Environmental and Urban Planning International Journal

EUPIJ
E-ISSN: 3155-5543
P-ISSN: 3116-6032

Comparative Assessment of Mangrove Diversity and Carbon Stock Quantification in Three Coastal Barangays in Davao del Sur, Philippines

[1]Jeffrey B. Galerio*, [1]Joel S. Pardillo

[1]University of Mindanao, Davao City, Philippines

*Corresponding Author's Email Address: jbgalerio@gmail.com

Received 18th June 2026; Accepted 28th July 2026; Published Online 13th August 2026
DOI: 10.63941/eupij.2026.1.2.03

ABSTRACT

Mangrove forests play an important role in protecting coastlines and storing large amounts of carbon; however, many stands in Davao del Sur continue to experience disturbance and declining species diversity. This study assessed mangrove diversity, ecological characteristics, ecosystem carbon stocks, and management implications in Barangays Tuban, Bato, and Cogon–Punta Biao, Davao del Sur, Philippines. Field measurements of trees, litter, downed wood, and soil were conducted to estimate ecosystem carbon stocks, while ecological indices were used to characterize mangrove communities. Seven mangrove taxa were recorded across the three sites. Mangrove diversity remained very low (H′ = 1.399–1.556), indicating simplified stand structures dominated by Rhizophora apiculata and Sonneratia alba, which also exhibited the highest ecological importance, as indicated by the Importance Value Index (IVI). Total ecosystem carbon stocks varied considerably among sites, with Cogon–Punta Biao recording the highest carbon storage (1,342.37 Mg C ha^{-1}), followed by Bato (1,162.83 Mg C ha^{-1}) and Tuban (925.83 Mg C ha^{-1}). Live biomass constituted the largest carbon pool, while soil organic carbon contributed to long-term carbon sequestration. Based on these findings, a site-specific Sustainable Mangrove Management Framework was developed to support biodiversity conservation, blue carbon management, and sustainable coastal planning in Davao del Sur. The findings further contribute to broader sustainability objectives related to climate action and ecosystem conservation under SDGs 13, 14, and 15.

Keywords: *Mangrove diversity; carbon stock; blue carbon; biodiversity; Sustainable Mangrove Management Framework; coastal resource management; Davao del Sur*

INTRODUCTION

Mangrove forests are important coastal ecosystems that provide shoreline protection, support biodiversity, and serve as significant carbon sinks that contribute to climate regulation and coastal resilience (Donato et al., 2011; Alongi, 2020; Barbier et al., 2011). Despite their ecological and socio-economic importance, mangrove ecosystems continue to experience degradation worldwide due to the expansion of aquaculture, land conversion, coastal development, and unsustainable resource use (Spalding et al., 2010; Valiela et al., 2001; IUCN, 2021).

In the Philippines, mangrove decline has been linked to natural disturbances and anthropogenic activities, leading to changes in species composition and ecosystem functions (DENR-FMB, 2013; Quevedo et al., 2021). Previous studies have reported generally low mangrove diversity but substantial carbon storage potential in various Philippine mangrove ecosystems (Abantao et al., 2015; Goloran et al., 2020; Jubilo & Rizon, 2018). However, information on mangrove diversity and ecosystem carbon stocks in Davao del Sur remains limited despite increasing environmental pressures and the need for site-specific conservation strategies (Pacyao & Llameg, 2018).

This study assessed mangrove species diversity, ecological characteristics, and ecosystem carbon stocks in three coastal barangays in Davao del Sur, Philippines. Specifically, it aimed to identify mangrove species composition, evaluate ecological characteristics, quantify ecosystem carbon stocks, and develop a site-specific Sustainable Mangrove Management Framework. The findings provide scientific evidence to support biodiversity conservation, blue carbon management, sustainable coastal planning, and broader sustainability objectives under SDGs 13, 14, and 15.

