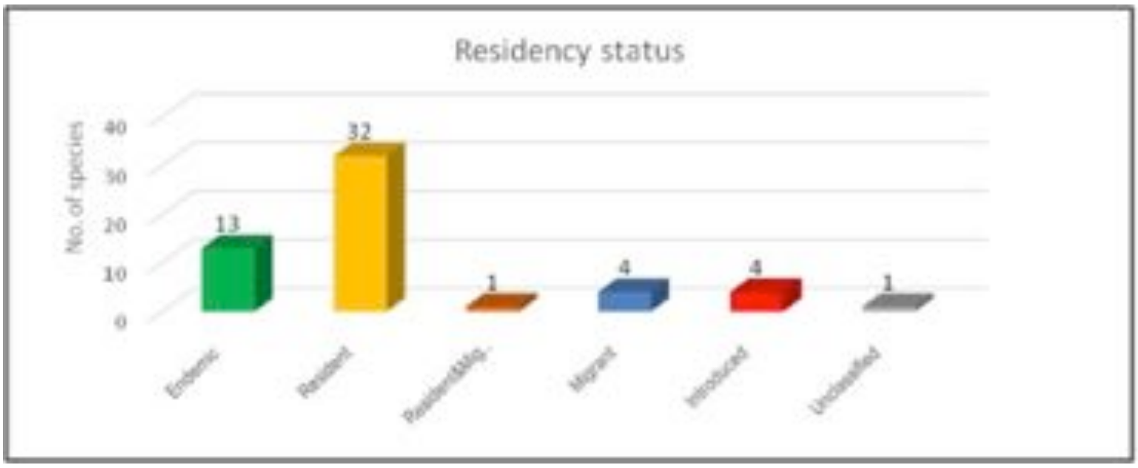

Figure 15. Graphical representation of the residency status of bird species recorded at the Pagbilao mangrove survey sites during the period June - July 2016

More than half (58 percent) of the species recorded (32/55 species) were residents. In contrast, endemic species comprised only 23 percent (13/55 species). Since the survey time was approaching the migration season (September to March), at least four species, constituting 7.2 percent, were migrants. One recorded species has resident and migratory populations.

Because of the site proximity to altered habitats, at least four species of introduced birds were recorded along the two study sites — fishponds and rice fields adjacent to mangroves stands. One species was marked unclassified since its record was not absolute, having been heard only while in flight).

Mammals

At least seven species of mammals were recorded within the study sites. Six, or 85 percent of the total species recorded, were pteropid bats. These bats are frugivores and nectarivores, suggesting that the site was home to many flowering and fruit-bearing trees and plants at the time of the survey. Endemicity was low, with only one species recorded — the greater musky fruit bat (Ptenochirus jagori). For murid rats, the common Oriental house rat (Rattus cf. tanezumi) was also found, apparently owing to the proximity of the study sites (mangrove areas) to human settlements. The list below tallies the species of mammals recorded within the sites.

Table 25. List of Mammals recorded during the survey of the Pagbilao mangroves[9]

No.	Family/ Scientific Name	Common Name	Distribution	Conservation status (IUCN)	Encounter
	PTEROPID BATS				
1	PTEROPIDAE Cynopterus brachyotis	Lesser Dog-faced Fruit bat/ Short-nosed Fruitbat	Southeast Asia	Least concern	netted
2	Eonycteris cf. spelaea	Cave-roosting Nectar Bat/ Common Nectar Bat	India to Timor, throughout the Philippines except Batanes region	Least concern	netted
3	Macroglossus minimus	Dagger-toothed Flower Bat/ Lesser Long-tonged Fruit Bat	Thailand to Australia; throughout the Philippines	Least concern	netted
4	Ptenochirus jagori	Greater Musky Fruitbat	Philippines	Least concern	netted
5	Pteropus sp.	Large Flying Fox	-	-	heard/ interview
6	Rousettus amplexicaudatus	Joffroy'sRousette/ Common Rousette	Thailand to the Solomon Islands, throughout the Philippines	Least concern	netted
	MURID RAT				
7	MURIDAE Rattus cf. tanezumi	Asian Black Rat/ Oriental House Rat	Cosmopolitan	Least concern	trapped

Mangrove Biomass Carbon Storage

Mangrove Biomass

The biomass computed for all the quadrats in the study sites ranged from 0.17 to 365.28 ton ha^{-1} with mean biomass stock of 132.51 ton ha^{-1} (see Table 26). The average aboveground biomass also varied from a low of 0.07 ton ha^{-1} to a high of 221.6 ton ha^{-1}, with a mean value of 76.76 ton ha^{-1}. The root biomass has lower average value, with a mean biomass stock of 55.75 ton ha^{-1}, ranging from 0.10 ton ha^{-1} to a high of 144.04 ton ha^{-1}. Quadrat 15, a dense

[9] Recorded at Pagbilao Mangrove Experimental Station station and vicinities (in?) barangay Pinagbayanan and Palsabangon in Pagbilao, Quezon between June and July 2016. Taxonomy and conservation status follow the IUCN Red List of Threatened Species 2016 (http://www.iucnredlist.org). Distribution follows Heaney and collaborators 1998 (?).

midward, riverine forest in Ibabang Palsabangon, recorded the highest mean biomass at 365.28 ton ha^{-1} while quadrat 2, a young mangrove plantation in Barangay Pinagbayanan, obtained the lowest mean biomass (0.17), primarily because it has only two individuals with a diameter exceeding 5 cm. The very wide range of values showed that mangrove biomass could greatly vary depending on the stand density and the maturity of trees inside the plot.

The mean aboveground biomass for this study (76.76 ton ha^{-1}) is within the range suggested by Hutchings and Saenger (1987) for mangroves, which is equivalent to 54 ton ha^{-1} to 184 ton ha^{-1}. The biomass estimates generated by this study were higher than that of North Sulawesi, Indonesia (61.4 t ha^{-1}, Murdiyarso et al., 2009), but slightly lower than that of Okinawa, Japan (80.5 t ha^{-1}, Khan et al., 2009).

