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Gastropod and Habitat Associations in Selected Mangrove Wetlands of Butuan Bay, Philippines

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ABSTRACT

The Philippines' extensive coastline and mangrove forests have played a crucial role in biodiversity conservation and coastal protection. The present study aimed to assess the gastropod diversity within the rehabilitated mangrove forests of Barangays Pagatpatan and Lumbocan, Butuan City. It also assessed the correlation of water quality, selected sediment edaphic parameters, and mangrove features to the abundance of gastropods. The analyses showed consistent water pH levels within the DENR DAO 2016-08 standard for Class B marine waters, along with fluctuating dissolved oxygen (DO) and spatial variations in total dissolved solids (TDS) and salinity. Soil pH also varied, along with differences in organic matter, phosphorus (P), and potassium (K) levels. A total of five mangrove species and ten gastropod species, including *Cerithidea quoyii*, were identified across six stations. Among the five gastropod families, the Neritidae family was present in both mangrove ecosystems. Pagatpatan showed higher species richness and diversity than Lumbocan. *Faunus ater* was most abundant and closely linked to the growth of *Avicennia marina* and *Rhizophora mucronata*, with its presence likely influenced by sensitivity to pH and humidity. This relationship significantly contributes to the variation explained by Principal Component Analysis (PCA 1), indicating that *F. ater* plays a major role in differentiating sampling stations. The findings underscore the importance of habitat integrity and biodiversity conservation to guide mangrove management strategies.

Keywords: *Arboreal snail, epifaunal species, abundance, water quality, edaphic factors*

1 Introduction

Mangroves, acting as the protectors of our coastlines, represent a distinctive and essential ecosystem in more than 120 tropical and subtropical countries and regions (Alongi 2008). Mangroves, often referred to as the "rainforests of the sea," occupy a small portion of the world's tropical forests yet span approximately 147,000 square kilometers across 118 tropical and subtropical countries, including the Philippines—where they are recognized for their rich biodiversity and vital ecological and socio-economic functions (Asari et al. 2021, Akram et al., 2023). The Philippines has one of the world's longest coastlines at 36,289 km and supports extensive mangrove growth. In Butuan City, around 7,456.52 hectares of mangroves exist within its total land area of 81,728 hectares (Mangadlao 2024). In addition, gastropods are recognized as effective biological indicators of water quality, underscoring their importance in assessing the ecological health of mangrove ecosystems (Cañada 2020, Pogado & de Chavez 2022, Octavina et al. 2019). Recent research has revealed extremely low mangrove diversity in Butuan Bay due anthropogenic activities posing threats to the long-term viability of rehabilitated mangrove forests in Barangay Lumbocan and Barangay Pagatpatan (Goloran et al. 2020). While some studies have shown the return of gastropod species following restoration efforts, long-term data on ecosystem recovery and factors influencing survival are needed to guide conservation initiatives (Salmo et al. 2016). Further research comparing species assemblages in restored regions to those in wild forests is essential to understanding gastropods' habitat needs and ecosystem services, aiding conservation and management efforts to maintain functional variety and resilience in these crucial coastal ecosystems.

The Pagatpatan Mangrove Project, established in 2013 in Barangay Pagatpatan, Butuan City, underscores the vital role of mangrove conservation by acting as a natural buffer against erosion and storm surges while fostering biodiversity and supporting fisheries, thereby contributing to both ecological stability and community livelihood (Alongi 2008). These ecosystems also help mitigate climate change by sequestering carbon and reducing greenhouse gas emissions (Asari et al. 2021). In addition, they provide local communities with valuable livelihood opportunities, including fishing, shellfish harvesting, tourism, fuel, and construction materials (Garcia et al. 2013). Barangays Pagatpatan and Lumbocan were selected as study sites due to their ecological significance within the Agusan River mangrove wetlands. Pagatpatan features a rehabilitated mangrove forest resulting from sustained local conservation efforts, while Lumbocan contains restored mangroves adjacent to a former industrial site. These sites represent contrasting hydrological and land-use conditions that offer important opportunities for understanding ecosystem recovery andmanagement. In accordance with the Department of Environment and Natural Resources' (DENR) environmental policies, specifically DAO 2016-08 which sets water quality guidelines and DAO 2019-11 which outlines procedures for environmental impact assessments, the project aims to investigate the ecological relationships among gastropod communities, mangrove species, and environmental factors such as water quality and soil characteristics. These mangrove ecosystems harbor a wide range of organisms due to their unique geographic position. Gastropods, in particular, are known for their adaptability and reliance on mangroves for food, shelter, and reproduction. Their population dynamics, shaped by competition, ecological tolerance, and environmental variables, influence nutrient cycling, food web structure, and shellfish availability, thereby affecting both ecosystem health and the livelihoods of local communities.

The main objective of this study was to assess the diversity and ecological associations of gastropods in relation to mangrove ecosystems and environmental conditions in Barangays Lumbocan and Pagatpatan, Butuan City.

2 Methodology

Study Area

The study was conducted in two mangrove sites located within Barangays Lumbocan and Pagatpatan, Butuan City, adjacent to the Agusan River (Figure 1). Sampling was conducted across six stations, with three stations established per site. Each station included three quadrats positioned 15 meters apart, while the distance between stations ranged from approximately 50 to 100 meters. In total, 18 quadrats were established across the two sites. All sampling activities were carried out during the first quarter of 2024 (Figure 2). All sampling activities were carried out during the first quarter of 2024. The Lumbocan sites is part of a restored mangrove area influenced by brackish water and situated near an abandoned industrial zone. In contrast, he Pagatpatan stations are within a rehabilitated mangrove zone along the Mantangue River and are directly connected to the freshwater flow of the Agusan River. These locations were selected due to their contrasting hydrological and land-use conditions, which may influence mangrove and faunal characteristics.

Water Physicochemical Parameters

The Horiba U-50 multi-parameter water quality checker was used to measure water parameters directly in situ, including pH, dissolved oxygen (DO), and total dissolved solids (TDS). Measurements were taken along the riverbanks adjacent to each quadrat, with readings replicated three times per station to ensure accuracy and account for potential anomalies. This approach allowed for reliable, real-time assessment of water quality conditions at each sampling station.

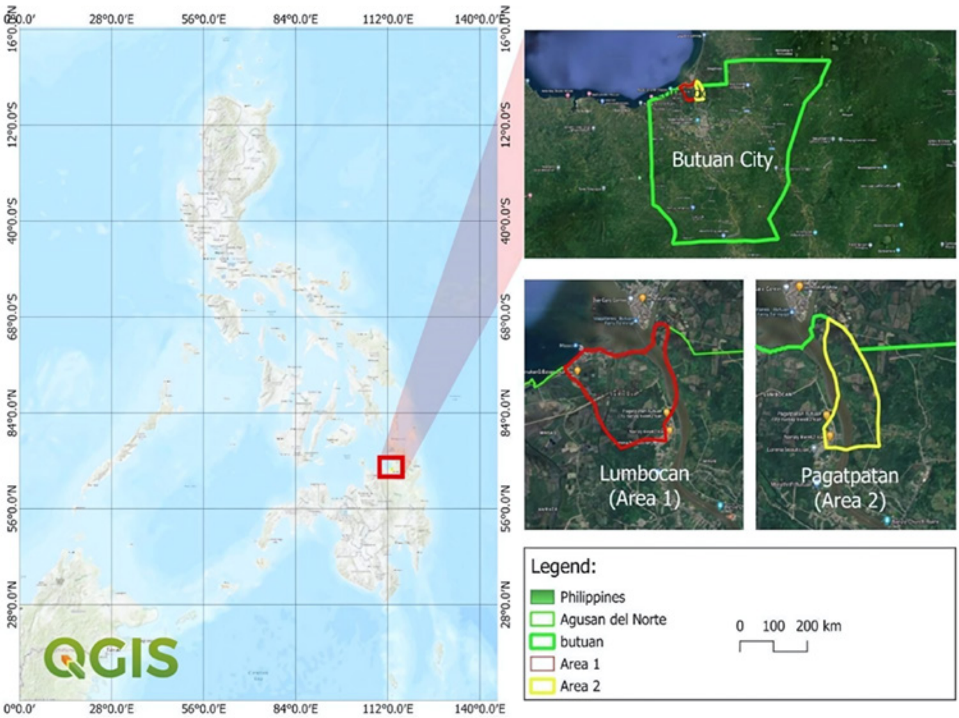

Figure 1. Map of the study area showing the designated sampling sites in Barangays Lumbocan (Area 1) and Pagatpatan (Area 2), Butuan City, Agusan River mangrove wetlands

Collection and Preparation of Soil Samples

Within the established quadrat, relative humdity data was gathered using Extech Instruments' Psychrometer. Approximately 1 kg of soil was collected per quadrat by compositing samples from each corner using a trowel. The composite sample was placed in 15 cm × 15 cm zip-lock bags, and labeled according to their corresponding stations and substations. This procedure was consistently applied across all sampling areas. Finally, the soil samples were sent to the Department of Agriculture for pH, organic matter content, phosphorus, and potassium analysis.

Mangrove Data Collection

In each 3 × 3 m quadrat, all mangrove individuals were also recorded. These quadrats were the same as those used for sediment and gastropod sampling. A transect tape was used to delineate the quadrats, while a straw thread marked the boundaries to ensure systematic evaluation of mangrove characteristics (Figure 2). The diameter at breast height (DBH) of each tree was measured using a tree caliper, and species were identified using the Handbook of Philippine Mangroves by Primavera et al. (2004).

Collection and Identification of Gastropods

Gastropods were collected using the handpicking method. In each quadrat, a 20-minute man-hour effort (three collectors per quadrat) was applied to ensure consistency and reduce sampling bias. While Beasley et al. (2005) suggested that 10 minutes is sufficient to capture an ideal sample size in similar habitats, the sampling duration in this study was extended to 20 minutes to increase the likelihood of detecting less abundant or cryptic species and to enhance species richness accounting. All visible gastropods found on mangrove roots, trunks, and surface sediments were collected during the lowest tide of the day. Specimens were placed in containers filled with 95% ethanol for transport and preservation. Easily identifiable species were counted and immediately released back into their natural habitat to minimize potential mortality. Only representative individuals were retained for photographic documentation and species-level identification. Permission for sample collection was

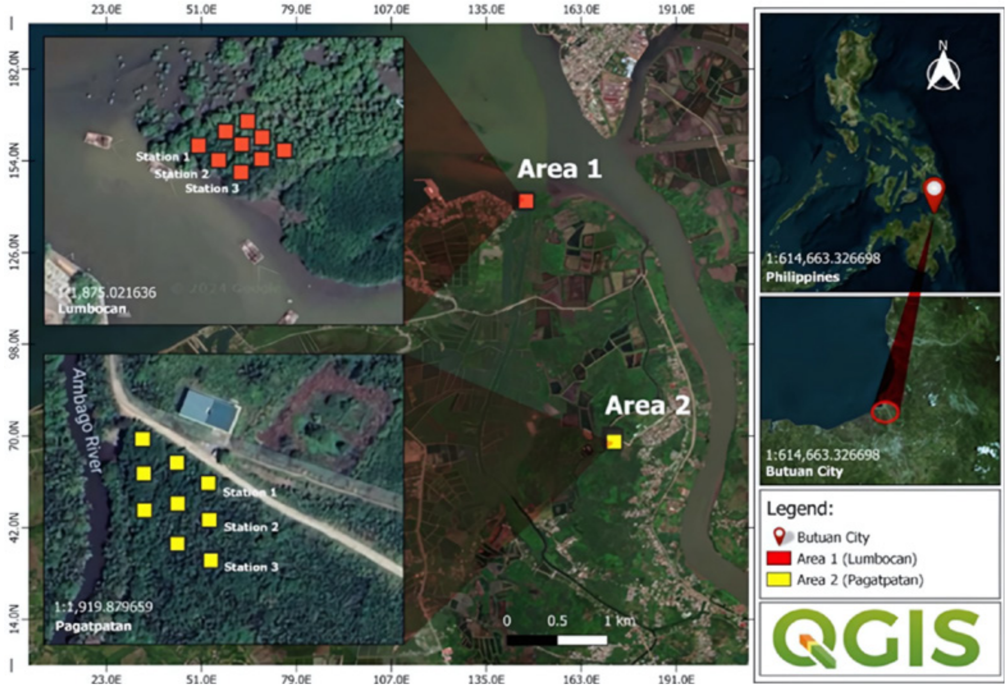

Figure 2. Map showing the layout of 18 sampling quadrats established across the mangrove habitats of Barangays Lumbocan and Pagatpatan, Butuan City

granted at the barangay level, as the local government units have jurisdiction and direct oversight of the wetlands. Specimens were transported to the Caraga State University laboratory, where they were cleaned, photographed, and identified using standard taxonomic references, including Poppe (2008a, 2008b, 2010, 2011), Springsteen and Leobrera (1986), Abbott and Morris (2001), and Laureta and Marasigan (2000).