MATERIALS AND METHODS

Research Subject and Location

The study was conducted in three coastal mangrove areas along the mid-section of Davao Gulf, Davao del Sur, Philippines: Barangay Tuban and Barangay Bato in the Municipality of Sta. Cruz, and Punta Biao in Barangay Cogon, Digos City (Figure 1). The three sites collectively cover approximately 40.72 ha of mangrove forests, consisting of 24.82 ha in Tuban, 12.35 ha in Bato, and 3.55 ha in Cogon–Punta Biao.

Figure 1. Map showing the subject area of the study.

These sites were selected for the presence of established mangrove stands and their varying environmental conditions and disturbance histories, enabling comparative assessment of mangrove diversity and ecosystem carbon storage.

Sampling Design and Procedures

A descriptive-quantitative approach was employed to assess mangrove diversity and ecosystem carbon stocks. Transect lines were established parallel to the shoreline, and 10 × 10 m plots were systematically distributed to capture stand variability. All mangrove trees with DBH ≥5 cm were identified and measured for diameter and height.

A 1 × 1 m subplot was established for litter and downed woody debris sampling. At the same time, soil samples were collected from representative disturbed and undisturbed plots using a zigzag sampling approach following established coastal blue carbon protocols. Forest structure and species diversity were analyzed using the Shannon–Wiener Diversity Index, Simpson Diversity Index, Pielou's Evenness Index, and Importance Value Index. Above-ground biomass for each tree was estimated using the mangrove-specific allometric equation developed by Komiyama et al. (2005), which incorporates tree diameter, height, and wood density and has been widely applied in tropical mangrove biomass assessments. Carbon stocks were derived using IPCC Tier-1 default carbon fractions.

Data Processing

Forest structure and species diversity were analyzed from fixed-area plots using standard community ecology indices: Shannon–Wiener Index (Shannon & Weaver, 1949), Pielou's Evenness (Pielou, 1966), and Simpson's Dominance Index (Simpson, 1949). Calculations were performed with PAST software (Hammer et al., 2001).

Biomass and Carbon Stock Estimation

Only trees with DBH ≥ 5 cm were included in biomass estimates to avoid bias from immature stems (Komiyama et al., 2005). DBH was measured at 1.3 m above ground, or just above the buttresses in species such as Rhizophora, following standard protocols (Kauffman & Donato, 2012). Tree height was recorded using fiberglass tapes or calibrated poles. Field data were screened for accuracy prior to biomass calculations.

Wood Density Assignment and Biomass Estimation

Species-specific wood densities were assigned following Chave et al. (2014).

Litter Sampling and Carbon Conversion

Litter samples were collected using 1×1 m subplots following Kauffman and Donato (2012).

Downed Woody Debris Assessment

Downed woody debris (DWD) was assessed in accordance with the IPCC and Coastal Blue Carbon protocols.

Field Collection Protocol

Soil samples were collected using a zigzag sampling approach. Samples from the (0–30 cm) layer were collected for bulk density and organic carbon analysis. Soil organic carbon was analyzed using the Walkley–Black method (Walkley & Black, 1934).

RESULT AND DISCUSSION

Mangrove Species Identification

Six of seven mangrove taxa occurred across all three barangays (Table 1): *Rhizophora apiculata* (Bakauan lalaki), *R. mucronata* (Bakauan babae), *Sonneratia alba* (Pagatpat), *S.caseolaris* (Pedada), *Nypa fruticans* (Nipa palm), and the associate *Hibiscus tiliaceus* (Malubago). *Aegiceras floridum* (Saging-saging) was found only in Tuban and Cogon–Punta Biao.