Table 26. Mean above ground biomass, root biomass, and total biomass per quadrat

Quadrat	Aboveground Biomass (ton/ha)	Root Biomass (ton/ha)	Total Biomass (ton/ha)
1	32.16	25.56	57.72
2	0.07	0.10	0.17
3	27.41	24.05	51.46
4	105.31	75.96	181.27
5	166.88	110.24	277.12
6	52.87	39.63	92.50
7	54.70	42.77	97.47
8	82.55	60.74	143.29
9	25.78	22.30	48.08
10	34.67	27.94	62.61
11	22.46	18.94	41.39
12	206.42	144.74	351.15
13	92.77	69.03	161.80
14	5.10	5.40	10.51
15	221.66	143.62	365.28
16	63.87	51.56	115.42
17	19.18	15.72	34.90
18	73.37	54.39	127.76
19	62.30	47.23	109.53
20	32.13	24.96	57.09
21	74.43	56.39	130.82
22	39.26	32.65	71.92
23	120.31	88.70	209.01
24	35.33	28.89	64.22
25	122.18	87.48	209.66
26	38.49	30.72	69.21
27	65.54	49.00	114.53
28	177.06	119.19	296.25
29	160.93	111.28	272.20
30	87.73	63.23	150.96
Average	**76.76**	**55.75**	**132.51**

The midward zone of the mangrove forest registered the highest average (aboveground and root) biomass, closely followed by the seaward zone (see Table 27). The landward zone has significantly lower biomass, which is not even half the biomass of the midward zone. The results can be attributed to the stocking density of the different mangrove zones. Both seaward and midward zones are naturally densely stock while the landward zone is always sparsely occupied by mangrove trees.

Table 27. Mean above ground biomass, root biomass, and total biomass per zone

Position	Mean ground Biomass (ton/ha)	Mean Root Biomass (ton/ha)	Total Biomass (ton/ha)
Landward	44.05	7.34	51.39
Midward	93.46	9.35	102.81
Seaward	78.86	5.63	84.49

The lone overwash mangrove forest in Patayan island far exceeds the rest of the forest types in terms of biomass (see Table 28). As mentioned in the inventory report, this quadrat is a monotypic overwash mangrove, more likely a remnant of an old-growth forest composed of large-diameter pagatpat (Sonneratia alba) trees. Of the nine individuals recorded from this quadrat, five individuals have more than 30 cm diameter. The two largest trees recorded in the survey came from this quadrat with diameters of 59 cm and 56.5 cm, respectively.

It should be emphasized that the wide variation in the computed biomass from the different mangrove forest types is attributed to the density and maturity of trees inside the plot, not to forest type. Moreover, the biomass value of the plantation forest was computed from the average of two plantation stands surveyed (quadrats 2 and 12). Q2, a very young plantation forest in Barangay Pinagbayanan, has the lowest total biomass value at 0.17 ton ha^{-1} while, Q12, one of the first plantations established by DENR at the Pagbilao Mangrove Experimental Forest in Ibabang Palsabangon, has the second highest value at 351.15 ton ha^{-1}.

Table 28. Mean above ground biomass, root biomass, and total biomass per forest type

Forest Type	Mean Aboveground Biomass (ton/ha)	Mean Root Biomass (ton/ha)	Total Biomass (ton/ha)
Basin	82.41	60.55	142.96
Fringing	87.73	63.23	150.96
Hammock	24.36	19.95	44.31
Over wash	166.88	110.24	277.12
Plantation	103.24	72.42	175.66
Riverine	70.39	52.15	122.54
Scrub	88.86	63.83	152.68

Carbon content per species

Determination of carbon fraction of the wood is necessary to obtain the carbon storage of a particular individual, species, and/or forest. The biomass of a tree is multiplied by its carbon fraction to get the total carbon stored in it.

One of the value-added information provided by this report is the carbon content analysis of the wood of each species, which is needed to compute for the carbon fraction. In previous studies on biomass carbon storage, a carbon fraction (usually between 0.45 and 0.5, dry basis) was used as constant multiplier regardless of the species. However, this method of estimation does not consider the fact that different tree species store different amounts of carbon. This study shows that carbon fraction varies among mangrove species — from 44.6 percent to 49.7 percent (see Table 29). Interestingly, the top four species (kulasi, malatangal, nilad, tangal) with the highest carbon fraction are small-diameter trees commonly found at the midward or landward position. The commonly used reforestation species (Rhizophora spp.), along with other large-diameter mangroves (Avicennia spp.), are among the lowest in terms of carbon fraction. Dungon (Heritiera littoralis) and alai (Mallotus tiliifolius), which are not true mangrove species (mangrove associates), were encountered in some landward plots.

Table 29. Carbon content of the wood of each mangrove species

Common Name	Scientific Name	Family	Carbon Fraction (C%)
Kulasi	Lumnitzera racemosa Willd.	Combretaceae	49.7
Malatangal	Ceriops zippeliana Blume	Rhizophoraceae	48.9
Nilad	Scyphiphora hydrophyllacea Gaertn. f.	Rubiaceae	48.2
Tangal	Ceriops tagal (perr.) C.B. Rob.	Rhizophoraceae	47.3

Common Name	Scientific Name	Family	Carbon Fraction (C%)
Tawalis	Osbornia octodonta F. Muell.	Myrtaceae	47.2
Tinduk-Tindukan	Aegiceras floridum Roem & Schult.	Myrsinaceae	47.1
Busain	Bruguiera gymnorrhiza (L.) Lamk.	Rhizophoraceae	46.9
Saging-Saging	Aegiceras corniculatum (L.) Blanco	Myrsinaceae	46.5
Pototan lalake	Bruguiera cylindrica (L.) Blume	Rhizophoraceae	46.5
Dungon	Heritiera littoralis Ait.	Malvaceae	46.5
Tui	Dolichandrone spathacea (L.f.) K. Schum.	Bignoniaceae	46.4
Tabigi	Xylocarpus granatum Koen.	Meliaceae	46.4
Pagatpat	Sonneratia alba (L.) Smith	Lythraceae	46.3
Api-api	Avicennia officinalis L.	Acanthaceae	46.2
Bakauan Babae	Rhizophora mucronata Lamk.	Rhizophoraceae	46.1
Bakauan Lalaki	Rhizophora apiculata Blume	Rhizophoraceae	45.9
Bungalon	Avicennia marina (Forsk.) Vierh.	Acanthaceae	45.6
Pi-api	Avicennia marina (Forsk.) Vierh. var. rumphiana (Hallier) Bakh.	Acanthaceae	45.6
Buta-buta	Excoecaria agallocha L.	Euphorbiaceae	45.2
Bakauan Bato	Rhizophora stylosa Griff.	Rhizophoraceae	45.2
Alai	Mallotus tiliifolius (Lamk) Muell.-Arg.	Euphorbiaceae	45.0
Piagau	Xylocarpus moluccensis (Lamk.) M. Roem.	Meliaceae	44.6

Biomass Carbon Stock

The biomass C-stock varied among quadrats from 0.08 ton C ha^{-1} to a high of 172.42 ton C ha^{-1} with a mean value of 61.34 ton C ha^{-1} (see Table 30). The above ground biomass carbon stock also greatly varied from 0.03 to 104.63 ton C ha^{-1} with a mean value of 35.54 ton C ha$^{-1.}$ On the other hand, a mean value of 25.8 ton C ha^{-1} was obtained from the root carbon stock, with values ranging from a low of 0.05 ton C ha^{-1} to a high of 67.79 ton C ha^{-1}. The carbon stored from the aboveground biomass accounts for about 58 percent of the total biomass carbon stock.