Data Analysis Tools

Diversity indices including species richness, abundance, dominance, Simpson diversity, Shannon diversity, and evenness were calculated to assess the overall diversity status of the mangrove ecosystem. Abundance data of the identified gastropod species were analyzed using Principal Component Analysis (PCA) to compare and highlight differences among stations. The Unweighted Pair Group Method with Arithmetic Mean (UPGMA) was employed to cluster sampling sites based on similarity, allowing the identification of distinct ecological groupings. Finally, Canonical Correspondence Analysis (CCA) was used to explore the relationships between environmental variables and species composition, providing insights into ecosystem interdependencies. All statistical analyses were conducted using the Paleontological Statistics Software Package (PAST), version 4.10.

3 Results and Discussion

Water and Soil Physicochemical Features

The physicochemical characteristics of water exhibited notable variation between the mangrove wetlands of Barangays Pagatpatan and Lumbocan (Table 1). Both sites showed relatively stable values for key parameters such as pH (6.71-7.04), total dissolved solids (0.43-1.3 g/L), and salinity (0.4-1.03 ppt). However, dissolved oxygen (DO) levels varied significantly, ranging from 6.18 to 9.57 mg/L in Lumbocan and reaching unusually high levels of 21.43 to 23.29 mg/L in Pagatpatan.DO levels in Lumbocan fall within the expected range for brackish waters, sufficient to support most aquatic organisms, including oxygen-sensitive species. In contrast, the elevated DO values in Pagatpatan are atypical and may reflect either specific environmental conditions or potential measurement anomalies (Susi & Ladesma 2020). A likely explanation is oxygen supersaturation caused by photosynthetic activity from phytoplankton blooms in nutrient-rich waters, particularly during daylight hours (Mitra 2013). Given Pagatpatan's proximity to agricultural and residential areas, nutrient runoff or wastewater discharge could have enhanced primary productivity, contributing to elevated DO concentrations.

According to DAO 2016-08, the observed pH values fall within the slightly acidic to neutral range, suitable for brackish ecosystems. The measured TDS levels are also within the normal range for brackish water and suggest good water quality with low ionic concentration. Salinity at both sites remained at the lower end of the brackish spectrum, and these consistently low values may lead to shifts in species composition and increased mangrove flora diversity (Cuenca-Ocay et al. 2023).

The low salinity readings further reflect strong freshwater input, consistent with both sites' proximity to the Agusan River. Sampling during the first quarter of 2024 coincided with frequent rainfall events, likely contributing to surface runoff and elevated river discharge. Field observations revealed that Pagatpatan, which is directly connected to the Agusan River and bordered by residential and agricultural areas, exhibited consistently lower salinity than Lumbocan. This suggests stronger freshwater influence in Pagatpatan due to combined natural(e.g.,rainfall, river flow) and anthropogenic (e.g.,agricultural and urban runoff) inputs. In contrast, Lumbocan appeared more influenced by estuarine mixing, maintaining relatively higher salinity and moderate DO levels. These site-specific differences highlight the complex interactions shaping water quality in mangrove ecosystems (Khondoker et al. 2023).

Soil properties were stable across the two barangays, with notable organic matter and potassium level variations. In Barangay Lumbocan, soil pH remained stable between 7.43 and 7.62, supporting essential nutrient availability and mangrove species. Conversely, in Barangay Pagatpatan, the pH ranged from 5.24 to 5.56, indicating slight acidity typical in mangrove habitats (Hossain & Nuruddin 2016).

Organic matter (OM) concentration in Lumbocan was relatively low ranged from 1-1.57, suggesting limited nutrient retention, while Pagatpatan exhibited significantly higher levels ranged from 8.9 to 9.07, enhancing soil vitality but posing risks of eutrophication (Bashir et al. 2021). The quantity of organic matter present in soil is commonly utilized as an indicator of its quality, influencing factors such as microbial activity, water retention, and nutrient availability within mangrove ecosystems (Hamada et al., 2024). Higher levels of organic matter typically correspond with greater diversity in gastropod populations (Strong et al. 2007). This organic material serves as both a food source and habitat for these mollusks, emphasizing its importance in supporting their abundance and overall ecosystem health. Phosphorus (P) levels ranged from 12.33 to 16.67, impacting mangrove growth and potentially influenced by community inputs. Stable relative humidity favored mangrove growth and gastropod presence, while potassium variation between the barangays indicated varied nutrient availability, influencing mangrove health and associated species (Akram et al. 2023) (Table 1).

Mangrove Accounts

The mangrove ecosystems of Barangays Lumbocan and Pagatpatan exhibited noticeable differences in species assemblages, structural maturity, and associated gastropod diversity. A total of five mangrove species were recorded across both sites: *Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Bruguiera cylindrica,* and *Nypa fruticans*.

In terms of species richness, both sites hosted the same number of mangrove species (n=5); however, species abundance and structural maturity varied. Lumbocan demonstrated a higher relative

Table 1. Physicochemical characteristics of water and soil in the two mangrove habitats of Butuan City

Parameters	Lumbocan			Pagatpatan			DAO 2016-08
	S1	S2	S3	S1	S2	S3	
Water pH	6.71±0	7±0.05	7.04±0.16	6.85±0.14	6.82±0.02	6.88±0.04	6.0-9.0
DO	9.57±0	9.57±0.49	6.18±0.29	23.29±1.22	21.62±0.55	21.43±0.47	2
TDS	0.51±0	0.70±0.04	1.3±0.26	0.43±0.06	0.52±0.31	0.67±0.29	110
Salinity	0.4±6.8	0.53±0.29	1.03±0.21	0.37±0.06	0.4±0.26	0.53±0.21	-
Soil pH	7.47±0.15	7.62±0.06	7.43±0.15	5.56±0.11	5.56±0.44	5.24±0.47	-
OM	1.17±0.40	1±0.26	1.57±0.50	8.9±0	9.03±0.06	9.07±0.12	-
P	12.33±2.31	12.67±1.53	14.67±1.53	16.67±1.53	15.67±6.03	14.33±2.52	-

abundance of *Avicennia marina*, which also had the largest average diameter at breast height (DBH) of 21.18 cm. This suggests a more mature and established mangrove community. In contrast, Pagatpatan was dominated by younger *Rhizophora* species (*R. apiculata* and *R. mucronata*), characterized by smaller DBH values and denser sapling populations, indicating ongoing rehabilitation and regrowth processes.

The ecological structure in Lumbocan characterized by older *A. marina* stands supported a richer gastropod community, with this species hosting up to 14 associated gastropod taxa. In comparison, *R. apiculata* and *R. mucronata* in both sites hosted fewer gastropod species, potentially due to their younger age or less complex root structures (Al-Khayat & Alatalo 2021). *Bruguiera cylindrica* and *Nypafruticans* were sparsely distributed and occurred in lower abundance at both sites. Their limited pneumatophore development and less favorable microhabitats may explain the reduced gastropod association (Abbasi et al. 2022).

Diversity of Mangrove-associated Gastropods

The distribution of gastropod species varied across sampling stations in Barangays Lumbocan and Pagatpatan. *Cerithidea quoyii* (family Potamididae) was consistently recorded at all stations, indicating its probable broad habitat adaptability. Similarly, *Vittina coromandeliana, V. jovis, V. turrita*, and *V. waigiensis* from the Neritidae family were commonly observed across both sites (Table 2; Figure 3). The widespread presence of these species suggests broad ecological tolerance, likely attributed to their euryhaline and eurythermal traits, as well as resistance to sedimentation, as noted in earlier studies (Velasco et al. 2018).

Neritodryas dubia (family Neritidae) exhibited the lowest occurrence among all sampled stations, suggesting that it may have more restrictive ecological requirements compared to other neritid species present in the area. Its limited distribution could be attributed to narrower substrate preferences, specific dietary needs, or sensitivity to fluctuating environmental conditions such as salinity or sedimentation (Craine et al., 2012). In contrast to more generalist species like *Vittina* spp., *N. dubia* may depend on microhabitats with stable physicochemi-cal characteristics, which were less prevalent or fragmented within the sampled mangrove zones.

Furthermore, interspecific competition may have contributed to its reduced abundance. Coexisting *Neritidae* species with overlapping niches may exert competitive pressure through resource exploitation or spatial dominance, further constraining the habitat availability for *N. dubia* (Tan & Clements 2008). These findings underscore the importance of examining biotic interactions and fine-scale habitat characteristics when interpreting gastropod diversity patterns in mangrove ecosystems. The limited presence of *N. dubia* could serve as an indicator of subtle environmental heterogeneity or localized habitat degradation, warranting further investigation into its ecological role and conservation status within Philippine mangroves.

The presence and abundance of gastropod species in Barangays Lumbocan and Pagatpatan reflect the overall ecological condition of the mangrove ecosystems. The widespread occurrence and notably higher abundance of *Cerithidea quoyii*

Table 2. Composition of gastropod species across the two mangrove habitats in Butuan City

		Lumbocan			Pagatpatan		
Species	**Family**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Cerithidea quoyii (Hombron & Jacquinot, 1848)	Potamididae	+	+	+	+	+	+
Stenomelania plicaria (Born, 1778)	Thiaridae	+	-	-	+	+	+
Vittina coromandeliana (G. B. Sowerby I, 1836)	Neritidae	+	+	+	+	+	+
Vittina jovis (Récluz, 1843)	Neritidae	+	+	+	+	+	+
Vittina turrita (Gmelin, 1791)	Neritidae	+	+	+	+	+	+
Vittina waigiensis (Lesson, 1831)	Neritidae	+	+	+	+	+	+
Vittina variegata (Lesson, 1831)	Neritidae	-	-	-	+	+	+
Pythia savaiensis (Mousson, 1869)	Ellobiidae	-	-	-	+	+	+
Neritodryas dubia (Gmelin, 1791)	Neritidae	+	-	-	-	+	-
Faunus ater (Linnaeus, 1758)	Pachychilidae	+	+	+	-	+	+

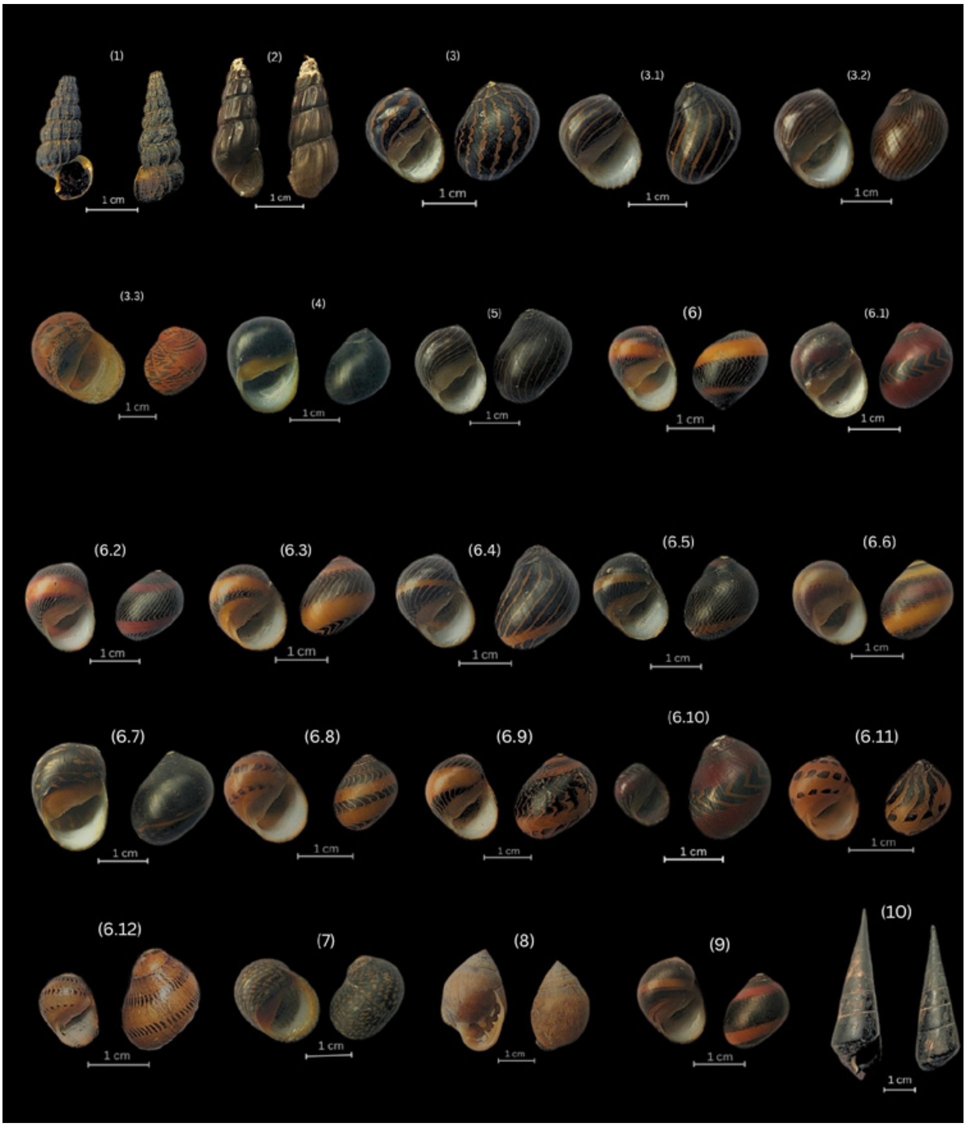

Figure 3. Species of gastropods in Pagatpatan and Lumbocan Mangrove Wetland, Butuan Bay. 1.*Cerithidea quoyii*; 2. *Stenomelania plicaria*; 3-3.3. *Vittina coromandeliana*; 4. *Vittina jovis*; 5. *Vittina turrita*; 6-6.12. *Vittina waigiensis*; 7. *Vittina va-riegata*; 8. *Pythia savaiensis*; 9. *Neriodryas dubia*; 10. *Faunus ater.*

in Pagatpatan suggest favorable environmental conditions that support active nutrient cycling and organic matter decomposition, a key indicators of mang-rove ecosystem functionality (Canencia et al. 2022, Reid et al. 2013). As a detritivore, *C. quoyii* likely benefits from high litterfall and organic enrichment, particularly in areas with strong freshwater input and sediment deposition.