Table 1. Mangrove species identified in three coastal barangays

Native Local Name	Scientific Name	Tuban	Bato	Cogon
Bakhaw lalaki	*Rhizophora apiculata*	✓	✓	✓
Bakhaw babae	*Rhizophora mucronata*	✓	✓	✓
Pagatpat	*Sonneratia alba*	✓	✓	✓
Pedada	*Sonneratia caseolaris*	✓	✓	✓
Saging-saging	*Aegiceras floridum*	✓	—	✓
Nipa	*Nypa fruticans*	✓	✓	✓
Malibago	*Hibiscus tiliaceus*	✓	✓	✓

Ecological Characteristics

Mangrove Species Diversity

Table 2 shows consistently very low Shannon–Wiener diversity indices across the three barangays—Tuban (1.556), Bato (1.406), and Cogon–Punta Biao (1.399)—despite similar species richness (6–7 taxa). This low diversity results from dominance by one or two species, reflected in moderate Simpson diversity (1–D = 0.668–0.712) and partial evenness (Pielou's J = 0.719–0.874), with Bato showing the highest evenness.

Table 2. Mangrove diversity indices in three coastal barangays

Site	Species Richness (S)	Shannon–Wiener (H')	Simpson (1–D)	Evenness (J = H′/ln S)	Interpretation (H')
Barangay Tuban	7	1.556	0.712	0.799	Very Low
Barangay Bato	6	1.406	0.695	0.874	Very Low
Barangay Cogon	7	1.399	0.668	0.719	Very Low

(H' = Shannon–Wiener Diversity Index; 1–D = Simpson Diversity; J = Pielou's Evenness)

Low diversity, combined with dominance by *Rhizophora* and *Sonneratia*, suggests vulnerability to disturbances that could strongly affect canopy structure, regeneration, and carbon storage. These findings highlight the need for biodiversity-focused management rather than just area expansion. Strategies should protect existing mixed stands and promote enrichment planting to enhance species heterogeneity.

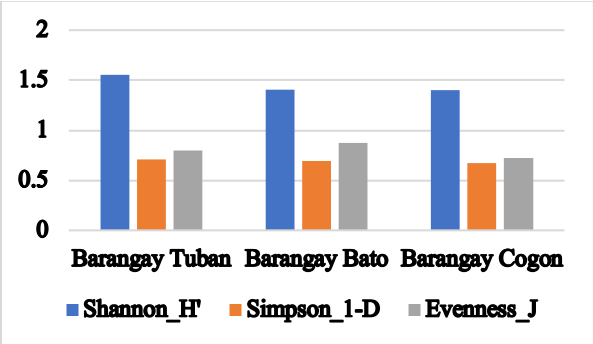

Figure 2. Diversity indices across barangays

Figure 2 illustrates consistently low Shannon–Wiener values and moderate Simpson diversity across sites, underscoring simplified stand structures typical of rehabilitated or mono-dominant mangroves. The observed low diversity indicates simplified stand structures that may reduce ecological resilience and adaptive capacity to disturbance.

Importance Value Index (IVI)

The IVI, combining relative density, frequency, and dominance (Curtis & McIntosh, 1951), highlighted *Rhizophora apiculata* and *Sonneratia alba* as the most ecologically influential species across all sites due to their abundance, dominance, and distribution.

Table 3. Importance value index of mangrove species

Site	Rank	Species	Relative Density (%)	Relative Dominance (%)	Relative Frequency (%)	IVI (points)
Tuban	1	*R.. apiculata*	47.60	48.50	41.10	137.19
Tuban	2	*S. alba*	19.71	25.78	36.99	82.48
Tuban	3	*A. floridum*	7.21	11.98	5.48	24.67
Tuban	4	*R. mucronata*	7.45	4.12	9.59	21.16
Tuban	5	*N. fruticans*	8.17	5.09	1.37	14.64
Bato	1	*S. alba*	48.58	82.77	50.00	181.36
Bato	2	*R. apiculata*	15.57	6.74	25.00	47.30
Bato	3	*R. mucronata*	14.15	4.25	16.67	35.07
Bato	4	*N. fruticans*	14.15	5.71	2.78	22.63
Bato	5	*H. tiliaceus*	7.08	0.32	2.78	10.17
Cogon	1	*R. apiculata*	51.72	67.41	26.32	145.45
Cogon	2	*S. alba*	20.95	19.42	42.11	82.48
Cogon	3	*A. floridum*	9.02	4.20	10.53	23.74
Cogon	4	*R. mucronata*	7.96	3.57	5.26	16.79
Cogon	5	*N. fruticans*	6.63	4.89	5.26	16.79

Table 3 shows that *Rhizophora apiculata* had the highest IVI in Tuban (137.19) and Cogon-Punta Biao (145.45), while *Sonneratia alba* dominated in Bato (181.36). The top five species accounted for nearly all ecological importance at each site.