The mean biomass carbon stock obtained by this study is much lower than that of the natural mangrove forest in Bahile, Puerto Princesa City, Palawan (356.1 ton ha $^{-1}$; Abino et al., 2014), which used the same allometric equations. The difference may be attributed to the fact that Bahile mangroves have older stands, owing to the larger trees in the area. The computed biomass carbon stock is also much lower than the estimated mean biomass carbon of mangrove forests in the Philippines (184 ton C ha^{-1}; Lasco and Pulhin, 2004). Again, this could be attributed to the relatively young age of the Pagbilao mangrove forest, being a secondary-forest type, not an old-growth mangrove stand.

As reported in the section on mangrove characterization, the average tree diameter across quadrats was only 11.19 cm. Moreover, one of the plantations surveyed (quadrat 2) had only two saplings, which significantly pulled down the mean value.

Table 30. Biomass carbon stock of Pagbilao mangrove forest

Quadrat	Aboveground Carbon (ton C ha^{1})	Root Carbon (ton C ha^{1})	Total Carbon (ton C ha^{1})
1	14.67	11.66	26.33
2	0.03	0.05	0.08
3	12.66	11.11	23.78
4	49.55	35.72	85.28
5	77.27	51.04	128.31
6	24.26	18.19	42.45
7	25.07	19.61	44.68
8	38.44	28.32	66.76
9	11.83	10.23	22.06
10	16.06	12.96	29.02
11	10.39	8.75	19.14
12	95.04	66.65	161.70
13	42.83	31.85	74.68
14	2.36	2.50	4.85
15	104.63	67.79	172.42
16	29.92	24.14	54.06
17	9.25	7.58	16.82
18	33.51	24.85	58.37
19	28.52	21.64	50.17
20	14.65	11.38	26.03
21	34.50	26.14	60.64
22	18.17	15.11	33.28
23	55.78	41.15	96.94
24	16.28	13.31	29.59
25	56.64	40.55	97.19
26	17.83	14.23	32.06
27	30.32	22.66	52.98
28	81.24	54.69	135.93
29	73.91	51.11	125.03
30	40.43	29.14	69.57
Average	**35.54**	**25.80**	**61.34**

Similar to the values obtained for biomass estimation, the midward zone of the Pagbilao mangrove forest has the highest biomass carbon stock, closely followed by the seaward zone (see Table 31). This pattern is understandable because the biomass, which is a function of density and diameter, becomes the predictive variable to obtain the carbon stock. Consequently, the overwash mangrove forest in Patayan island has the largest carbon stock (see Table 32).

Table 31. Mean above ground biomass, root biomass, and total carbon stock per zone

Position	Aboveground Carbon (ton C/ha)	Root Carbon (ton C/ha)	Total Carbon (ton C/ha)
Landward	20.26	15.59	35.86
Midward	43.48	31.25	74.73
Seaward	36.40	26.29	62.69

Table 32. Mean above ground biomass, root biomass, and total carbon stock per forest type

Forest Type	Aboveground Carbon (ton C/ha)	Root Carbon (ton C/ha)	Total Carbon (ton C/ha)
Basin	38.14	28.03	66.17
Fringing	40.43	29.14	69.57
Hammock	11.37	9.31	20.69
Overwash	77.27	51.04	128.31
Plantation	47.54	33.35	80.89
Riverine	32.77	24.26	57.03
Scrub	40.94	29.41	70.36

Soil Types

There are six soil types in the municipality of Pagbilao: Bantay clay, Bolinao clay loam, Buguey loamy sand, Guadalupe clay loam, Macolod clay loam, and Quingua sandy clay loam (see Figure 6).

The Bantay soil series was first described in the municipality of Bantay, Ilocos Sur. It is classified as Typic Eutrustepts in the United States Department of Agriculture (USDA) soil classification system (Soil Taxonomy). This soil series is developed from tertiary sediments of shale with some mixture of coralline limestones. The external drainage is free to excessive while the internal drainage is poor. The color ranges from light brown to brown while texture ranges from clay to clay loam (Carating et al., 2014). The surface soil has a depth of 20 cm to 35 cm. The lower subsoil can reach down to 60 cm. The subsoil is a zone of highly weathered shale that has a tendency to break into cubes about 1 cm in diameter, with some concretion-like pellets of grayish white lime precipitate. The substratum that reaches down to the control section, measuring 150 cm, is a dense mass of yellowish to very light brown shale of variable thickness. A smattering of gravel and pebbles are sometimes embedded in this layer in some places (Mariano et al., 1954, as cited by Carating et al., 2014). Bantay clay covers 3,411 ha in Pagbilao, Quezon.