Although *Semisulcospira plicaria* contributed to overall gastropod diversity, its low abundance in Barangay Lumbocan may indicate habitat constraints such as limited food resources, unsuitable sediment texture, or increased competition. *Vittina coromandeliana*, which was highly abundant in both sites, played a consistent ecological role in detritus processing, highlighting its resilience and broad habitat tolerance (Tan & Clements 2008). Other *Neritidae* species like *V. jovis, V. turrita, V. waigiensis, V. variegata,* along with *Pirenella savaiensis* and *Neritodryas dubia,* added to the diversity of the gastropod community by occupying different microhabitats and contributing to nutrient turnover (Abbasi et al. 2022, Craine et al. 2012).

The high abundance of *Faunus ater,* particularly in Pagatpatan, emphasizes its ecological significance. As a sediment-dwelling detritivore, its population density may indicate healthy sediment quality and sustained nutrient flow within the ecosystem (Velasco et al., 2018). Continued monitoring of these gastropod communities is essential for detecting early shifts in ecological balance, especially under pressures from urban runoff, pollution, or habitat alteration.

Barangay Pagatpatan exhibited higher species richness compared to Lumbocan, suggesting a more complex ecosystem with diverse microhabitats that support species with narrower ecological niches (Table 3). In contrast, Lumbocan demonstrated greater average species abundance, which may imply a less diverse but more evenly structured community. This contrast highlights differing ecological strategies: Pagatpatan appears to support a wider range of specialized species, while Lumbocan sustains fewer species in greater numbers, possibly due to more stable or less disturbed habitat conditions.

The diversity metrics of gastropods across the mangrove wetlands of Barangays Pagatpatan and Lumbocan reveal distinct ecological profiles between the two sites (Table 3). Pagatpatan exhibited higher species richness (6.78) and greater diversity, as indicated by its Shannon index (1.47) and Simpson index (0.71). These values suggest a more heterogeneous and compositionally diverse community, potentially driven by habitat complexity, varied sub-strate conditions, or stronger freshwater influence due to the site's proximity to the Agusan River (Kovalenko et al. 2012).

In contrast, Lumbocan recorded higher species abundance (681 individuals) but lower species richness (5.67). This indicates that while fewer species were present, they occurred in larger numbers (Magurran 2021). Evenness was slightly higher in Lumbocan (0.72) than in Pagatpatan (0.66), sug-gesting a more balanced distribution of individuals across species, with no single taxon overwhelmingly dominant. Pagatpatan's slightly lower evenness, combined with higher richness, reflects a community with more species but greater variability in their representation, which is common in structurally complex and resource-diverse environments (Magurran 2021, Moreno & Rodriguez 2010).

Dominance values were relatively similar between sites (0.32 in Lumbocan and 0.29 in Pagatpatan), indicating that neither community was heavily skewed toward a single dominant species. However, when interpreted alongside richness and diversity metrics, Pagatpatan's lower dominance and higher diversity point to a more functionally diverse ecosystem.

Distinctive Composition of Gastropods in the Two Mangrove Habitats

The Principal Component Analysis (PCA) provided key insights into the distribution patterns of 10 gastropod species across the mangrove wetlands of Lumbocan and Pagatpatan (Figure 4). PCA 1 alone accounted for 65.47% of the total variation, indicating its strong explanatory power in differentiating species assemblages between the two sites. The most significant contributor to PCA 1 was *Faunus ater* (loading value= 0.89796), suggesting its dominance in Lumbocan and its strong association with local environmental conditions. This implies that *F. ater* is well-adapted to the physicochemical and habitat features (Nair et al. 2024) specific to Lumbocan, possibly benefiting from favorable sediment quality and nutrient availability.

In contrast, *Cerithidea quoyii* exhibited the most negative loading on PCA 1 (-0.43309), indicating an inverse relationship with the conditions favoring *F. ater.* This could reflect *C. quoyii's* broader ecological tolerance or preference for microhabitats less dominated by *F. ater* (Zvonareva & Kantor 2016), such as areas with higher organic matter,

Table 3. Diversity of gastropod species in Pagatpatan and Lumbocan Mangrove wetlands in Butuan City

Parameters	Lumbocan	Pagatpatan
Richness	5.67	6.78
Abundance	681.00	486.00
Dominance	0.32	0.29
Simpson Diversity	0.68	0.71
Shannon Diversity	1.35	1.47
Evenness	0.72	0.66

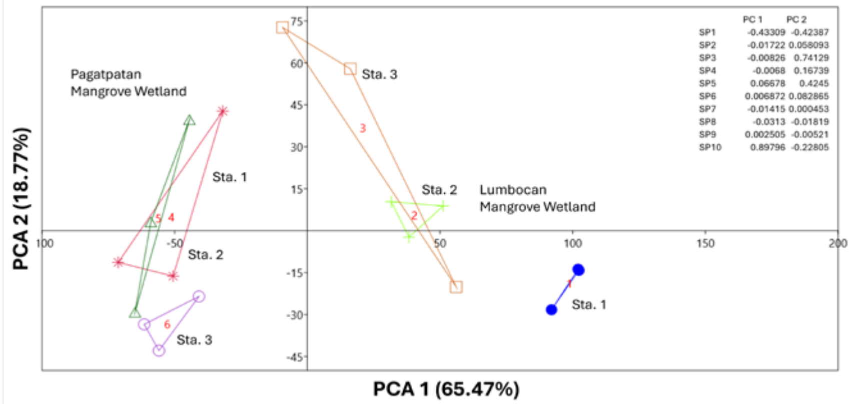

Figure 4. Principal Component Analysis showing the distinct characteristics of stations relative to the abundance of gastropods in the two mangrove habitats of Butuan City

different salinity gradients, or root structures less densely occupied by other species.

The differences observed in species abundance between the two barangays highlight distinct ecological dynamics. While Lumbocan exhibited higher species abundance and notable dominance by *F. ater,* Pagatpatan supported a more evenly distributed assemblage with higher species richness. The dominance of *F. ater* in Lumbocan suggests not only its adaptability but also the ecological resilience of this mangrove habitat, which may be driven by reduced environmental stressors or well-established sediment and hydrological conditions.

Understanding the roles of key species like *F. ater* is crucial, as they contribute significantly to nutrient cycling, detritus processing, and overall ecosystem functioning. Their abundance and spatial distribution can also serve as reliable indicators of environmental change (Fullerton et al. 2021). Thus, PCA not only highlights species-level associations but also underscores the importance of maintaining diverse and balanced gastropod communities to support mangrove ecosystem health.

Association of Mangrove-associated Gastropods Towards Soil and Water

Physicochemical Parameters

The Canonical Correspondence Analysis (CCA) revealed significant associations between gastropod species and measured environmental variables across the mangrove wetlands of Barangays Lumbocan and Pagatpatan (Figure 5). The first canonical axis (CCA 1), explained 68.68% of the total variance, indicating that most of the variation in gastropod distribution is strongly influenced by environmental factors.

Among the species examined, *Vittina waigiensis* showed a strong positive association with several environmental variables, including water availability, soil pH, relative humidity, total dissolved solids (TDS), and salinity. This suggests that *V. waigiensis* thrives in areas with well-defined physicochemical gradients. Conversely, *Faunus ater* demonstrated minimal correspondence with the measured environmental variables. Its broad ecological tolerance and high adaptability likely explain its stable occurrence across diverse conditions, supporting previous findings on its euryhaline and sediment-tolerant nature (Raganas & Magcale-Macandog 2020).

The second canonical axis (CCA 2), which captured 16.31% of the total variance, highlighted more specific relationships. Species such as *Semisulcospira plicaria*, *Vittina coromandeliana*, and *V. jovis* were positively associated with elevated soil phosphorus levels, implying nutrient-specific habitat preferences (Almadin et al. 2020). In contrast, *Cerithidea quoyii, V. waigiensis, V. variegata,* and *Pirenella savaiensis* displayed negative correlations with dissolved oxygen, potassium, and organic matter. This inverse relationship suggests these species may be more prevalent in areas with relatively lower concentrations of these soil parameters.

Association of Gastropods Towards Mangrove Species

Figure 6 illustrates the relationships between gastropod species and mangrove tree abundance across Barangays Lumbocan and Pagatpatan using Canonical Correspondence Analysis (CCA). CCA 1 explained 71.27% of the total variation, indicating a strong correspondence between gastropod distribution and mangrove structure in the area.

A notable pattern observed is the inverse relationship between *Rhizophora mucronata* and gastropod species such as *Vittina turrita, Neritodryas dubia*, and *Faunus ater*. This suggests that in areas where *R. mucronata* is less abundant or experiencing growth limitations, these gastropods tend to be more prevalent. Such an association may reflect a compensatory ecological role of gastropods in nutrient cycling, detritus decomposition, and maintaining trophic balance in microhabitats with sparse canopy cover or reduced structural complexity. Gastropods also utilize available mangrove structures for refuge and substrate, while their feeding and burrowing behaviors enhance nutrient availability and support ecosystem function (Ebadzadeh et al. 2021).

In contrast, CCA 2 accounted for a smaller

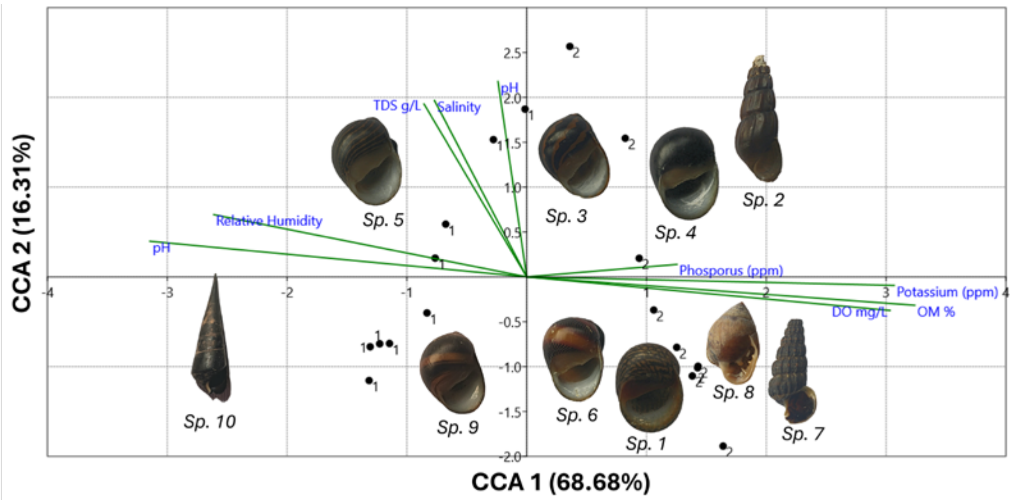

Figure 5. Canonical Correspondence Analysis showing the association of gastropods, and the water and soil parameters in the two mangrove habitats of Butuan City. Sp. 1. *Cerithidea quoyii;* Sp. 2. *Stenomelania plicaria;* Sp. 3. *Vittina coromandeliana;* Sp. 4. *Vittina jovis;* Sp 5. *Vittina turrita;* Sp. 6. *Vittina waigiensis;* Sp. 7. *Vittina variegata;* Sp. 8. *Pythia savaiensis;* Sp. 9. *Neriodryas dubia;* Sp. 10. *Faunus ater.*

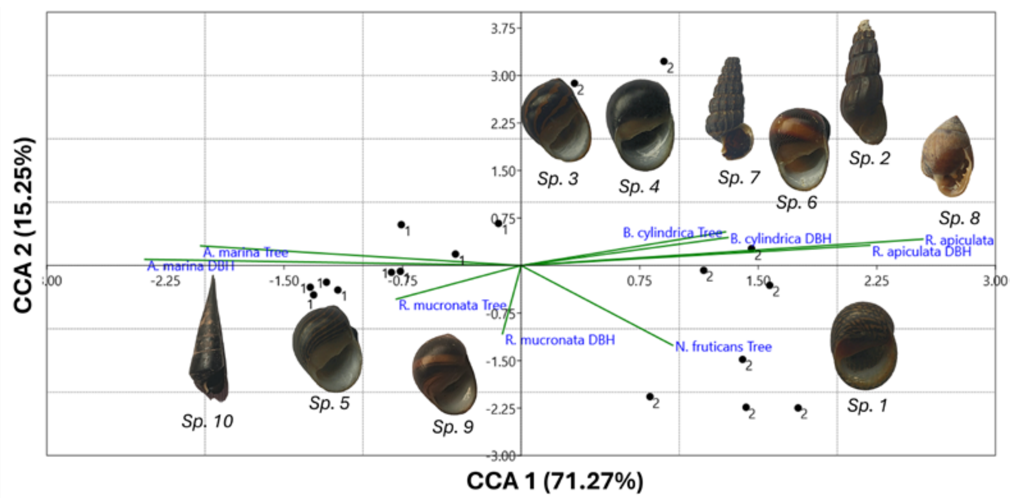

Figure 6. Canonical Correspondence Analysis showing the association of gastropods and mangrove features in the two mangrove habitats of Butuan City. Sp. 1. *Cerithidea quoyii*; Sp. 2. *Stenomelania plicaria*; Sp. 3. *Vittina coromandeliana*; Sp. 4. *Vittina jovis*; Sp 5. *Vittina turrita*; Sp. 6. *Vittina waigiensis*; Sp. 7. *Vittina variegata*; Sp. 8. *Pythia savaiensis*; Sp. 9. *Neriodryas dubia*; Sp. 10. *Faunus ater*.

proportion of variation and revealed weaker species–mangrove associations, as indicated by the disper-sed distribution of species in the ordination space. Despite this, species such as *Semisulcospira plicaria, Vittina coromandeliana, V. jovis, V. waigiensis, V. variegata,* and *Pirenella savaiensis* showed po-sitive correlations with the growth and abundance of *Rhizophora apiculata* and *Bruguiera cylindrica* (Imamsyah et al. 2020). These mangrove species likely provide preferred microhabitats, offering shade, detritus-rich sediments, and root complexity that support gastropod settlement, foraging, and reproduction. This underscores a mutually reinforcing ecological relationship, where gastropods benefit from structural shelter and substrate, while their presence contributes to sediment aeration and nutrient turnover (Lee et al. 2019).