These IVI results align with diversity indices, confirming that ecosystem functions are driven mainly by one or two dominant species, which explains the very low Shannon–Wiener diversity and is consistent with Biodiversity–Ecosystem Functioning Theory (Loreau & Hector, 2001).

The ecological dominance of *R. apiculata* and *S. alba* indicates their major contribution to stand structure, productivity, and carbon accumulation (Giesen et al., 2007; Alongi, 2020). However, relying on a few dominant species may reduce ecosystem resilience if they are affected.

The dominance of these species indicates that the stability and function of the mangrove ecosystem depend heavily on their persistence and health (Loreau & Hector, 2001; Donato et al., 2011; Alongi, 2020).

Biomass and Carbon Stocks Estimation

Quantification of above-ground biomass (AGB) and below-ground biomass (BGB) provided the basis for estimating mangrove carbon storage. Biomass-to-carbon conversion employed the IPCC default carbon fraction of 0.48 for live biomass (IPCC, 2006, 2014).

Table 4 summarizes the biomass and carbon stocks of mangrove forests across the three study sites. Biomass and carbon stocks varied considerably among barangays, reflecting differences in stand structure and species composition. Barangay Tuban recorded the lowest total biomass (956.27 Mg ha^{-1}) and carbon stock (459.01 Mg C ha^{-1}) despite having the highest number of trees (n = 416), indicating that stem abundance alone does not necessarily determine ecosystem carbon storage. Barangay Bato exhibited intermediate biomass (1,210.35 Mg ha^{-1}) and carbon stock (580.97 Mg C ha^{-1}), whereas Cogon–Punta Biao had the highest total biomass (1,393.26 Mg ha^{-1}) and carbon stock (668.77 Mg C ha^{-1}).

Table 4. Biomass and carbon stock of mangrove forests

Site	Trees	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total Biomass (Mg ha^{-1})	Total-C (Mg C ha^{-1})
Tuban	416	869.04	87.23	956.27	459.01
Bato	212	1,107.83	102.52	1,210.35	580.97
Cogon	377	1,261.71	131.56	1,393.26	668.77
Mean ± SD	—	1,079.53 ± 197.86	107.10 ± 22.51	1,186.63 ± 219.46	569.58 ± 105.34

Note. *Carbon stocks were estimated using a biomass carbon fraction of 0.48 (IPCC, 2006).*

The higher biomass and carbon values observed in Cogon–Punta Biao may be attributed to the dominance of *Rhizophora apiculata*, a species characterized by extensive root development and high biomass accumulation potential (Komiyama et al., 2005; Alongi, 2020). These findings suggest that ecosystem carbon storage is strongly influenced by stand maturity, species composition, and structural characteristics rather than stem abundance alone (Donato et al., 2011). In contrast, the lower biomass values in Tuban likely reflect younger or developing mangrove stands. As shown in Figure 3, live-biomass carbon stocks increased progressively from Tuban to Bato and reached their highest values in Cogon–

Punta Biao, further illustrating differences in biomass accumulation among sites.