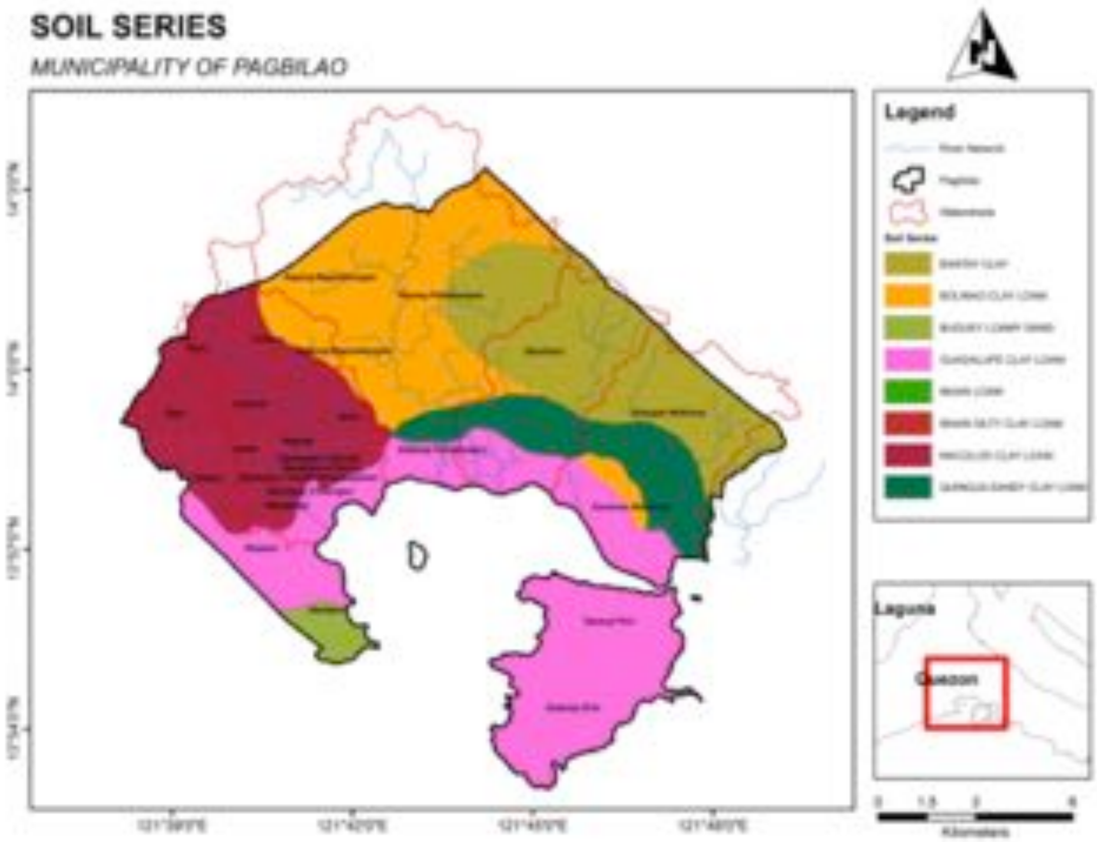

Figure 16. Soil types covering the municipality of Pagbilao, Quezon

The Bolinao series was first identified in the municipality of Bolinao, Pangasinan province. It is classified as Typic Hapludalfs in the USDA Soil Taxonomy. This soil series is a product of a weathered coralline limestone. The soils are red or dark reddish brown or chocolate brown and therefore grouped among the red soils of the Philippines. While the internal drainage is poor, the external drainage ranges from good to excessive (Carating et al., 2014). The surface soil is reddish brown to chocolate brown to almost red, with fine granular structure and compact clay-bearing limestones, and height ranging from 20 cm to 35 cm. The subsoil is brownish gray to light reddish brown, fine granular and compact clay structure. The presence of limestone gravels and weathered limestone rocks can be observed. The depth is from 40 cm to 80 cm from the surface. The upper substratum is reddish brown weathered limestone rock and the lower substratum is hard limestone rock (Alicante et al. 1940a as cited by Carating et al., 2014). Bolinao clay loam covers 3,669 ha in Pagbilao, Quezon.

Buguey series was first mapped in Cagayan province and is classified as mixed isohypertermic Typic Udipsamments in the USDA Soil Taxonomy. Buguey is derived from fluvio-marine sediments deposited by waves or from recent coast deposits of sandy materials washed up on the shores from rivers and oceans. Its distinguishing characteristic is the presence of marine shells in the substratum (Carating et al., 2014). The surface soil is brownish gray to dark brown, loose and structureless fine sandy loam. Its depth is from 10 to 30 cm. The C horizon (no B horizon) is dark brown in the upper part and could be olive brown in the lower part; sand depth could reach up to 150 cm. A few pieces of marine shells are observed in some places (Dagdag et al., 1967, as cited by (Carating et al., 2014). Buguey loam covers close to 295 ha of land in Pagbilao, Quezon.

The Macolod series was mapped at the footslope of Mount Macolod in Cuenca municipality, province of Batangas. It is classified as Typic Dystrudepts in the USDA Soil Taxonomy and is formed from weathered andesite. The distinguishing features of the Macolod series include the presence of boulders marked by a mixture of fine rounded and sharp angular weathered andesites on the surface, and the dark brown surface soil. External drainage is excessive while internal drainage is good. The surface soil is 10 to 15 cm thick, brown to grayish brown, plastic and sticky clay. Below is light reddish brown, slightly compact clay, reaching down to 65 cm. The substratum consists of weathered rocks, which are generally andesites (Alicante et al. 1938 as cited by Carating et al., 2014). Macolod clay loam was mapped in 3,468 ha of Pagbilao, Quezon.

The Quingua series was first described in Quingua, Bulacan. It is classified as fine clayey, mixed, isohyperthermic Typic Tropudalfs in the USDA Soil Taxonomy. These soils are associated with river levees. They are very well-drained and is characteristically brownish in color throughout the profile (Carating et al., 2014). Surface horizons are brown to dark brown silty clay loam with yellowish brown and grayish brown mottles. The soil structure is friable, consistency is sticky and plastic. The argillic B-horizons are grayish or dark grayish brown with mottles. The soil structure is moderate to strong subangular blocky; consistency is sticky and plastic. The C-horizon that occur mostly below 150 cm are brown to dark brown, yellowish brown with yellowish red mottles (Soil Survey Division 1987 as cited by (Carating et al., 2014)). Quingua sandy clay loam covers 1,528 hectares of Pagbilao, Quezon.

Among the six soil series found in Pagbilao, only one series occupies the mangrove forest in Pagbilao — the Guadalupe series, so called since it was first described in Barangay Guadalupe in Makati City. This soil series is now buried under urban development of this city whereas it occupies the largest area of Pagbilao, Quezon (~4,796 ha).

It is classified as fine montmorillonitic, isohyperthermic Leptic Udic Haplustert, and is developed from tuff (Carating et al., 2014). The surface soil is dark brown to nearly black clay, with depth reaching down from 2 to 3 cm. The subsoil is made up of light brownish black clay, and contains spherical tuffaceous concretions. Its depth is between 50 and 80 cm from the surface. The substratum consists of light grayish brown tuffaceous materials of varying degrees of weathering. Beneath the layer of tuffaceous concretions is hard and massive tuff (Alicante et al., 1938, as cited by Carating et al., 2014).

Soil Carbon Storage

To determine the soil carbon storage of an area, the soil's bulk density and percent total carbon must be measured. Bulk density is the weight of dry soil per unit volume and is an indicator of soil compaction and soil health (USDA-NRCS, n.d.). The higher the bulk density, the more compact the soil is. Bulk density was measured at the Pagbilao mangrove forest to determine the amount of soil on a per hectare basis.

The PMF recorded bulk density values ranging from 0.6 to 1.8 milligram per cubic meter (Mg m^{-3})(see Table 5). The seaward position registered bulk density values of 0.6 to 1.7 Mg m^{-3}. The midward and landward positions have bulk density values of 0.7 to 1.8 Mg m^{-3}. The highly variables result obtained from the sites could be reflective of the varying textures of the soil in the different mangrove zones.