Additionally, *Cerithidea quoyii* demonstrated a strong association with *Nypa fruticans* (Hilmi et. Al 2022), a mangrove palm typically found in the muddy, low-lying fringes of mangrove zones. This rela-tionship may be mutually beneficial, with *C. quoyii* utilizing the soft sediments around *N. fruticans* for burrowing and detritus feeding, while in return aid-ing nutrient cycling and organic matter breakdown in areas where *N. fruticans* thrives (Alongi 2008). The observed patterns emphasize the importance of conserving both gastropods and their associated mangrove hosts, given their functional interdependence and contributions to the resilience and health of coastal ecosystems.

4 Conclusion

The study demonstrates a strong influence of environmental variables on gastropod diversity and distribution in Barangays Lumbocan and Pagatpatan. Pagatpatan exhibited higher gastropod species richness, diversity, and evenness, which were linked to elevated organic matter and more heterogeneous mangrove habitats. In contrast, Lumbocan, though richer in abundance, was dominated by a few species, particularly *Faunus ater*.

These findings imply that mangrove ecosystem health and biodiversity can be effectively assessed through gastropod community structure. Therefore, conservation and management strategies should prioritize maintaining mangrove habitat heterogeneity and minimizing anthropogenic stressors such as nutrient runoff. The use of gastropods as ecological indicators offers a cost-effective and locally adaptable tool for monitoring environmental quality and guiding rehabilitation efforts in coastal wetlands.

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6 Statement of Conflict of Interest

MV Elvira, who serves on the JESEG Editorial Board, had no involvement in the review of this manuscript to preserve objectivity in the evaluation process. Furthermore, the authors affirm that there are no financial or personal relationships that could be perceived as potential conflicts of interest in relation to this work.

7 Author Contribution

DJR Malinao, MPL Nicmic, and TC Abrea Jr contributed to the conception and design of the study, analysis and interpretation of data, as well as the drafting and revision of the manuscript for significant intellectual content. ARV Galolo was involved in the drafting and revision of the manuscript for significant intellectual content and approved the final version to be published. L Calagui participated in the study's conception and design and approved the final manuscript. SL Paz contributed to the conception and design of the study, drafting and revision of the manuscript for significant intellectual content, and approved the version for publication. MV Elvira was involved in the conception and design of the study, data analysis and interpretation, drafting and revision of the manuscript for significant intellectual content, and gave final approval for the version to be published.

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SHORT COMMUNICATION

Gastropod Community and Coliform Contamination in Langihan Lagoon: A Call for Improved Sanitation Management

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ABSTRACT

Freshwater ecosystems in urban areas are increasingly threatened by biological contamination and declining water quality, posing risks to biodiversity and public health. Survey and inventory of gastropods in Langihan Lagoon, Butuan City, Philippines and the examination of snail's coelomic contents were conducted. Total coliform counts and basic physico-chemical features of the lagoon were also assessed. Results revealed a total of 1,389 freshwater snail individuals from five species (*Pomacea canaliculata, Gyraulus* sp., *Melanoides maculata,* and *Mieniplotia scabra*) from four families. Artificial shedding and dissection of the snails' body cavity showed the absence of any cercaria. However, sporocysts, hookworm eggs and two species of bdelloid rotifers (*Rotaria* sp. and *Philodina* sp.) were isolated from *P. canaliculata.* Physico-chemical parameters from all study stations were within the standard limits except the high salinity and low DO levels during dry season and the low pH during wet season assessment. Total coliform tests indicate the highest probable presence of coliform (>1,6000 MPN/100mL) from all stations across seasons which imply high risk of exposure to coliform-associated diseases when in contact with the lagoon water. Improved management of the lagoon to improve water quality and reduce the coliform contamination in the area is recommended.

Keywords: *Man-made lagoon, pollution, public market, bioindicators, invasive species, Caraga*

Aquatic ecosystems play a critical role in maintaining ecological balance, supporting biodiversity, and providing essential services such as food supply, water filtration, and recreation. However, these systems are increasingly threatened by anthropogenic pressures, including pollution, habitat modification, and resource overexploitation. The discharge of pollutants into freshwater environments can disrupt biotic integrity by altering community structure and function, often resulting in disease, behavioral anomalies, and the loss or migration of sensitive species (Emmanuel et al. 2008). These disruptions may cascade through trophic levels, affecting not only microorganisms and invertebrates but also fish and other higher aquatic organisms.

Lagoons, particularly those situated in urban landscapes, serve as transitional aquatic systems that are vulnerable to these stressors. Freshwater lagoons—whether natural or artificial—are typically shallow and influenced by variable hydrological and salinity regimes, precipitation-evaporation dynamics, and inputs from surrounding land use (Boadella et al. 2021, Kjerfve 1994). While man-made lagoons are often constructed for flood control, sewage retention, or water stabilization (Boadi & Kuitunen 2002), their bio-physicochemical health is frequently neglected. Due to their enclosed nature, they are especially prone to siltation, eutrophication, salinity fluctuations, and oxygen depletion (Esteves et al. 2008, Rodrigo et al. 2013), making them potential hotspots for environmental degradation and public health risks.

Langihan Lagoon, located in the heart of the public market in Butuan City, Philippines, exemplifies such a scenarioConstructed in the 1970s as part of flood mitigation efforts for the lowland areas of Langihan, Bading, Pagatpatan, and Poyohon (Magcuro et al. 2024), the lagoon has since evolved into a multipurpose waterbody used for fishing, livestock grazing, bathing, and informal waste disposal (personal observation). In its early years, the lagoon supported a diverse community of freshwater fish, which were harvested and sold by residents of nearby communities. Today, however, only a few non-native species tolerant of turbid and oxygen-poor conditions—such as *Channa striata, Pterygoplichthys* sp., and *Oreochromis niloticus*—are occasionally captured through electrofishing (BarangaynCaptain, personal communication).

Growing concerns over the lagoon's declining water quality are further exacerbated by its continued exposure to human and animal waste from surrounding establishments. This raises the potential risk of waterborne diseases, especially through contact with lagoon water during recreational or domestic activities. Yet, despite its socio-ecological importance, Langihan Lagoon remains poorly studied, par-ticularly in terms of biological indicators and microbial contamination.

Gastropods are key bioindicators in freshwater ecosystems due to their sensitivity to environmental changes and their ecological role in nutrient cycling, food webs, and disease transmission (Estaño & Jumawan 2023, Gianelli et al. 2016). They also serve as intermediate hosts for parasites that can affect both humans and animals, making them important for understanding zoonotic disease risks. Depending on their species and abundance, gastropods may indi-cate ecosystem productivity, pollution levels, or the presence of parasitic infections (Fitria et al. 2023).

This study aims to assess the ecological and public health condition of Langihan Lagoon by examining the diversity and parasitic potential of its gastropod community, alongside key physicochemical parameters and indicators of water contamination. The findings are intended to provide a scientific basis for improving lagoon management, pollution mitigation, and community awareness in urban freshwater settings.

The study was conducted through a single intensive sampling effort, carried out over three consecutive days for each index season—dry (June) and wet (December) of 2018. Permission to collect for gastropod samples were secured from Barangay Obrero key officials. Three cluster stations were established in the Langihan Lagoon based on anthro-pogenic activity were established, each with three substations 30 m apart (Figure 1). Cluster 1 station is nearest to Tabuan Market and Bus Terminal. This area is most often cleared from aquatic macrophytes. The Cluster 2 station is situated across the bridge crossing S. Calo St. and has the least number of households fronting the lagoon with the banks stabi-lized by concrete. Cluster 3 station is nearest the dense population of houses fronting the lagoon. A belt transect with triplicate 30-m distances was established within each cluster station to assess the biophysico-chemical features of the lagoon. Extensive sampling was done for three consecutive days for a representative month for two index seasons (May for southwest monsoon/dry season; December for northeast monsoon).

Routine physico-chemical parameters (salinity, temperature, conductivity, total dissolved solids (TDS), pH, and dissolved oxygen (D.O.) concentration) were measured (Hanna HI98194) multi-meter tester in each cluster station every morning (7am-10am) for three consecutive days for every index season. Water samples for microbial analyses were collected for each cluster station from 7:00 am-9:00 am. Multiple tube fermentation technique (MTFT) was used to identify the most probable number (MPN) of bacteria present in the sample following APHA (1992). The presumptive test for coliform bacteria was done initially on single strength lauryl sulfate tryptose (LST) broth. The most probable number (MPN) of coliform bacteria per 100 mL sample were determined from the MPN table for 100, 10^{-1} and 10^{-2} dilutions.

Prior to collection of snails, permission was secured from the local government of Barangay 18, Obrero, Butuan City. Gastropods were collected along the 30 meter stretch of each sampling station with five jabs/kicks using 0.3 m wide D-frame dip net, with a 500-μm mesh size. The collected snails were stored individually in vials with lagoon water and brought to the laboratory and were documented and identified using standard keys (Brown 1994, DBL-WHO 1998). For each species per station, at least ten individuals were viewed and examined

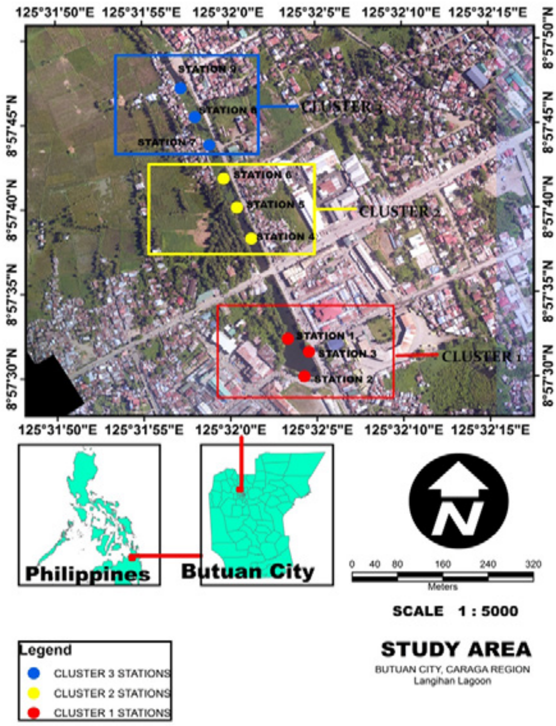

Figure 1. Map of study stations in Langihan Lagoon, Butuan City, Philippines

in the laboratory to survey the coelomic contents of their body tissues following Opisa et al (2011). Indices of biodiversity such as species richness, abundance, dominance, evenness and Shannon's diversity of gastropods from each cluster station, as well as multivariate analyses were computed using PAST software. Comparison of physico-chemical data between index seasons was done using T-test, while difference between cluster stations was done using One-way ANOVA. Principal Component Analyses (PCA) and Bray Curtis index of similarity were performed to compare possible relationships between physico-chemical and abundance of gastropods across cluster stations and seasons.

Based on DAO 08-2016, lagoons are classified as Class C-mainly for growth of fish, fishing, and irrigation. Following the standards for this classification, the water collected from all the study stations was within the standard limits except for the high salinity (0.52 mg/L) and low DO (1.29 mg/L) for both dry and wet seasons and low pH during the wet season (Table 1). By PCA, temporal influence can be seen affecting parameters such as D.O., salinity, pH, temperature and conductivity as these were higher during the dry season except for TDS which was observed higher during the wet season (Figure 2).