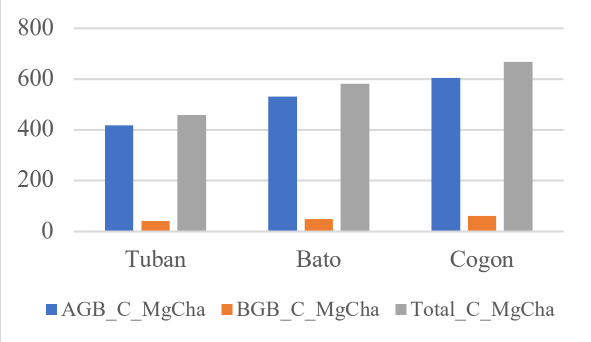

Figure 3. Live-biomass carbon stocks by barangay

These findings emphasize the importance of conserving mature mangrove stands and promoting regeneration in developing areas to enhance long-term carbon sequestration and climate change mitigation (Alongi, 2020; Donato et al., 2011). The substantial carbon storage potential of mangrove ecosystems further supports their role in blue carbon conservation and sustainable coastal resource management in Davao del Sur.

Carbon Stocks of Downed Wood

Downed wood accounted for less than 0.3% of total ecosystem carbon and showed minimal variation among sites.

Carbon Stock of Litter

Litter carbon was similarly low across sites and contributed minimally to total ecosystem carbon.

Soil Organic Carbon

Soil organic carbon (SOC) in the 0–30 cm soil layer varied among the three study sites. Barangay Bato recorded the highest mean SOC (11.42 Mg C ha^{-1}; ~41.89 t CO_2e ha^{-1}), followed by Cogon–Punta Biao (7.95 Mg C ha^{-1}; ~29.16 t CO_2e ha^{-1}) and Tuban (6.96 Mg C ha^{-1}; ~25.51 t CO_2e ha^{-1}). The observed variation reflects differences in vegetation structure, hydrological conditions, sediment deposition, and disturbance regimes.

As shown in Figure 5, disturbed plots in Barangay Bato exhibited relatively higher SOC values, possibly due to enhanced sediment accumulation, whereas undisturbed areas in Tuban and Cogon–Punta Biao showed greater SOC stability associated with intact vegetation and hydrological conditions. These findings emphasize the importance of maintaining soil integrity and hydrological connectivity to sustain long-term carbon storage in mangrove ecosystems.

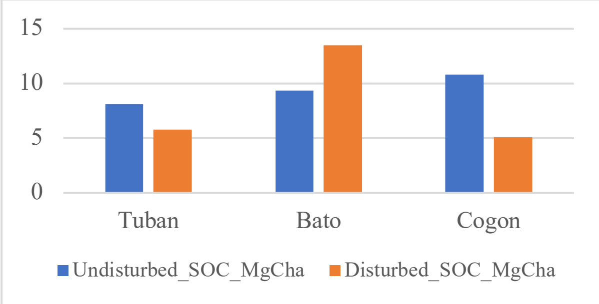

Figure 5. SOC by condition across barangays

Combined with live biomass carbon (Figure 3), SOC results demonstrate that mangrove ecosystems function as multi-layered carbon reservoirs. While live biomass represents active carbon accumulation, soil organic carbon serves as a stable, long-term carbon sink that contributes substantially to ecosystem resilience and sustained carbon sequestration (Donato et al., 2011; Kristensen et al., 2008; Alongi, 2020). These findings further underscore the critical role of below-ground carbon pools in long-term climate change mitigation and blue carbon conservation.

Total Ecosystem Carbon Stocks

Figure 6 presents total carbon stocks from above-ground biomass (AGB-C), below-ground biomass (BGB-C), downed woody debris (DWD), litter, and soil organic carbon (SOC) across three barangays. Cogon-Punta Biao had the highest carbon storage (1,342.37 Mg C ha^{-1}), followed by Bato (1,162.83 Mg C ha^{-1}) and Tuban (925.83 Mg C ha^{-1}), reflecting differences in stand structure, species composition, and forest development.

Live biomass (AGB + BGB) accounted for over 90% of total carbon, while SOC contributed 1–2%, and DWD plus litter accounted for less than 1%. Despite their small proportion, these pools play essential roles in nutrient cycling and long-term carbon sequestration (Donato et al., 2011; Alongi, 2020; IPCC, 2014).

Total ecosystem carbon stocks by pool (Mg C ha^{-1}): AGB, BGB, downed wood (DWD), litter, and soil (SOC, 0–30 cm) across study sites.

