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# Mitigating climate change through mangrove forest

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One of today's major environmental concerns is the accelerated accumulation of greenhouse gases, particularly carbon dioxide ($CO_2$), in the atmosphere (Castillo and Breva 2012). Their excessive production affects the world's climate, resulting in the greenhouse effect. This phenomenon causes climate change by increasing the temperature of the Earth's surface and triggering extreme conditions. In turn, these events can damage and deplete natural resources and affect livelihood and food security. These observed impacts have the most adverse effects in developing countries, such as the Philippines (IPCC 2014).

This *Policy Note* emphasizes the role of mangroves in sequestering significant amount of $CO_2$ by harnessing their potential as $CO_2$ capture and storage (CCS). As an ecosystem-based disaster risk reduction and adaptation measure, the conservation and maintenance of the areal cover of mangrove forests can serve as an effective way in reducing the levels of greenhouse gases in the atmosphere. This is expected to significantly contribute to the global efforts at mitigating the impacts of climate change.

## Mangrove forest in climate battle

Mangroves are a group of salt-tolerant shrubs and trees usually found in coastal intertidal zones of the tropics and subtropics (Long and Giri 2011; Primavera et al. 2012). Currently, there are 35 species of mangroves found in the Philippines belonging to 13 families dominated by species from family Rhizophoraceae, Avicenniaceae, and Sonneratiaceae (Primavera et al. 2012). While these mangroves can be found in 82 provinces of the country, their largest areas are located in Palawan and Sulu (Long and Giri 2011).

Mangroves are relevant because of the wide array of ecosystem services that they offer to coastal inhabitants. These services include protection from erosion, nursery habitat for many marine species, and natural barriers against tropical storms and depocenters for sediment, carbon, and other elements primarily in the carbon sequestration process (Primavera et al. 2012; Alongi 2014; Bhomia et al. 2016).

In particular, CCS is a method to capture $CO_2$ and store it in carbon sinks, such as forests, oceans, and lithosphere instead of emitting it in the atmosphere (Fu and Gundersen 2012). Mangrove forests, known as blue carbon sinks, along with their surrounding sediments have an ability to store large amount of carbon. As such, they can serve as an instrument in CCS. This mechanism has a significant role in the reduction of greenhouse gases in the Asia-Pacific Economic Cooperation (APEC) region.

Unfortunately, mangrove forests face a serious problem in terms of diversity. In particular, their total area is decreasing, from an early estimate of as much as 500,000 hectares down to 153,777 hectares (Primavera 2000). This trend is likely due to the accessibility of mangrove forests, exposing them to developmental activities. Many areas are also subjected to deforestation and forest loss.

Pangasinan is one of the Philippine provinces to experience severe mangrove forest destruction. Its total area of mangrove forest has noticeably declined, from 990 hectares in 1978 down to 615.02 hectares as of 2015 (Mayo et al. 2015). Most of the remaining mangrove forests are also secondary growths composed of reforested and old trees, with only a few remain to be primary growth (Mayo et al. 2015). This continuous reduction of the population of mangroves can contribute significantly to the alarming concentration of $CO_2$ in the atmosphere. As such, sustaining the role of mangrove forests in mitigating the impacts of climate should be a primary concern.

Given the destruction experienced by mangrove forests in Pangasinan, this study zeroed in on the province. It specifically covered the Mangrove Forest Park in Barangay Bued, Alaminos City, Pangasinan, with a total area of 5.49 hectares, inclusive of old and reforested mangrove stand and the mangrove nursery grounds.

The study assessed the diversity of mangroves, sediment carbon, mangrove distribution and carbon stock, and vegetation index. Species diversity, known as Shannon-Weiner's Index, was determined to indicate the quantitative description of the area in terms of species richness and abundance. Sediment carbon, on the other hand, was measured to determine the soil carbon stock of the area in addition to the mangroves. The mangrove distribution and carbon stock were determined using two pools of carbon, namely, above-ground biomass (AGB) (e.g., branches and leaves) and below-ground biomass (BGB) (i.e., roots). These pools are relevant to determine the carbon storage capacity of the mangrove forests. The vegetation index, in combination with satellite images data downloaded from United State Geological Survey, was used to quantify and identify areas of varying levels of biomass and carbon stock within the mangrove forests and create a map for better visualization on the carbon sequestration ability of the area. This is often used to assess the regional and global vegetation like forests (Xue and Su 2017).

## Mangrove forest as CCS

Mangrove forest has a potential to sequester significant amount of $CO_2$. The primary factors that determine this ability are species diversity and biomass and carbon content. Changes in species diversity have consequent changes in both standing biomass and carbon uptake rates and capacities of a mangrove forest.

Despite the low species diversity of mangrove forest in Pangasinan, the study found that the AGB mean value of the area was 317.45 tons per hectare with a total of 166,024.88 tons. Meanwhile, the BGB mean value obtained was about 247.25 tons per hectare with a total of 129,313.46 tons. With respect to total biomass and carbon stock, the mean values observed were 564.70 tons per hectare and 262.02 tons per hectare

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with a total of 295,338.33 tons and 137,036.99 tons, respectively. These biomass and carbon stock values were significantly higher than the values in India (Sahu et al. 2016), Matang, Malaysia (Hamdan et al. 2013), Southwest Thailand (Jachowski et al. 2013), and Northwestern Madagascar (Jones et al. 2014). On the other hand, they were lower than the findings in Cotabato City (Dimalen and Rojo 2019), Bohol (Gevaña et al. 2017), Palawan (Abino et al. 2014), Mtimbwani, Tanzania (Alavaisha and Mangora 2016), Berau, Indonesia (Kusumaningtyas et al. 2019), and Sigogor Mountain Nature Reserve, Indonesia (Waskitho and Triwanto 2018).