Typical of freshwater lagoons, the low elevation of Langihan Lagoon often experiences altered freshwater inflows, with estuarine water from Butuan Bay often seeping into the area and this may have contribute to the rather higher salinity which exceeded the standard limit (<0.5 ppt) for freshwaters and is observed during months with low precipitation. Although Langihan Lagoon is not an estuary, several factors may explain its slightly elevated salinity. Effluents from nearby markets likely in-troduce salts from food waste and cleaning agents, a common source of salinity in urban freshwater systems (Kida et al 2024). Evapoconcentration during dry seasons can further concentrate dissolved salts due to high evaporation rates (America et al. 2020). Additionally, while not directly connected to the sea, saltwater intrusion from rising sea levels or hydrological shifts may also contribute, as seen in similar coastal lagoons (Su et al 2025).

Salinity acts as a limiting factor in the distribution of organisms as dilution and evaporation influences faunal distribution through increased stress, decrased reproduction and survival rates (Palmer et al. 2008). The dissolved oxygen in all stations was

Table 1. Water Physico-chemical parameters and Most Probable Number (MPN) coliform index using MTFT of Langihan Lagoon from both dry and wet season of 2018

Physico-chemical Parameters	**DAO 08-2016 Standard Class C water**	**Cluster 1**		**Cluster 2**		**Cluster 3**		**Overall Mean**
		Dry	Wet	Dry	Wet	Dry	Wet	
pH	6.5-9.0	7.41±0.39	5.08±0.21*	7.38±0.16	5.16±0.08*	7.10±0.26	5.20±0.03*	6.22 mg/L
Temperature	32-350C	29.31±1.18*	27.14±0.46	29.24±1.30*	27.47±0.37	28.47±0.51*	27.37±0.46	28.17°C
Conductivity	<1,500 µs/cm	1103.55±23.03*	632.67±29.25	1094.11±26.6*	724.41±70.4	1072.85±10.7*	823.44±149.46	908.505 µs/cm
TDS	< 1,000 mg/L	240.26±31.80	326.15±30.9*	309.94±60.05	377.67±31.6*	342.04±76.90	439.00±58.53*	339.18 mg/L
Salinity	< 0.5 ppt	0.55±0.17*	0.31±0.02	0.72±0.28*	0.36±0.02	0.78±0.30*	0.43±0.07	0.525 ppt
DO	5 mg/L	3.55±2.52*	0.26±0.13	3.06±2.32*	0.30±0.18	0.33±0.24*	0.25±0.10	1.29 mg/L
MPN coliform index	APHA 1992							
Total Coliform	1000 MPN/100 mL	>1,6000	>1,6000	>1,6000	>1,6000	>1,6000	>1,6000	>1,6000MPN/100mL **

*P≤ 0.05. ; **Highest probable presence of total coliform; Data presented as Mean± SEM

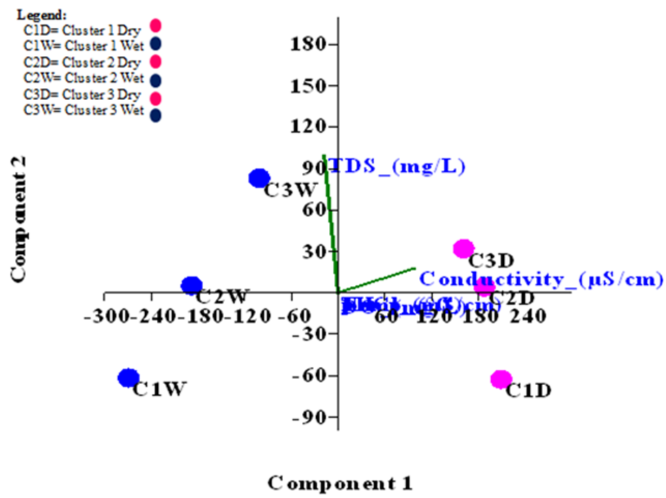

Figure 2. Principal components analysis (PCA) of physico-chemical parameters for both dry and wet seasons

below the standard limit of minimum of 5 mg/L). T-test analyses show that DO is significantly low, even critically lower during the wet season. Low DO levels could lead to low species diversity as very few organisms have tolerance to low DO often resulting in the disruption of reproductive cycle and even the dominance of certain species which best tolerate certain poor water quality parameters. The sparse vegetation and shade surrounding the lagoon could also be an important consideration as it also increases water temperature and consequently decreases DO. The high level of pH may be due to geographical location of Langihan lagoon as receiver of sewage wastes from the local public market, bus terminals, and homes through a system of pipes. Conversely, industrial discharges containing alkaline substances, such as detergents or lime, can raise the pH, making the water more basic. These alterations in pH can have detrimental effects on aquatic ecosystems, affecting the health and diversity of aquatic organisms (Baker et al. 1990).

Freshwater gastropods, such as *Pomacea canali-culata*, exhibit remarkable resilience to low dissolved oxygen (DO) levels and polluted conditions due to several physiological and behavioral adaptations. Notably, *P. canaliculata* possesses a dual respiratory system comprising both gills and a lung-like structure, enabling it to utilize atmospheric oxygen when aquatic oxygen levels are insufficient. This adaptation allows the species to thrive in hypoxic or stagnant waters where other organisms may not survive (Wang et al. 2025, Qin et al. 2022).

Water samples from both dry and wet seasons showed extremely high total coliform levels (>16,000 MPN/100 mL), exceeding safe limits for human use (APHA, 1992). Although the study did not distinguish thermotolerant or fecal coliforms, such high counts strongly suggest fecal contamination, likely due to direct discharge of domestic, livestock, and market waste into the lagoon. Total coliforms, while not all pathogenic, serve as indicators of microbial pollution and signal compromised water quality (UNEP/WHO, 1996; AS/NZS 4276.6, 2007).

This level of contamination poses serious public health risks. Communities using the lagoon for bathing, washing, or fishing may be exposed to waterborne diseases, especially vulnerable populations like children and the elderly. Persistent microbial pollution can also disrupt aquatic life and food safety, threatening both ecological and human health. The findings underscore the urgent need to assess and mitigate contamination in water bodies within urban settlements.

Addressing coliform contamination requires immediate and long-term interventions. In the short term, public awareness and restricted use of contaminated lagoon water should be prioritized. In the long term, improvements in sanitation infrastructure, proper waste disposal, and regular water quality monitoring are essential. These actions are vital not only for reducing health risks but also for sustaining the lagoon as an urban ecological resource.

A total of 1,389 freshwater snail individuals represented by five species from four families were identified (Table 2). These five snail species were known vectors of zoonotic diseases and were notorious for tolerance under stressful water conditions. The golden apple snail, *Pomacea canaliculata* was the most abundant snail collected from the lagoon. Interestingly, this species also had the widest spectrum of commensals and parasites surveyed from its digestive cavity with *Angiostrongylus cantonensis* that causes eosinophilic meningitis (angiostrongyliasis) being the most important (Damborenea et al. 2017, Lv et al. 2009). Moreover, *P. canaliculata* is also reported as a passive host for *Mycobacterium ulcerans* that cause chronic skin ulcers such as Buruli ulcer disease (Marsollier et al. 2004). *Gyraulus* sp. is a hermaphroditic planorbid snail which mostly prefer habitats with slow moving or stagnant waters like ponds, lakes and swamps (Beran & Horsák 2011). *Melanoides maculata* is known pathogenic member of family Thiaridae with long periods of survival and was also found to harbor *A. cantonesis* (Tujan et al. 2016). *Radix rubiginosa* are known to survive long periods of time without oxygen and various fluctuations in water temperatures and is found to be a vector for *Schistosoma incognitum* (Bunnag et al. 1983) and Fasciola gigantica (Corea et al. 2010). The horny operculum of *Mieneplotia scabra* enables it to close its shell for protection against drought and predators. It is also a known vector for *Haplorchis taichui* causing haplorchiasis (Chontananarth & Wongsawad 2010), paragonimiasis, and echinostomiasis (Sriaroon et al. 2015).

Species richness in sampling stations was rather uniform for the two index seasons of collection, nonetheless, there is low dominance value while evenness is approaching 1.0 in all stations (Table 3). Shannon_H values were low and comparable between the dry and wet seasons for each cluster, probably because very few species (five only) were observed and are consistently observed across seasons. *Pomacea canaliculata* was found abundantly and was consistently observed in all of the stations during the dry and wet season of the year. T-test comparison indicates that gastropods were significantly abundant during the dry season in Clusters 1 ($p=0.024$) and 2 ($p=0.035$) whereas gastropods were significantly abundant in Cluster 3 ($p=0.023$) during the wet season probably due to the heavy growth of water hyacinth in the area. Clusters 1 and 2 obtained a high index of similarity (Figure 3) and are closely related due to its overall high density of population.

Out of five species, only three species (*P. canaliculata, M. maculata,* and *R. rubiginosa*) were further examined in the laboratory due to viability of live samples for the assay. Of the three snails examined, only one gastropod (*P. canaliculata*) was found harboring unidentified eggs of trematodes but

Table 2. Gastropods identified from Langihan Lagoon, Butuan City, Philippines

Family	Snail species	Common Name	Medical importance
Ampullariidae	*Pomacea canaliculata*	Apple snail	Vector for angiostrongyliasis; Passive host for *Mycobacterium ulcerans*
Planorbidae	*Gyraulus* sp.	Ram horn snail	----
Thiaridae	*Melanoides maculata*	Mahogany trumpet snail	Vector for angiostrongyliasis
Lymnaeidae	*Radix rubiginosa*	Big ear radix	Vector for echinostomiasis, cercarial dermatitis, vector of *Schistosoma incognitum* and *Fasciola gigantica*
Thiaridae	*Mieniplotia scabra*	Thiara	Vector for haplorchiasis, Paragonimiasis, and echinostomiasis

Table 3. Diversity indices of gastropod collected in the area from both dry and wet season of 2018

	Cluster 1		Cluster 2		Cluster 3	
	Dry	Wet	Dry	Wet	Dry	Wet
Taxa_S	3	3	3	3	3	3
Dominance_D	0.357	0.383	0.340	0.336	0.353	0.384
Simpson_1-D	0.643	0.616	0.659	0.663	0.646	0.616
Shannon_H	1.063	1.025	1.088	1.094	1.067	1.016
Evenness_e^H/S	0.95	0.939	0.989	0.995	0.968	0.920
Abundance	336*	236	306*	245	36	230*

no mature cercaria were observed (Table 4; Figure 4). An unidentified species of hookworm egg was isolated from *P. canaliculata* only during the dry season from the Cluster 1 station. The presence of ho-okworm eggs indicates the presence of parasitic nematode adults.

The presence of hookworm eggs and sporocysts confirm that *P. canaliculata* could harbor a wide spectrum of organisms that by facultative or obligate manner, could cause diseases of medical importance (Damborenea et al. 2017). No known snail vector for schistosomiasis (i.e. *Oncomelania quadrasi*) was collected from Langihan Lagoon.

The findings of this study reveal that Langihan Lagoon is experiencing significant ecological stress, as evidenced by persistently low dissolved oxygen levels, elevated salinity, acidic conditions during the wet season, and extremely high total coliform counts across all stations. These conditions indicate both chemical and microbial pollution, largely stemming from unregulated waste disposal and untre-ated effluents entering the lagoon from nearby markets, households, and livestock areas.

The abundance of pollution-tolerant gastropods such as *Pomacea canaliculata*, coupled with the presence of hookworm eggs and sporocysts, further underscores the potential of this ecosystem to act as a reservoir for zoonotic pathogens. These biological and physico-chemical indicators provide a compelling picture of a degraded aquatic environment with immediate and long-term implications for public health and biodiversity.

Given its location and multifaceted use by surrounding communities, Langihan Lagoon represents a critical urban ecosystem that requires urgent attention. The results of this study underscore the need for integrated lagoon management strategies that include the establishment of proper sanitation infrastructure, regulation of waste disposal, and continuous water quality monitoring. Public health interventions—such as awareness campaigns about the risks of direct contact with lagoon water—should be prioritized.

Future research should include the identification of thermotolerant coliforms and pathogenic parasites to further clarify the lagoon's role in disease transmission. Additionally, ecological restoration efforts, such as the reintroduction of aquatic vegetation and bioremediation, may help improve water quality and ecological function. Sustainable management of Langihan Lagoon is not only vital for environmental protection but also

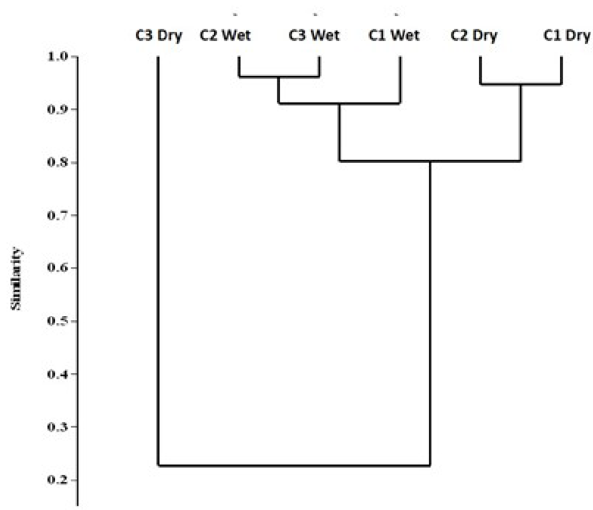

Figure 3. Cluster Analysis using Bray Curtis index of similarity for gastropods collected in cluster stations (C1,C2,C3) in Langihan Lagoon for two index (Dry and wet) seasons of 2018.