Variations among sites highlight the influence of forest maturity and site conditions on carbon storage. The higher stock in Cogon-Punta Biao reflects mature stands, whereas lower values in Tuban suggest growth potential. Bato's balanced biomass and soil carbon levels emphasize the role of stand structure in ecosystem carbon dynamics. These results support a Sustainable Mangrove Management Framework focused on conserving diversity, enhancing carbon sequestration, and adaptive management for long-term ecosystem sustainability in Davao del Sur.

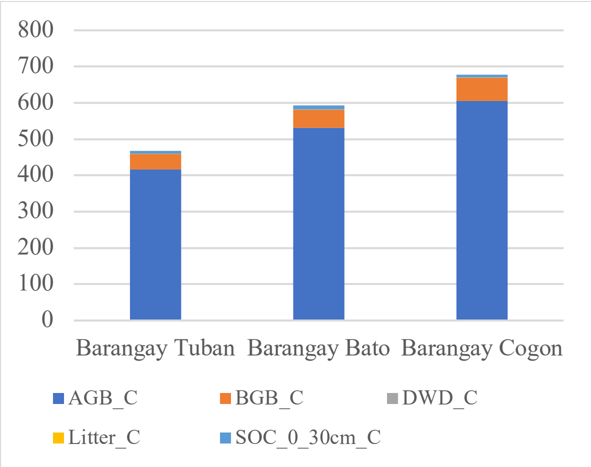

Figure 6. Total ecosystem carbon by pool (AGB, BGB, DWD, Litter, SOC)

Mangrove Management Framework

The framework (Figure 7) integrates findings on mangrove diversity, ecology, and carbon stocks in Barangays Tuban, Bato, and Cogon–Punta Biao, offering a site-specific guide for conserving biodiversity, enhancing carbon storage, and promoting sustainable mangrove management. It responds to site differences in species composition, structure, and carbon, guided by the Biodiversity–Ecosystem Functioning Theory (Loreau & Hector, 2001), Blue Carbon Framework (Donato et al., 2011; Alongi, 2020), and adaptive management principles (Holling, 1978).

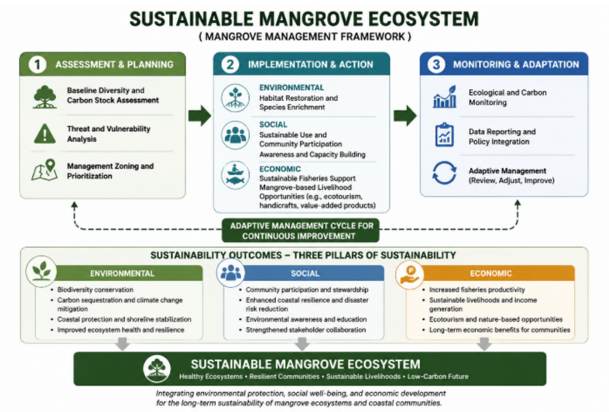

Figure 7. Mangrove Management Framework

1. Assessment and Planning

Baseline assessments revealed low species diversity dominated by *Rhizophora apiculata* and *Sonneratia alba*, and varied carbon stocks—with Cogon–Punta Biao highest and Tuban lowest—highlighting the need for tailored management. Threat analyses identified vulnerabilities linked to dominance and disturbance history. Management zoning prioritizes long-term protection of mature stands (Cogon–Punta Biao), rehabilitation in younger areas (Tuban), and ecosystem maintenance (Bato).

2. Implementation and Action

Conservation focuses on protecting dominant species integral to ecosystem functions and enriching species diversity through native planting. Community engagement ensures long-term stewardship, education, and sustainable resource use. Economic strategies promote fisheries, coastal protection, and sustainable livelihoods like ecotourism, thereby reducing resource pressure.

3. Monitoring and Adaptation

Baseline ecological indicators (diversity, biomass, carbon stocks) enable tracking of the effectiveness of conservation and rehabilitation. Regular monitoring supports data-driven reporting, informs policy, and fosters adaptive management to refine strategies as conditions change.