It was observed during field work that the soil at the seaward area ranged from sandy to clayey. The same variations were observed at the midward and landward zones. Substrate in a mangrove forest tends to show differentiation as it is derived from sediments of varying sizes and degrees of transportability, resulting in particle selectivity. Sandy soils tend to have higher bulk densities than clayey soils (Brady and Weil, 2002). Nevertheless, the values derived at the different sites most likely provided the range of values that can be observed in a mangrove forest.

Still another determinant of soil carbon storage, total carbon is defined as the sum of organic and inorganic carbon found in the soil. Organic carbon is found in the soil organic matter fraction while inorganic carbon is largely present in carbonate minerals (Nelson and Sommers, 1996). Analysis of the soil samples taken at the Pagbilao magrove forest showed that its total soil C ranges from 1.0 to 7.6 percent (see Table 5). The majority of the samples analyzed yielded higher values compared to those generated by Racelis (2000) during a study of a mahogany and dipterocarp stand in Mount Makiling Forest Reserve. Such values ranged from 0.98 to 2.92 percent and

0.98 to 2.89 percent for mahogany and dipterocarp stands, respectively. However, it is important to note that Racelis (2000) was looking into soil organic C, not total soil C.

Ontl & Schulte (2012) said that for every 2,500 GT of carbon found in soil, 1,550 Gt (62 percent) is organic and 950 Gt (38 percent) is inorganic. Taking this information into account, the total soil C in a mahogany and dipterocarp plantation falls below that of a mangrove forest. The mangrove forest stores more carbon in the soil due to its waterlogging condition that favors the accumulation of organic matter brought about by slow organic matter decomposition.

Using the bulk density and total soil C content (percent) values, the total soil C on a per hectare basis was calculated (see Table 33). The landward position from Barangay Ibabang Palsabangon (sample 15) registered the lowest value, 40.9 t C ha^{-1}. The highest value, 190.5 t C ha^{-1}, was found at the seaward location in Barangay Pinagbayanan (sample 6).

Overall, the PMF recorded an average of 123.5 t C ha^{-1}. This value is higher than what was obtained by Sahu et al. (2016) for a natural mangrove stand (54.3 t C ha^{-1}) and mangrove plantation (60.9 t C ha^{-1}) in India. The PMF average, however, was lower than what was observed by Abino et al. (2014) of the mangrove forest of Palawan province (173.8 t C ha^{-1}, the value of which is still for soil organic C, and if converted to total C could yield 280 t C ha^{-1}).

Overall, based on the total mangrove forest area of Pagbilao (646 ha) and the total soil C stored on a per hectare basis (123.5 t C ha^{-1}), the estimated C stored in the substrate of the mangrove forest of Pagbilao is 79,781 tons.

Monetary accounting of carbon stock in PMF

Findings showed that the mean carbon stock of PMF from the biomass and soil totalled 184.84 t C ha^{-1}. About 67 percent of this stock is composed of the sediment/soil carbon storage.

To determine the monetary value of the carbon stock in Pagbilao mangrove forest, two carbon market values were used, the Carbon Brief and the Climate Group prices. Carbon Brief is a UK-based news website covering the latest developments in climate science, climate policy, and energy policy. The Climate Group, on other hand, is an award-winning international non-profit organization specializing in bold, catalytic and high-impact climate and energy initiatives involving the world's leading businesses and state and regional governments.

The carbon stock in PMF was initially converted to CO_2 storage prior to monetary accounting, because most references do not set a price for carbon. The carbon stock in PMF obtained a mean value per hectare of US$ 739.36 and US$ 714.71 based on the Carbon Brief and Climate Group, respectively (see Table 34). The total value of the whole PMF was obtained by multiplying the price per hectare by the total area of the mangrove forests. The computed carbon price for PMF was estimated at US$ 477,610.13 and US$ 461,689.79 based on the two price indices. These sums are equivalent to PhP 22,839,316.32 and PhP 22,078,005.78, respectively at Php 47.82 to the US$.

Table 33. Bulk density, total soil C, and soil C storage of the different soil samples taken at the mangrove forest of Pagbilao, Quezon

Sample	Plot Number	Position	Bulk density ($Mg\ m^{-3}$)	Total Carbon (%)	Amount of Carbon ($t\ C\ ha^{-1}$)
1	7	Seaward	1.4	1.0	42.9
2	8	Midward	0.7	4.8	92.7
3	14	Landward	0.9	2.9	75.5
4	13	Landward	0.9	2.6	68.9
5	12	Midward	0.9	4.9	132.3
6	4	Seaward	0.8	7.6	190.5
7	3	Midward	0.8	7.4	169.7
8	2	Seaward	1.7	1.7	86.5
9	1	Seaward	0.6	8.7	164.0
10	5	Seaward	1.7	8.3	412.6
11	23	Midward	0.9	2.6	71.9
12	20	Landward	1.0	3.1	90.4
13	18	Landward	1.1	2.8	88.4
14	9	Midward	0.8	5.5	125.1
15	11	Landward	1.3	1.0	40.9
				AVERAGE	**123.5**

Table 34. Monetary accounting of the carbon stock at the Pagbilao mangrove forest

		Carbon Stock (ABG)	Carbon Stock (RB)	Soil Carbon of PMF	Total Carbon of PMF
	Carbon Stock	35.54	25.80	123.50	184.84
	CO_2 Storage	47.38	34.41	164.67	246.45
Mean value per/ha (carbon Brief=$3/ton)	USD	142.14	103.22	494.00	739.36
	PHP	6,797.20	4,935.79	23,623.08	35,356.07
Mean value per/ha (Climate group = $2.9/ton)	USD	137.40	99.78	477.53	714.71
	PHP	6,570.63	4,771.26	22,835.64	34,177.54
Total value of PMF (Carbon Brief $3/ton)	USD	91,820.54	66,675.46	319,114.12	477,610.13
	PHP	4,390,858.44	3,188,420.67	15,260,037.22	22,839,316.32
Total value of PMF (Climate group = $2.9/ton)	USD	88,759.86	64,452.95	308,476.98	461,689.79
	PHP	4,244,496.49	3,082,139.98	14,751,369.31	22,078,005.78

Note: Total area of PMF = 645.98 ha; 1US$ = PhP 47.82

Potential soil loss

The soil erosion factors were multiplied on a grid basis using the raster calculator to determine the potential soil loss in tons per hectare per year (see Figure 17).