Table 4. Survey of coelomic inhabitants in gastropods of Langihan Lagoon

	Dry Season	**Wet Season**
Pomacea canaliculata	Unidentified hookworm egg, unidentified sporocyst, *Rotaria* sp., *Philodina* sp.	*Rotaria* sp., *Philodina* sp.
Melanoides maculata	none	none
Radix rubiginosa	none	none

for safeguarding the health and well-being of the communities that surround it.

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Statement of Conflict of Interest

To ensure impartiality in the evaluation of this article, one of the authors, J.C. Jumawan, who serves as the Editor-in-Chief of JESEG, had no involvement in the review process or editorial decision-making for this submission.

Author Contribution

A.A. Dollano and A.A. Libot conducted the study, collected data, performed the analysis, and contributed to the original draft. J.C. Jumawan conceptualized the study design, supervised the project, and handled manuscript editing. J.C. Jumawan and A.A. Libot co-wrote the manuscript draft for the journal. All authors reviewed and approved the final version of the article.

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Assessing Land Cover Change and Flood Exposure from River Embankment Using GIS and Remote Sensing for Sustainable River Management: A Case Study of the Tumampit River in Ampayon, Butuan City, Philippines

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ABSTRACT

This research assessed the environmental and social effects of the Tumampit River Embankment Project in Ampayon, Butuan City, Philippines, built between 2018 and 2022 to address flooding and riverbank erosion. With GIS-based analysis, land cover transformation and flood exposure were evaluated based on the comparison of 2018 (pre-embankment) and 2023 (post-embankment) data of an 82.13-hectare subwatershed with 728 structures in 2018, rising to 881 in 2023. Findings indicated a great conversion of natural land cover to built-up land. An estimated 73,500 m² of agricultural land and 42,800 m² of forest cover were converted into urban use during 2018-2023, while built-up land increased by 111,000 m². In spite of flood control, built-up areas continued to be the most flood-exposed land cover and were exposed to as much as 376,870 m² under the 100-year return period with the embankment in existence. Flood simulation indicated decreased areas of inundation for all but the highest hazard levels. In the 5-year event, the embankment lowered low-level flood exposure by 4,080,000 m². Under the 100-year event, exposure to moderate and high flood levels increased within urban areas, indicating spatial real location of flood hazards. In 2023, 303 structures were still exposed to low-level floods under the 5-year event and 549 structures under the 100-year event, compared to 498 and 619 structures, respectively, without the embankment. Although the embankment was effective in curbing flood extent in certain locations, it also had an effect on land cover conversions and continued exposure of developed areas to higher flood levels. The results highlight the intricate trade-offs between urban growth and ecosystem integrity, reminding us to incorporate land use planning and ecological measures into future flood control policies.

Keywords: *Flood Control, Land Cover, River Embankment, Flooding*

1 Introduction

River systems are the lifeblood of landscapes, providing essential ecological, economic, and social services that promote human well-being and environmental sustainability (Tiwari et al. 2003). Nevertheless, these dynamic systems face growing pressures from anthropogenic activities like urbanization, agricultural expansion, and infrastructure development. These alterations interfere with natural flow regimes, sediment transport, and riparian habitats, compromising river health and long-term community resilience (Zamroni et al. 2020).

For the Philippines, rivers play a unifying central function in supporting livelihoods, heritage, and environmental security. The tension between conservation and development is particularly difficult in the case of highly populated or fast-growing areas (Salvaña & Arnibal 2019). Sustainable river management means, therefore, having a profound sense of such trade-offs so that infrastructural interventions do not compromise ecological integrity.

Among the most prevalent river engineering structures are embankments, constructed for flood mitigation and riverbank stabilization. Although effective in minimizing near-term flood risks, these structures can radically change river dynamics and create unforeseen environmental and socio-economic impacts (Ogilvie et al. 2025). For example, flow velocity changes and channelization tend to downgrade aquatic habitats and biodiversity, with disturbance of sediment transport possibly leading to downstream erosion and decreased fertility of the floodplains (Wohl et al. 2019, Jähnig et al. 2023, Wang et al. 2021).

Urbanization further exaggerates these effects by substituting vegetated floodplains with impermeable coverings, increasing runoff and flood susceptibility. To counter, combined measures such as river restoration and spatial surveillance are becoming increasingly prominent as vital mesures of developing resilient urban landscapes (Voulvoulis et al. 2024, Calheiros et al. 2021).

Flooding is one of the Philippines' most enduring risks, and it continues to pose a significant threat in low-lying and riverine zones such as Butuan City. To counter recurrent flood occurrences and safeguard infrastructures of vital importance, structural countermeasures have been executed. Among these interventions is the Tumampit River Embankment in Barangay Ampayon, Butuan City—a 780.80 m. concrete embankment constructed from 2018 to 2022 to regulate flooding and shore protection along a critical stretch of the Tumampit River.

Although intended for protection, embankments can promote land cover change and modify flood exposure patterns. Vegetated strips can be transformed into urbanized areas, hence enhancing localized risk. Still, after-construction assessments of em-bankment projects within the Philippines are rare—particularly studies that apply spatial analysis to determine environmental and disaster-related effects.

This research aims to bridge that gap by examining land cover change and flood exposure along the Tumampit River Embankment. Employing GIS and remote sensing, the study contrasts spatial data across pre- and post-embankment years (2018 and 2023), analyzes land use change, simulates flood scenarios, and evaluates the performance of the embankment in flood risk reduction. It aims to provide insights for more sustainable and evidence-based river management.

Particularly, the research seeks to examine changes in land cover in the 821,300 sq.m. subwatershed to determine the stability or change of urban, agricultural, and vegetated zones; Quantify flood exposure under various return periods (5-year and 100-year cases) with and without a river embankment; and measure the reduction of flood-prone areas by the embankment and evaluate the residual vulnerability of built-up areas in spite of structural mitigation.

The research targets an 821,300 m² subwatershed along a 3,997.35-meter reach of the Tumampit River. Land cover detection is for urban, tree, crop, and rangeland. Flood exposure of each land class is estimated under simulated 5-year and 100-year return periods. The performance of the embankment is evaluated by comparing flood extents with and without the embankment.

However, the research confines itself to physical and spatial information and does not incorporate socio-economic or demographic vulnerability estimation. It employs existing models of floods from 2017 and does not take future climate projections into account. The analysis applies the ideal per-formance of the embankment and does not take structural depreciation or maintenance matters into consideration. Moreover, whereas built-up exposure is estimated, damage assessment and ground-truthing are outside the framework of the study.

2 Methodology

Study Area

Figure 1 shows the study area at Tumampit River, Barangay Ampayon, Butuan City. It has an area of 821,300 square meters or 82.13 hectares. In this study, we only focus on the sub-watershed area where the Tumampit River is located, with a river length of 3,997.35 meters.

Landcover Change and Analysis

The landcover maps of 2018 and 2023 were

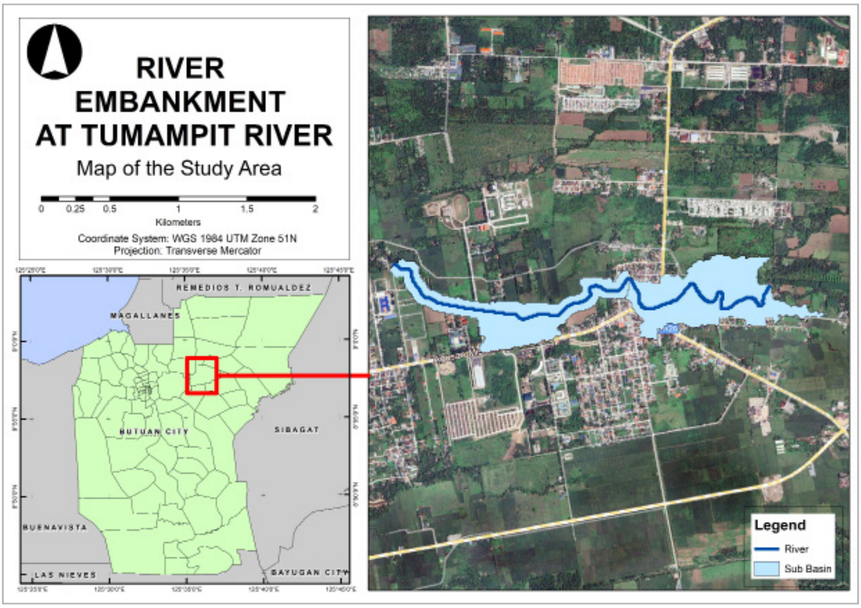

Figure 1. Map of the Study Area along Tumampit River in Brgy. Ampayon, Butuan City, Philippines

downloaded in July 2023 from the ArcGIS Living Atlas of the World (https://livingatlas.arcgis.com/en/home). It provides a detailed, accurate, and timely LULC map of the world derived from ESA Sentinel-2 imagery at 10m resolution. This data results from a collaboration between Esri, Impact Observatory, and Microsoft (Esri, Impact Observatory, & Microsoft, 2024). These landcover maps are generated using a deep learning AI land classification model that uses a massive training dataset of billions of human-labeled image pixels developed by the National Geographic Society. The LULC maps were clipped using the boundary of the Tumampit subwatershed. In 2018, it comprised trees, crops, built area, and rangeland, while in 2023, it comprised trees, crops, built area, rangeland, and bare ground.

The area of each class in LULC maps was computed and subtracted to determine the class changes from 2018 to 2023. For better analysis, the 2018 LULC was intersected with the 2023 LULC to identify the conversion of each class.

Watershed Delineation

The delineation procedure follows the three major processes: Terrain Preprocessing, Project Set-Up, and Basin Processing. This was conducted to determine the boundaries of the watershed. The boundaries were identified by the topography of the study area, including the elevation, slope, and direction of the land surface.

Terrain Pre-processing

The reconditioned DEM enabled the elevation of the stream cells to be lowered, which was created through the utilization of the digitized river shapefile. One of the complications with the watershed cells is that some cells can trap water in a single cell, as each cell differs in elevation. The solution to this is the fill sink function. This study defined the elevation value of higher-elevation cells within the watershed's boundary. Flow direction followed this step, where each value of the grid in the cell was computed to know the direction of the steepest descent from the given cell. Next, the Flow Accumulation function allowed the calculation of the flow accumulation grid containing the gathered number of cells upstream of a particular cell. Another necessary function to implement was the stream definition which is a parameter that classifies streams in a cell that follows the detected flow accumulation value greater than the user value. The smaller values will have a greater number of delineated subbasins. The same grid code was assigned to cells that fall on a specific segment. The function of Stream Segmentation was employed to create the grid for the specific stream segment. With each stream segment identified, Catchment Grid Delineation was also conducted to delineate each stream segment's subbasin. The computed catchment grid was then used for the next function. The Catchment Polygon Processing allows the catchment grid feature to be converted into a catchment polygon. With this function, a vector layer of the subbasins was created. Drainage Line Processing is another function that converts the stream grid into a line feature class. The feature class line has an individual identifier for where it is located. With this, another stream vector layer was created. The last function done as part of the major procedure was the Adjoint Catchment Processing. In this process, the drainage line and catchment processing data were used as input to combine the upstream catchment.

Project Set-up

This step in the delineation procedure was setting the project point, which is situated at the downstream outlet. This point was the project area for developing the Hydrologic Model using the HEC-HMS. Through HEC-GeoHMS, the upstream subbasin and rivers that are linked to the project point were delineated as well.

Basin Processing

This procedure is necessary for the polishing of the sub-basin delineation. In this step, the delineated sub-basins were enhanced. The option for dividing the sub-basins into smaller ones was also given. This function allowed the researchers to understand the hydrologic response at particular locations connected to the project area.

Analysis of Inundated Area

The lower Padsan River basin exhibits modThe Interferometric Synthetic Aperture Radar (IfSAR) Digital Elevation Model (DEM) was used as the input terrain data in HEC-RAS for simulating flood inundation. IfSAR-derived elevation data is widely used in flood modeling due to its high spatial resolution and ability to capture topographic variations critical for hydrologic and hydraulic analyses, even in vegetated or cloudy areas (Zandbergen, 2008). Several studies have demonstrated the reliability of IfSAR for delineating flood-prone areas and analyzing drainage networks, especially in large-scale or data-scarce regions (Sanders, 2007).

The Hydrologic Engineering Center River Analysis System (HEC-RAS), developed by the U.S. Army Corps of Engineers, is a robust, widely used modeling tool capable of performing one- and two-dimensional hydraulic simulations. It is particularly effective for assessing the impacts of river engineering structures, such as embankments and levees, on water surface elevations and flood extents (Horritt & Bates, 2002; Teng et al., 2017). HEC-RAS allows users to simulate flood behavior under different scenarios, evaluate structural interventions, and generate spatial outputs like flood depth, velocity, arrival time, and inundation dura-tion. This makes it well-suited for assessing how river embankment projects alter flood patterns and exposure in surrounding areas. The setup of the HEC-RAS interface for this study is shown in Figure 2.

The Elevation model incorporating the embankment was prepared in GIS by mosaicking the raster with the actual characteristics of the embankment. Shown in Figure 3 is the image showing the elevation model before(left) and after(right) the river embankment project.