4. Adaptive Management Cycle

The framework is a continuous process in which monitoring feedback informs ongoing assessment and planning, ensuring responsive and effective management aligned with ecosystem dynamics.

5. Sustainability Outcomes

The integrated approach advances environmental conservation, social resilience, and economic livelihoods, fostering healthy mangrove ecosystems with stable carbon stocks and resilient communities. While designed for Davao del Sur, the framework offers a model for similar coastal areas, aiming to combine biodiversity and blue carbon conservation within sustainable coastal management.

CONCLUSION

Mangrove ecosystems in Barangays Tuban, Bato, and Cogon–Punta Biao exhibited low species diversity despite the presence of seven recorded taxa, with *Rhizophora apiculata* and *Sonneratia alba* dominating the species composition, stand structure, and ecological traits. Very low Shannon–Wiener diversity indicates limited functional redundancy and higher vulnerability to disturbances affecting dominant species.

Carbon storage varied among sites, with the highest in Cogon–Punta Biao, reflecting the influence of stand structure and species composition on stem abundance. Above- and belowground biomass accounted for the largest carbon pools, with soil organic carbon contributing significantly to long-term storage. Litter and downed woody debris were minor but important for nutrient cycling.

The study confirmed that mangrove diversity and structure directly affect carbon storage and ecosystem resilience. Protecting mature stands, conserving soil carbon, and restoring degraded areas with improved species composition are crucial for sustaining biodiversity, blue carbon, and ecosystem services.

A site-specific Sustainable Mangrove Management Framework was developed to integrate environmental, social, and economic sustainability through biodiversity conservation, carbon management, community engagement, and sustainable livelihoods. This science-based framework guides local authorities in conservation zoning, rehabilitation, climate adaptation, and coastal resource management in Davao del Sur.

These findings provide baseline data to support effective conservation planning and sustainable mangrove management in the region.

Recommendations

Based on the study and Sustainable Mangrove Management Framework, it is recommended that local governments, DENR, barangay officials, and agencies use this study as a baseline for planning and policy. Site-specific data on mangrove diversity, ecology, and carbon stocks support the identification of priority conservation, restoration, and sustainable-use zones in Davao del Sur. Integrating these findings into CLUPs, CRM, and LCCAPs will enhance sustainable coastal management.

Management should be tailored by site:

Barangay Cogon–Punta Biao, with the highest carbon stock, should be prioritized as a core protection area to conserve mature stands, biodiversity, and carbon sequestration.

1. Barangay Cogon–Punta Biao, with the highest carbon stock, should be a core protection area.
2. Barangay Tuban requires natural regeneration, enrichment planting, and habitat rehabilitation.
3. Barangay Bato should maintain hydrological connectivity, reduce soil disturbance, and protect soil carbon.

Sustainable-use zones should allow regulated community activities like nipa harvesting, ecotourism, and responsible fisheries. Rehabilitation must prioritize mixed-species planting with native mangroves to improve resilience, biodiversity, and carbon storage while protecting mature stands.

Long-term monitoring and adaptive management of diversity, biomass, litter, debris, and soil carbon should be institutionalized, with community-based partnerships strengthened for transparency and stewardship. Programs like Adopt-a-Mangrove Forest should be expanded for ongoing support.

Implementation should balance environmental conservation, social engagement, and economic livelihoods. Promoting education, participation, and sustainable income sources such as ecotourism and fisheries will reduce pressure on mangroves and support conservation.

These recommendations operationalize the framework, providing a science-based guide for planners, governments, and communities to improve zoning, climate action, resource management, and long-term mangrove protection in Davao del Sur.

Recommendations for Future Research

Future studies should examine deeper soil carbon pools, environmental drivers of carbon variability, ecosystem service valuation, and long-term monitoring using GIS and remote sensing approaches.