These differences in biomass and carbon stocks globally may be explained by the latitudinal zone, which controls the growth and distribution of mangroves (Liu et al. 2014). Biomass and carbon stocks increase at lower latitudes or toward the equator (Giri et al. 2011; Thant et al. 2012; Liu et al. 2014; Yessoufuo and Stoffberg 2016; Estrada and Soares 2017). This is the reason why areas found near the equatorial regions, such as Indonesia, Tanzania, Palawan, Bohol, and Cotabato City, had higher carbon stock compared to the carbon stock in this study. In contrast, those areas located at higher latitudes, such as India, Thailand, and Madagascar, were shown to have lower values than the study.

Other factors, such as variability in climatic conditions and disturbances like forest loss, may also affect the distribution of carbon stocks at global and regional scale (Estrada and Soares 2017). For instance, Malaysia showed lower values for carbon stocks than the data obtained in the study. This might be due to the fact that this country had the highest loss of mangrove forests among the countries in Southeast Asia, according to Hamilton and Casey (2016).

Additionally, the distribution of the amount of biomass and carbon stock varied significantly within the area. Lower biomass and carbon stocks were observed at the edges or adjacent to the mainland. This is probably due to disturbances, such as anthropogenic activities, as the area is surrounded by vendor establishment, port for boat, salt farm, and fishpond. Anthropogenic activities, such as illegal dumping of wastes by the tourist, firewood collection, and boating around the area, contribute significantly to the decline of the biomass and carbon stock. The result is similar to the findings of Candra et al. (2016) and Patil et al. (2013), who found that there was inhibition on the growth of mangroves adjacent to the mainland caused by human activities.

In contrast, high biomass and carbon stock values were observed in mangrove forest near the sea. This is due to its ecology, wherein mangroves thrive near the sea given the enough supply of water that can accelerate their growth (Candra et al. 2016). Additionally, areas least impacted by anthropogenic activities obtained a relatively high carbon content (Patil et al. 2013).

The total carbon stocks of Bued Mangrove Forest, including the mangrove and soil carbon stock were estimated to be 137,605.19 tons of carbon, equivalent to 504,552.37 tons $CO_2$. These results suggest a high carbon storage and carbon sequestration potential in the area. The species that contribute more to this high carbon storage were *Avicennia marina*, *Sonneratia alba*, and *Rhizophora apiculata*.

The significant amount noted revealed these mangroves had a potential for large carbon sink benefit, which can lead to notable strategies for climate change mitigation. Therefore, the conservation, restoration, and sustainable management of this mangrove forest is needed to maintain and increase the carbon stock.

## Conclusion and recommendations

This study presented the first carbon stock estimates in Bued Mangrove Forest. It revealed that this mangrove forest obtained a very low diversity index. This was attributed to the dominance of few species, specifically those belonging to the family of Avicenniaceae, Rhizophoraceae, and Sonneratiaceae.

Despite its low species diversity, the estimated biomass and carbon stock revealed to have the potential to sequester and store as high as 262.02 tons of carbon per hectare for mangrove stands, and 43.71 tons of carbon per hectare for sediment. The estimated value was higher than the mean carbon storage found by some studies on mangrove forest in the Philippines and other countries.

This implies that Bued Mangrove Forest has a potential for large carbon sink benefit, which can lead to notable strategies for climate change mitigation and provide adaptation measurements. The study also proved the ability of mangroves as CCS, which can be beneficial to the APEC region. They can separate $CO_2$ from large source points, such as fossil fuels used by developing economies, and store it in other sinks, such as mangrove and sediments.

Given these benefits of mangrove forests, the study recommends the following courses of action:

### *Mitigate the impact of human actions*

The government must adopt policies and regulations relevant in mitigating the stress brought by human actions, especially in areas where ecotourism is dominant. These efforts may include the construction of boardwalk and wood deck around the trees, as well as information drive that can guide tourists and tour companies on the proper disposal of garbage and restriction on the collection of wood from mangroves. The conversion of the Bued Mangrove Forest Park into a marine-protected area may also help in the conservation and restoration of the forest.

### *Establish an incentive system*

Unsustainable anthropogenic activities and natural phenomenon threaten the existence of mangrove forests. As such, the government must establish a sustainable funding and concrete incentive systems to balance the conservation of mangrove ecosystem and sustainable livelihood for coastal inhabitants and regulations for tourism.

Among the emerging options is the recently implemented blue carbon trading, which pertains to the ocean equivalent of Reducing Emissions from Deforestation and Forest Degradation. The government may also consider payment for environmental services, which include participation of local communities in the protection and conservation of mangroves and the creation of marine protected zones. This presents an opportunity to balance the conservation of mangrove ecosystems and sustainable livelihood for coastal inhabitants.

### *Conduct further study on carbon stock*

Additionally, a further study is needed to compare estimation of carbon stock among different vegetation indices. This can provide validation assessment and develop modelling on the carbon stocks of the different mangrove species.

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