The highest recorded potential soil loss value in the study area is 31.5 t ha^{-1} yr^{-1} while the smallest recorded value is 0.0003 t ha^{-1} yr^{-1}. Most of the high potential soil loss values were determined in the Pagbilao watershed, specifically in barangays Tukalan and Ibabang Bagumbungan.

Sedimentation rate

Based on the application of the sediment delivery ratio formula, the average potential soil loss and sediment delivery ratio value (based on size) were determined for each of the watershed zones (see Tables 35 and 36). Using the calculated product of the two values, the highest sedimentation rate (low zone where the mangrove forests are) was found within the Pagbilao watershed (0.756 t ha^{-1} yr^{-1}), followed by the Palsabangon watershed (0.347 t ha^{-1} yr^{-1}; (see Table 37). On average, the mangrove forest of Pagbilao receives an estimated 0.368 t ha^{-1} yr^{-1} of sediments. For a 646 ha mangrove forest, that is equivalent to 237.7 tons yr^{-1}.

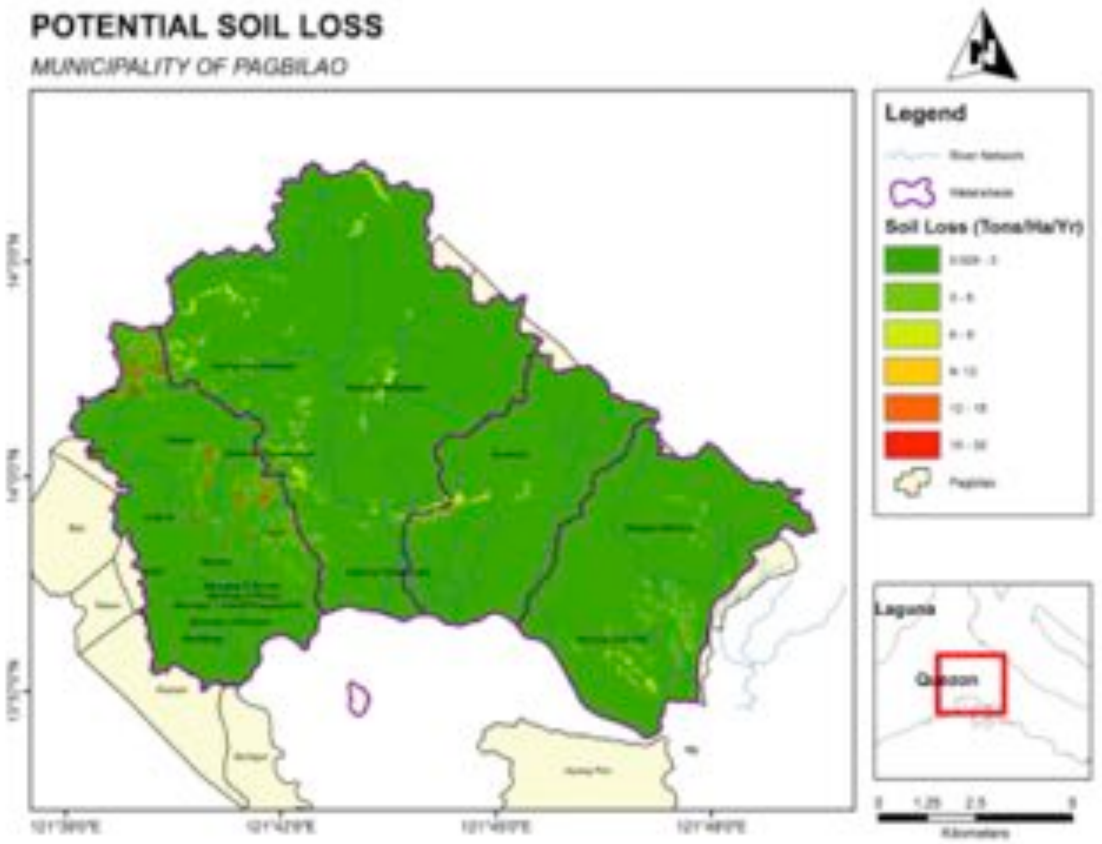

Figure 17. Potential soil loss in the four watersheds covering the mangrove forest of Pagbilao, Quezon

If a sequential sedimentation process were disregarded and the watershed were viewed as a whole, Pagbilao forest would still yield the highest sedimentation rate (see Table 38). On the average, the mangrove forest of Pagbilao receives an estimated 0.213 t ha^{-1} yr^{-1} of sediments. That is equivalent to 137.6 tons yr^{-1} across the entire mangrove forest of Pagbilao. Combining this data with the above figure, it can be said that the whole area receives 137.6 to 237.7 tons of sediments per year.

Table 35. Average potential soil loss per zone in each of the watersheds covering the mangrove forest of Pagbilao, Quezon

Watershed	Zone	Average Potential Soil Loss (t ha^{-1} yr^{-1})
	High	0.195
Palsabangon	Mid	0.795
	Low	0.848
	High	3.609
Pagbilao	Mid	1.722
	Low	0.980
	High	0.067
Malicboy	Mid	0.169
	Low	0.630
	High	0.100
Locohin	Mid	0.325
	Low	0.283

Table 36. Zones and corresponding sedimentation delivery ratio

Watershed	Zone	Area (Hectares)	SDR value
	High	353.6	0.38
Palsabangon	Mid	2543.0	0.23
	Low	3,022.6	0.21
	High	15.5	0.53
Pagbilao	Mid	1,100.4	0.34
	Low	2,092.4	0.26
	High	45.0	0.49
Malicboy	Mid	646.8	0.36
	Low	2,334.8	0.24
	High	395.2	0.37
Locohin	Mid	670.1	0.35
	Low	1,236.5	0.30

Table 37. Zones and estimated annual average sedimentation rate (t ha/yr)

Watershed	High	Mid	Low
Palsabangon	0.079	0.276	0.347
Pagbilao	2.155	1.359	0.756
Malicboy	0.035	0.076	0.225
Locohin	0.040	0.136	0.145
Average	0.577	0.462	0.368

Table 38. Watersheds and estimated annual average sedimentation rate (t ha/yr)

Watershed	Area (Ha)	SDR	Sedimentation Rate
Palsabangon	5,919.14	0.284	0.223
Pagbilao	3,208.36	0.307	0.382
Malicboy	3,026.46	0.309	0.162
Locohin	2,301.86	0.320	0.084
Average			**0.213**

4 | Conclusion and Recommendations

This study confirms the diversity of species in the mangrove forest of Pagbilao, being home to more than 81 percent of the total true mangrove species in the country. It is safe to assume that PMF is one of the most complete mangrove forests in the country in terms of number of mangrove flora. It is also home to four mangrove species listed in the IUCN Red List of threatened species. It can thus be readily concluded that PMF is an ecologically critical area.