REFERENCES

Abantao, S. C., Apacible, T. C., Cortez, S. P., Pereda, L. T., & Yllano, O. (2015). Mangrove species diversity and on-site impact assessment of mangrove coastal areas. *Expert Opinion on Environmental Biology, 4*(3). https://doi.org/10.4172/2325-9655.1000122

Alimbon, J., & Manseguiao, M. R. (2021). Species composition, stand characteristics, above-ground biomass, and carbon stock of mangroves in Panabo Mangrove Park, Philippines. *Biodiversitas Journal of Biological Diversity, 22*(6), 3067–3077. https://doi.org/10.13057/biodiv/d220615

Alongi, D. M. (2020). Carbon cycling in the world's mangrove ecosystems revisited: Significance of non-steady-state diagenesis and subsurface linkages between the forest floor and the coastal ocean. *Forests, 11*(9), 977. https://doi.org/10.3390/f11090977

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological*

Monographs, 81(2), 169–193. https://doi.org/10.1890/10-1510.1

Bronez, A. (2023). *What is biodiversity and why does it matter for you?* Tualatin River Watershed Agricultural Water Quality Management Area Plan. https://tualatinswcd.org/biodiversity

Canizares, L. P., & Santos, R. A. (2016). Diversity and species composition of mangroves in Barangay Imelda, Dinagat Island, Philippines. *AACL Bioflux, 9*(2), 518–526.

Carugati, L., Gatto, B., Rastelli, E., Lo Martire, M., Coral, C., Greco, S., & Danovaro, R. (2018). Impact of mangrove forest degradation on biodiversity and ecosystem functioning. *Scientific Reports, 8*(1), 13298. https://doi.org/10.1038/s41598-018-31683-0

Castillo, J. A. A., Apan, A. A., Maraseni, T. N., & Salmo, S. G. (2018). Tree biomass quantity, carbon stock, and canopy correlates in mangrove forest and land uses that replaced mangroves in Honda Bay, Philippines. *Regional Studies in Marine Science, 24*, 227–235. https://doi.org/10.1016/j.rsma.2018.08.006

Dimalen, F. K., & Rojo, M. J. A. (2018). Floral diversity of a mangrove forest in Cotabato City, Philippines. *Journal of Biodiversity and Environmental Sciences, 13*(6), 117–123.

Dittmann, S., Thiessen, E., & Hartung, E. (2017). Applicability of different non-invasive methods for tree-mass estimation: A review. *Forest Ecology and Management, 398*, 1–9. https://doi.org/10.1016/j.foreco.2017.05.013

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M., & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience, 4*(5), 293–297. https://doi.org/10.1038/ngeo1123

Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., & Silliman, B. R. (2011). The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. *Climatic Change, 106*(1), 7–29. https://doi.org/10.1007/s10584-010-0003-7

IPCC. (2014). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/publication/2013-wetlands-supplement/

Kristensen, E., Bouillon, S., Dittmar, T., & Marchand, C. (2008). Organic carbon dynamics in mangrove ecosystems: A review. *Aquatic Botany, 89*(2), 201–219. https://doi.org/10.1016/j.aquabot.2007.12.005

Loreau, M., & Hector, A. (2001). Partitioning selection and complementarity in biodiversity experiments. *Nature, 412*(6842), 72–76. https://doi.org/10.1038/35083573

Nagelkerken, I., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., … & Sommer, C. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review. *Aquatic Botany, 89*(2), 155–185. https://doi.org/10.1016/j.aquabot.2007.12.007

Pacyao, E. A., & Llameg, M. R. (2018). Community perception on the ecological importance of mangroves in Davao Gulf. *Philippine Journal of Environmental Science, 7*(2), 43–54.

Spalding, M., Kainuma, M., & Collins, L. (2014). *World Atlas of Mangroves* (2nd ed.). Routledge. https://doi.org/10.4324/9781849776608

UNDP. (2023). *Sustainable Development Goals*. United Nations Development Programme. https://www.undp.org/sustainable-development-goal