The 5-year and 100-year rain return periods (T) were used to calculate the watershed's discharge. A 5-year return period rain event corresponds to a 20% probability of occurrence in any given year, while a 100-year return period event has a 1% annual probability. These return periods represent moderate and extreme rainfall scenarios, respectively, and were used to model flood inundation extents under varying conditions. The rain values (in millimeters) were based on the Rainfall Intensity Duration Frequency (RIDF) by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAG-ASA) (Table 1). As shown in the table, the 5-year return period is associated with a cumulative precipitation of 175.2 millimeters. Moreover, the 100-year return period rainfall data, with a cumulative total reaching 308.6 millimeters over 24 hours, indicates an extreme precipitation event that poses a high risk of widespread flooding.

The Hydrograph Output Interval in HEC-RAS (located under Unsteady Flow Analysis of the Computation Settings) refers to how frequently the model saves and displays results in the HEC-DSS file and Mapper, not how often internal calculations are performed. While the engine may compute flows every few seconds or minutes to maintain numerical accuracy, setting a 1-hour output interval is a strategic choice. It reduces data volume, keeps file sizes manageable, and supports smooth hydrograph visualization by averaging ungaged inflows over a

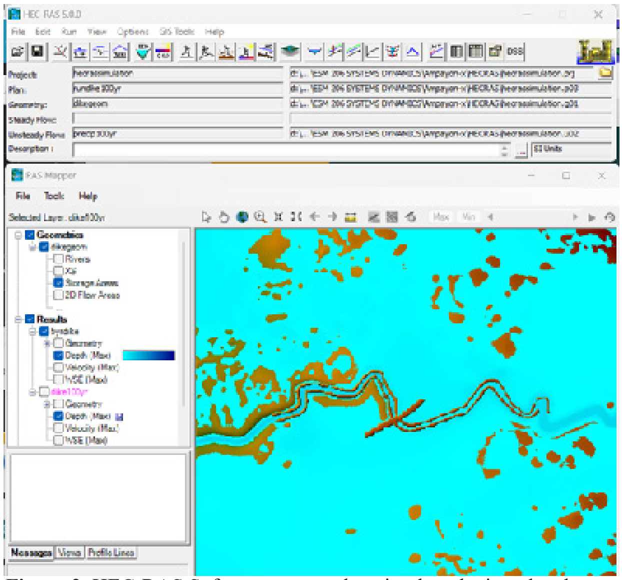

Figure 2. HEC-RAS Software was used to simulate the inundated area

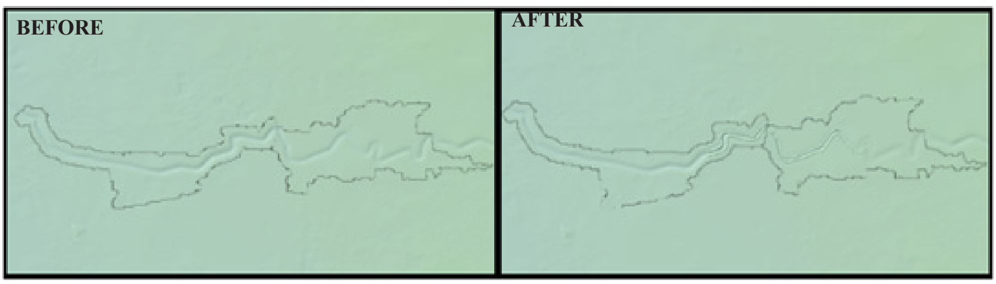

Figure 3. The image shows the elevation model of the area before and after the river embankment project.

Table 1. The level of flood hazard classification used in the study is based on its flood depth.

T(yrs)	5 mins	10 mins	15 mins	1 hr	2 hrs	3hrs	6 hrs	12 hrs	24 hrs
5	11.9	23.9	27.4	52.9	71.2	81.3	104.6	142.6	175.2
100	19.6	39.2	44.6	85.8	114	129.5	167.1	259.1	308.6

centered time window. This interval is particularly appropriate for planning studies where hourly data resolution is sufficient to capture flow behavior without overwhelming post-processing tasks (USACE, 2023). The setup of the interface of the HEC-RAS Model is shown in Figure 4.

Flood depth classifications in this study follow widely accepted thresholds used in hazard mapping and risk assessment. The classifications, as shown in the table, correspond to varying levels of impact on human safety and infrastructure. Depths of up to 0.5 m are generally considered low hazard but can still hinder pedestrian mobility, especially for vulnerable populations (ThinkHazard! Methodology, 2021). Floodwaters between 0.5 m and 1.0 m begin to pose risks to building integrity and vehicular movement (Vu, 2010). In the range of 1.0 m to 1.5 m, the potential for structural damage significantly increases, as supported by flood vulnerability studies that document a steep rise in damage ratios within this depth band (Xue et al., 2020). Depths exceeding 1.5 m are typically classified as high hazard, with increased risk to life, particularly in densely populated or poorly prepared areas (Vu, 2010; ThinkHazard! Methodology, 2021).

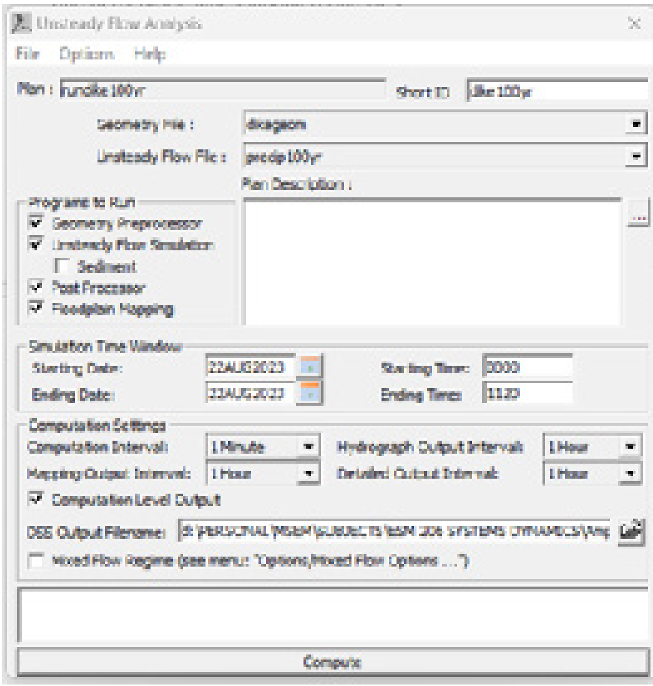

Figure 4. The interface of the HEC-RAS for Hydraulic Simulations.

3 RESULTS AND DISCUSSION

Land Cover Change and Analysis

Crops had the highest area in 2018 with 337,400 sq.m.; however, it is less with 39,600 sq.m. in 2023 (Figure 5). Also, negative changes can be observed in trees and rangeland, with an area of 80,600 sq. m. and 1,5400 sq. m., respectively. This means that trees, crops, and rangeland in 2018 were converted into other classes in 2023. On the other hand, an additional 111,000 sq.m. were added to the built area from 2018 to 2023.

There are 326,700 sq.m. for built area, 251,100 sq.m. for crops, 7,800 sq.m. for rangeland, and 36,600 sq.m. for trees, which were not converted to other classes (Figure 6; Table 3). Furthermore, 42,800 sq.m. of trees and 73,500 sq.m. of crops were converted into built-up areas. With 326,700 sq.m. of unchanged built area, urban zones exhibit stability despite flood risks. However, the shift of 73,500 sq.m. of crops and 42,800 sq.m. of trees to built-up areas underlines the pressure for urban expansion.

Flood Inundation Scenario Simulation

Table 4 summarizes the resulting flood levels, indicating the corresponding area in square meters for each hazard level. The 5-year scenario reduced values, showing a difference of 4,080,000 sq. m. between the two scenarios in the low level. Similarly, for the other levels, the values also decreased in the scenario with the embankment. The 100-year scenario also decreased values for all categories except the low flood level, although the difference is relatively minor. In general, the results demonstrated that the flood levels, in terms of the inundated area, experienced a decreasein the scenario with the embankment, a finding that aligns with previous studies on the effectiveness of structural flood mitigation measures (Wang et al. 2018, Lo et al. 2021). These findings reinforce the observed effectiveness of the Tumampit River embankment in mitigating flood exposure. Based on the results, there were 728 buildings within the boundary of the study area in 2018 and 881 buildings in 2023. These building footprints were initially obtained from the Phil-LiDAR-1 - Hazard Mapping of the Philippines using LiDAR and updated during the Geo-informatics for the Systematic Assessment of Flood Effects and Risks for a Resilient Mindanao (GeoSAFER) project datasets, which provide high-resolution spatial data for flood hazard mapping and exposure assessment. The tabulation of the affected buildings in 2018 under the 5-year and 100-year

Table 2. The level of flood hazard classification used in the study is based on its flood depth.

Depth Value	Hazard Level
0.01 to 0.5	Low
0.51 to 1.0	Medium
1.01 to 1.5	High
1.5 above	Very High

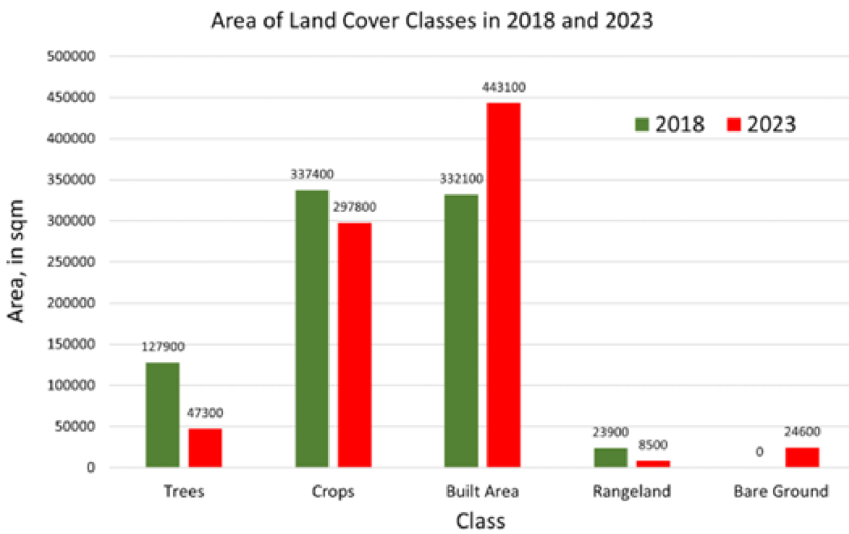

Figure 5. Area of land cover classes in 2018 and 2023.

flood hazard scenarios (Table 5 &6).

On the other hand, the tabulations of the results of the affected buildings of the year 2022 using the 5-year and 100-year flood hazards are shown in Tables 7 and 8, respectively.

Landcover Classes Affected by the Inundated Area

Based on the simulation without embankment, land cover classes in 2018 affected by 5-year and 100-year floods were computed and tabulated (Table 9 & 10). Based on the result, the Built Area is more exposed to flood in 5-year and 100-year scenarios, with an area of 229,130 and 274,392 square meters, respectively. While the least affected class was the rangeland, with an area of 17,257 sq.m. Moreover, crops are more exposed to very high flood levels for the two scenarios, with an area of 34,759 and 46,978 sq.m.

By computing land cover classes (Table 11 and 12), the results show that the built area is still the most exposed class to flood in the 5-year and 100-year scenarios, with an area of 215,662 and 376,870 sq.m., respectively.

Figure 7 is a bar graph showing the area affected by flood without an embankment (in 2018) and with the presence of an embankment (in 2023) for a 5-year scenario. In low flood levels, more built areas were affected in 2018 than in 2023. However, there are more affected areas in 2023 for the rest of the flood levels. For the 100-year flood scenario (Figure 8), built areas are more exposed to all flood levels in 2023 than in 2018. This suggests that, based on spatial modeling alone, built areas remain exposed to flooding even with the presence of an embankment. The visual comparisons in the figures indicate that the embankment had a varying impact on different flood levels. However, these results are derived from geospatial analysis and modeling and do not account for the actual physical condition, design, or performance of the embankment on the ground. Field validation, structural assessment reports, or flood impact studies would be necessary to confirm the effectiveness of the embankment in real conditions.

The Tumampit River Embankment Project is effective in minimizing the flood area under common and moderate flood intensities.

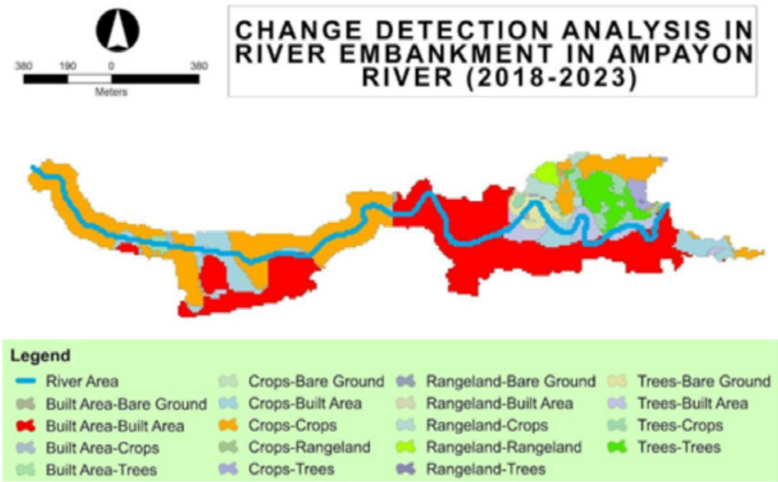

Figure 6. Change detection analysis in the river embankment.