DENR and all other concerned agencies or institutions should exert all efforts possible to protect and conserve the area. Measures such as the issuance of BFD Administrative Order in 1975 that declared the 145-ha mangrove forest in Ibabang Palsabangon as Pagbilao Mangrove Experimental Forest (PMEF), which has led to conservation and protection of the covered area, must be sustained and intensified. Consider, for instance, the mangrove forests located outside the PMEF, which were heavily devastated, primarily due to fishpond conversion. A similar, even stronger, legislation (whether local or national) must be passed in order to prevent further degradation of critical ecosystems in the country such as the mangrove forest in Pagbilao .

It is also recommended that the ecotourism and public awareness campaign of the PMEF be expanded to include labelling those trees, particularly those along the commonly traversed trail. Such efforts could still be enhanced by including other important information (e.g., uses, distribution, historical account, etc.) regarding the species. These proposed measures are expected to generate increased public awareness of Philippine mangroves, particularly of the need conserve them.

Pagbilao mangrove is also an important staging, feeding, and resting area for many species of migratory and resident birds because of the variety of habitats that the site offers (i.e., fishponds, rice fields, beach, tidal mudflats, estuaries, and mangrove forests). As such, this rich ecosystem in Pagbilao has long been counted among the 117 Important Bird/Biodiversity Areas (IBA), where it is listed as the Pagbilao and Tayabas Bay IBA (PH 026).

At least three threatened bird species, which can be used as basis for ecotourism (i.e., bird tourism), were recorded at the study sites. The sites also contain some of the remaining populations of the Philippine duck in the country. Similarly, remnants of some uncommon wetland species such as the watercock can still be found in one of the four study areas within the Pagbilao mangroves project site. In other taxa, endemic and near-threatened species such as the monitor lizard (Varanus cf. marmoratus) and Philippine common cobra were also recorded at the survey site.

In 1987, more than 200 individuals of Philippine duck were recorded in Pagbilao. The species was regularly seen in good numbers in Tayabas bay, Agdangan, and the Mangrove Forest Research Center (Mallari et al., 2001). During the survey, a total of five individuals were observed while they were in flight. There were also several sightings of a pair of Philippine ducks along fishponds. Locals who were interviewed could not say with certainty how many individuals of this species remain in the mangrove of Pagbilao, but that there were still "a good number" of them. Similarly, community residents said the stronghold of the Philippine duck populations lies deep within the Palsabangon river and its mangroves.

Thus it was proposed by the study team that a purposive research be undertaken to systematically determine the extant population of the species within the Pagbilao mangrove experimental station and further study its biology and ecology in the area as well as the current possible threat to the species. A similar study may also be undertaken for other threatened species existing at the site such as the Chinese egret (Egretta eulophotes), Philippine dwarf-kingfisher (Ceyx melanurus) (Mallari et al., 2001), and Philippine eagle-owl and Java sparrow, which was found during the survey for this study. Similar efforts such as the establishment of semi-permanent monitoring stations (i.e., transects and/or observation stations for birds and for volant mammals) and the conduct of an annual or bi-annual bird/bat census in selected sites of the mangrove experimental station may also be exerted. Data from this census may help in research and conservation efforts such as the production of IEC materials for the site, as well as boost bird tourism in the area.

Based on the estimation of carbon stock in the area, the Pagbilao mangrove forest stores an average of 184.84 t C ha^{-1} from the biomass and soil. Consequently, the whole mangrove forest stores 119,406.6 tons C. The same area receives an estimated amount of 137.6 to 237.7 tons of sediments per year.

This report provides a good baseline information for various ecosystem services (i.e., provisioning services including timber and biomass, food, medicine, and habitat for wildlife; regulating services such as carbon sequestration) provided by the mangrove forests. The results highlight the critical role of mangrove forests in the changing climatic pattern.

As this study has shown, a huge amount of carbon is stored in the mangrove forests' substrate and biomass. This and other relevant findings can form a more accurate basis for an overall assessment of the ecosystem services of the mangrove forests in the country, as the variation and stratification of the different mangrove zones and forest types are evaluated. In this regard, efforts should be exerted by the government toward the following:

1. Conduct of a comprehensive assessment of the current extent and condition of mangrove forests in the country;
2. Formulate a mangrove-specific conservation, rehabilitation, and protection program; and
3. Promote value-based information on the Philippine mangroves through a determination of their whole ecosystem services (i.e., provisioning, regulating, and cultural services).

5 | Appendices

Appendix 1

Sample Calculations

SAMPLE CALCULATIONS OF SOIL CARBON STORAGE AND
SEDIMENTATION RATE

A. Soil Carbon (C) storage

The information used in the following calculations were taken from sample 1.

Step 1. Calculate the Bulk Density (BD) based on the collected sample.

Bulk density was determined by taking an intact soil core of known volume and determining its oven-dry weight. Given the resulting findings:

Dimensions of the metal cylinder: 4.1 cm (diameter) x 27.3 cm
Oven-dry weight of soil: 504.9 g

Volume of cylinder = $\pi r2*H$ = 360.43 cm^3

$$\text{Bulk density} = \frac{\text{ovendry weight of soil}}{\text{volume of soil core}} = \frac{504.9g}{360.43} = 1.4015\ g/cm^3 \text{ or } 1.4015\ Mg/m^3$$

Step 2. Calculate the weight of soil on a per hectare basis

Determine the volume of soil in a hectare.

1 hectare = 10,000 m^2

Since the depth of soil sampling is 30 cm (0.3 m), the volume of soil in a hectare is

Volume of soil = Area * depth of sampling
Volume of soil = (10,000) (0.3) = 3,000m^3

Using the bulk density information, the weight of soil per hectare basis is calculated as

Weight of soil = Bulk density x Volume of soil per hectare = 4,200 Mg
Weight of soil = (1.4015 Mg/m^3) (3,000 m^3/ ha) or 4,204.5 T/ha since 1 Mg = 1T

Step 3. Determine soil C storage on per hectare basis

Using the result of analysis for soil C = 1.02 percent, soil C storage is calculated as

Soil C storage per ha = (Weight of soil/ha) (% soil C/100%) = (4,204.5 T/ha) (1.02%/100%) = 42.9 T/ha

To estimate the total soil C storage in the entire mangrove forest of Pagbilao, use the average soil C storage for all samples (123.5 T/ha) and the total area of the mangrove forest (646 ha) and calculate as follows:

= (Average soil C storage/ha) (Area of mangrove forest)
= (123.5 T/ha) (646 ha) = 79,781 T carbon/ha

B. Sedimentation rate

The calculation of soil loss potential using the RUSLE was on a per grid (5 m x 5 m) basis. The calculation of the soil loss potential for the entire Pagbilao was automated using the Raster Calculator tool in GIS.

Step 1. Generate the Rainfall Erosivity Factor (R-Value).

Since the monthly rainfall (mm) was obtained from a single rainfall station, all the grids covering Pagbilao are assigned a single r-value following David's (1988) estimation of rainfall erosivity index (R):

$R = 0.002 * (TADR * 31^2)$

TADR = Total Average Daily Rainfall in a year

Using the monthly rainfall data obtained from the PAGASA office in Tayabas station from 1990 – 2012, the R value for the entire Pagbilao is:

$R = 195.58$ MJ mm ha^{-1} h^{-1} yr^{-1}

Step 2. Generate the Soil Erodibility Factor (K-Value).

The K value of each grid is determined based on the estimated K values of different soil series in the Philippines developed by David (1988), as cited by De Asis (2006).

If a grid has a Bolinao clay loam soil texture type, its corresponding K value is:

K = 0.25

Step 3. Generate the Topographic Factor (LS-Value).

The LS value of each grid is determined based on the estimated LS value per slope class. The slope classes in Pagbilao are generated from the elevation values using GIS.

If a grid has a slope class of 0 – 3%, the corresponding LS value is:

$LS = 0.01306$

Step 4. Generate the Cover and Management Factor (C-Value) and Conservation Support Practice Factor (P-Value).

The C value of each grid is determined based on the estimated C values of major land use groups identified by Bantayan (2006) and Dumas (2010).

If a grid has an Annual Crop land use type, its corresponding C value is:

$C = 0.16$

Owing to the lack of data on the support practice factor in the study area, a single P value of 1 is assumed for all the grids.

$P = 1$

Step 5. Calculate the Soil Loss Potential.

Following the USLE equation, use the values generated from the previous steps to calculate the Soil Loss Potential (tons ha^{-1} yr^{-1}):

Soil Loss Potential = $R \cdot K \cdot L \cdot S \cdot C \cdot P$

$= 195.58 \cdot 0.25 \cdot 0.01306 \cdot 0.16 \cdot 1$

The Soil Loss Potential of a specific grid (5 m x 5 m) is:

0.102170992 tons ha^{-1} yr^{-1}

Step 6. Calculate the Sediment Delivery Ratio (SDR).

SDR is needed to estimate the sedimentation rate of a watershed. It is calculated based on the size of a watershed using the formula developed by Vanoni (1975), as cited by Ouyang (1997). Thus:

$SDR = 0.42 * A^{-0.125}$

A - Drainage area in square miles

If the drainage area for a specific watershed is 12.3875 square miles,

$SDR = 0.42 \cdot (12.3875)^{-0.125}$

The SDR of a specific watershed is expressed as follows:

SDR = 0.307

Step 7. Calculate the Sedimentation Rate.

Estimated Sedimentation Rate (tons ha^{-1} yr^{-1}) = Average Soil Loss Potential • SDR

The average soil loss potential of a specific watershed is calculated by getting the mean soil loss potential value of all the grids covering a specific watershed.

Using the SDR value from the previous step, 0.307, and an average soil loss potential value of 1.24692 tons ha^{-1} yr^{-1}, the sedimentation rate of a specific watershed is expressed as follows:

Estimated sedimentation rate = 1.24692 • 0.307

= 0.38235 tons ha^{-1} yr^{-1}

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Photos

Plate 1. Pristine riverine mangroves along Palsabangon River

Plate 2. The lone pagatpat (Sonneratia alba) tree at the seaward mouth of the river

Plate 3. A scenic view of a scrub forest along the shore of Kanlurang Malicboy

Plate 4. A view of Mount Banahaw from the mangrove forest of Palsabangon one of the barangays or villages in Pagbilao, Quezon.

Plate 5. The first study team during the data gathering in the mangrove forest of Pagbilao, Quezon.

Plate 6. The second study team during the data gathering in Binahaan Mangrove.


Plate 7. The study team at Patayan Island sandbar in


Plate 8. Photo of Dr. Marco A. Galang getting some soil sample.

Plate 9. Aegiceras corniculatum

Plate 10. Aegiceras floridum

Plate 11. Avicennia marina

Plate 12. Avicennia officinalis


Plate 13. Bruguiera gymnorhiza


Plate 14. Bruiguiera sexangula

Plate 15. Camptostemon philippinensis

Plate 16. Ceriops tagal

Plate 17. Ceriops zippeliana

Plate 18. Dolichandron spathacea


Plate 19. Kandelia kandel


Plate 20. Lumnitzera racemosa

Plate 21. Osbornia octodonta

Plate 22. Rhizophora apiculata

Plate 23. Rhizopora stylosa

Plate 24. Rhizophora mucronata

Plate 25. Scyphiphora hydrophyllaceae

Plate 26. Sonneratia alba

Plate 27. Xylocarpus granatum

Plate 28. Xylocarpus moluccensis

Common birds of the Pagbilao Mangroves
Pagbilao, Quezon
July 2016


PURPLE HERON


GREAT EGRET


INTERMEDIATE EGRET


LITTLE HERON


CATTLE EGRET


LITTLE EGRET


PHILIPPINE EAGLE-OWL


PHILIPPINE SCOPS-OWL


PHILIPPINE NIGHTJAR


PHILIPPINE COUCAL


ZEBRA DOVE


SPOTTED DOVE


PHILIPPINE DUCK


WHIMBREL


BARRED RAIL


WHITE-BREASTED WATERHEN


WHITE-EARED BROWN DOVE


PINK-NECKED GREEN-PEGION


BLUE-TAILED BEE-EATER


BLACK-NAPED ORIOLE


ORIENTAL MAGPIE ROBIN


WHITE-COLLARED KINGFISHER


MANGROVE BLUE FLYCATCHER


JAVA SPARROW

Amphibians and Toads recorded the Pagbilao Mangroves
Pagbilao, Quezon
July 2016

CANE TOAD

BRACKISH WATER FROG

MALAYSIAN NARROW-MOUTH TOAD

Volant mammals recorded the Pagbilao Mangroves
Pagbilao, Quezon
July 2016

COMMON SHORT-NOSED FRUITBAT

MUSKY FRUITBAT

COMMON NECTAR BAT

COMMON ROUSETTE

DAGGER-TOOTHED FLOWER BAT