Table 3. Changes of classes from 2018 to 2023 based on the change detection analysis.

2018	2023	Change	Area
Built Area	Bare Ground	Built Area-Bare Ground	1,900
Built Area	Crops	Built Area-Crops	3,100
Built Area	Built Area	Built Area-Built Area	326,700
Built Area	Trees	Built Area-Trees	400
Crops	Crops	Crops-Crops	251,100
Crops	Built Area	Crops-Built Area	73,500
Crops	Trees	Crops-Trees	9,800
Crops	Bare Ground	Crops-Bare Ground	2,300
Crops	Rangeland	Crops-Rangeland	700
Rangeland	Crops	Rangeland-Crops	14,900
Rangeland	Rangeland	Rangeland-Rangeland	7,800
Rangeland	Bare Ground	Rangeland-Bare Ground	600
Rangeland	Trees	Rangeland-Trees	500
Rangeland	Built Area	Rangeland-Built Area	100
Trees	Crops	Trees-Crops	28,700
Trees	Built Area	Trees-Built Area	42,800
Trees	Trees	Trees-Trees	36,600
Trees	Bare Ground	Trees-Bare Ground	19,800

Table 4. The area (in sq. m.) of specific hazard levels for 5-year and 100-year rain return flood hazards, with consideration of having and without embankment.

Hazard Level	5-Year (in sq. m.)		100-year (in sq. m.)	
	Without Embankment	With Embankment	Without Embankment	With Embankment
Low	17,190,000	13,110,000	17,230,000	17,390,000
Moderate	1,070,000	310,000	1,620,000	1,550,000
High	480,000	90,000	820,000	810,000
Very High	760,000	110,000	1,530,000	1,540,000

Table 5. Tabulation of affected buildings for the 5-year rain return flood hazard in the year 2018.

2018 Building Footprints		
5-year Flood Hazard	**Without Embankment**	**With Embankment**
Hazard Level	*No. of Household Affected*	
Low	407	249
Moderate	20	38
High	11	11
Very High	10	10
Not Flooded	280	420
Total	728	728

Table 6. The tabulation of affected households for the 100-year rain return flood hazard in the year 2018

2018 Building Footprints		
100-year Flood Hazard	**Without Embankment**	**With Embankment**
Hazard Level	*No. of Household Affected*	
Low	495	425
Moderate	35	131
High	25	48
Very High	28	22
Not Flooded	145	102
Total	728	728

Table 7. The tabulation of affected households for 5-year rain return flood hazard in the year 2023.

2023 Building Footprints		
5-year Flood Hazard	**Without Embankment**	**With Embankment**
Hazard Level	*No. of Household Affected*	
Low	498	303
Moderate	10	32
High	3	8
Table 7. The tabulation of affected households for 5-year rain return flood hazard in the year 2023.	10	10
Very High	15	11
Not Flooded	355	527
Total	881	881

Table 8. The tabulation of affected households for 100-year rain return flood hazard in the year 2023.

2023 Building Footprints		
100-year Flood Hazard	**Without Embankment**	**With Embankment**
Hazard Level	*No. of Household Affected*	
Low	619	549
Moderate	25	166
High	13	44
Very High	22	23
Not Flooded	202	99
Total	881	881

Nevertheless, flood threats in urban centers still exist, especially during rare events. The further encroachment of built areas into traditional natural and agri-cultural areas adds exposure and decreases the natural flood-modulating ability of the ecosystem. Geospatial modeling supports a reduction of inundated areas due to embankment, but, as per the paper, based only on models and has not yet been tested with field-based hydrological measurements or comparison of historical flood occurrences. Additional research involving ground-based flood data, structural performance analysis, and participatory risk assessment is advised to evaluate the long-term performance of the embankment and to inform sustainable land use and disaster risk reduction policy.

Table 9. Area of affected land cover classes (in sq. m.) for 5-year flood without embankment scenario.

Flood Level	Trees	Crops	Built Area	Rangeland
Low	74,574	132,410	188,743	15,878
Moderate	5,432	9,721	6,813	1,379
High	4,768	8,605	6,793	0
Very High	16,580	34,759	26,781	0
Sum	101,355	185,495	229,130	17,257
Total Inundated Area				**533,236.23**

Table 10. Area of affected land cover classes (in sq. m.) for 100-year flood without embankment scenario.

Flood Level	Trees	Crops	Built Area	Rangeland
Low	82,407	167,153	221,427	16,290
Moderate	8,670	14,639	9,691	2,244
High	5,242	9,120	7029	0
Very High	22,954	46,978	36,245	0
Sum	119,274	237,890	274,392	18,535
Total Inundated Area				**650,090.12**

Table 11. Area of affected land cover classes for the 5-year flood with embankment scenario.

Flood Level	Trees	Crops	Built Area	Rangeland	Bare Ground
Low	44,978	108,109	151,921	644	8,595
Moderate	479	11,888	18,485	0	4,561
High	127	8,502	10,752	0	510
Very High	86	8,114	34,504	0	3,683
Sum	4,5670	136,614	215,662	644	17,349
Total Inundated Area				**415,938.05**	

Table 12. Area of affected land cover classes (in sq. m.) for 100-year flood with embankment scenario.

Flood Level	Trees	Crops	Built Area	Rangeland	Bare Ground
Low	44,877	140,418	249,259	3,524	4,970
Moderate	1,893	22,480	61,973	0	6,546
High	343	6,971	18,400	0	4,176
Very High	165	31,149	47,238	0	4,122
Sum	47,278	201,017	376,870	3,524	19,814
Total Inundated Area				**648,503.13**	

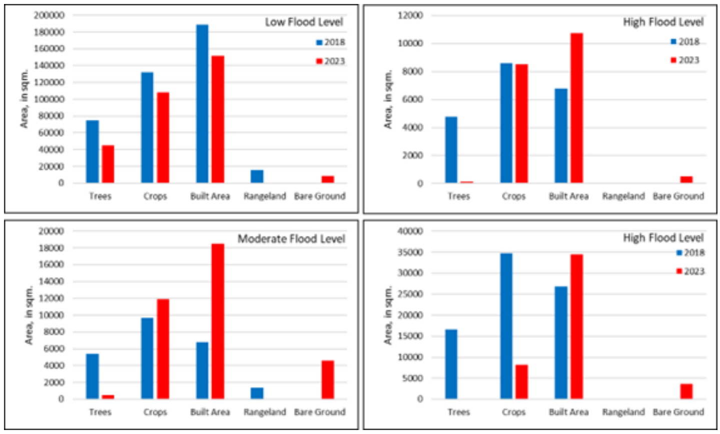

Figure 7. 2018 vs 2023 inundated area of land cover classes for 5-year flood scenario.

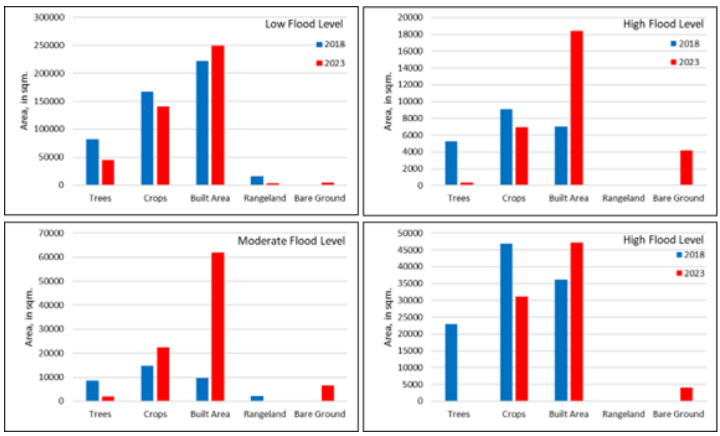

Figure 8. 2018 vs 2023 inundated area of land cover classes for the 100-year flood scenario.

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5 Statement of Conflict of Interest

To ensure impartiality in the evaluation of this article, MV Elvira, a member of the JESEG Editorial Board, recused himself from the review process. The authors also declare that they have no competing financial interests or personal relationships that could have influenced the work presented in this paper.

6 Author Contribution

AC Gagula: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, Writing - Review and Editing, Supervision. SM Salcedo-Albores: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Review and Editing. JLE Gesta: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Review and Editing.

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Perceived Economic Impacts of the Projects Under the Community-Based Forest Management-Comprehensive Agrarian Reform Program (CBFM-CARP) in Caraga Region

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ABSTRACT

The Community-Based Forest Management-Comprehensive Agrarian Reform Program (CBFM-CARP) is a national strategy designed to empower local communities through sustainable forest resource use and improved livelihoods. This study assessed the perceived economic impacts of the CBFM-CARP projects among nine People's Organizations (POs) in the Caraga Region, Philippines. Using the standardized assessment tool from FMB Technical Bulletin No. 9., the study evaluated household income changes before and after project implementation through one-on-one assisted interviews with 129 direct project beneficiaries. Findings revealed that the estimated contribution of CBFM-CARP interventions to total household income ranged from 24% to 62%. Eight out of nine POs showed a statistically significant increase in household income after project implementation (α=0.05), indicating the positive effect of agroforestry, mangrove rehabilitation, and livelihood diversification supported by the program. The study also documented increases in net farm-based income, particularly among upland beneficiaries involved in rubber, falcata, and fruit tree cultivation. Meanwhile, coastal POs engaged in mangrove rehabilitation showed mixed outcomes. Overall, the CBFM-CARP projects have contributed meaningfully to improving household income and socio-economic conditions of participating communities, while promoting sustainable forest resource management. The findings support the continued integration of community-based forestry and agrarian reform initiatives to foster inclusive rural development.

Keywords: *Rural Livelihoods, Forest-Based Enterprises, Agroforestry Development Rural Livelihoods,*

1 Introduction

Sustainable forest management seeks to harmonize current social, economic, and environmental requirements with those of the coming generations. The Forest Stewardship Council (FSC) is a global organization promoting responsible forest management. They facilitated and joined with environmental organizations, representatives of the forest industry, and community representatives in the multi-stakeholder process that resulted in developing a set of guidelines and standards for forest management. The FSC certification procedure demands that forests be maintained in a way that is commercially sustainable, socially just, and environmentally responsible (Council 2021). In the Philippines context, addressing rural poverty remains a pressing concern, particularly in rural areas where poverty remains a recurring issue, especially in areas where agriculture and forest resources are primary sources of livelihood.

In response to the continued degradation of the country's forestlands and the inequitable distribution of benefits from forest resources, the Philippine government adopted the Community-Based Forest Management (CBFM) strategy in 1995 to address widespread deforestation and rural poverty (Carandang 2012). CBFM advocates for active community participation in managing, conserving, and utilizing forest resources, thereby improving both environmental outcomes and community welfare (Guiang et al. 2001, Carandang et al. 2013). Historical data from the Food and Agriculture Organization (1997) reveal a drastic reduction in Philippine forest cover from 12 million hectares in 1960 to approximately 5.7 million hectares, largely due to illegal logging, land conversion, and population pressures. Along with the Comprehensive Agrarian Reform Program (CARP), the government initiative aims to empower communities through land tenure security, livelihood opportunities, and greater participation in natural resources stewardship. However, economic impacts remain mixed due to limited market access, inadequate support, and policy inconsistencies (Ballesteros 2017).

The Caraga Region, commonly referred to as the "timber corridor" of the Philippines, is a key area for smallholder tree farming and agroforestry. Despite favorable biophysical conditions and significant timber production potential, many of the region's farmers continue to face economic hardship. Recent studies have shown that a large proportion of both tree farmers and non-tree farmers earn below the national and regional poverty thresholds, indicating persistent income insecurity and limited access to sustainable livelihood opportunities (Peras et al. 2020). Participation in the CBFM program, however, has demonstrated potential in enhancing the well-being of upland communities with notably increased household income compared to pre-CBFM levels, acquisition of household and farm assets previously uncommon in forest-dependent areas, and the creation of local employment opportunities (Espiritu et al. 2010).

Caraga Region, with a total land area of approximately 1.9 million hectares and 523,292 hectares of forest cover (as per the 2007 Philippine Forestry Statistics), has been one of the key regions for the implementation of CBFM-CARP. Characterized by a mix of mountainous, rolling, and lowland terrain, it has seen the active participation of several People's Organizations (POs) engaged in reforestation, livelihood generation, and forest management. Given the scale of intervention, it is imperative to assess the economic impacts of the program on its beneficiaries. This study, therefore, aims to evaluate the perceived economic impacts of the CBFM-CARP projects in the Caraga Region. Through this assessment, the research seeks to determine how these initiatives have influenced household incomes, employment opportunities, land productivity, and community resilience. Moreover, the impact assessment will provide critical insights into the program's effectiveness, highlighting both its advantages and limitations and guiding future improvements in policy and implementation (FMB Technical Bulletin No. 9). As such, the Community-Based Forest Management and the Comprehensive Agrarian Reform Program stand as cornerstones of inclusive environmental governance and rural development in the Philippines.

2 Materials and Methods

Profile of Participating People's Organizations

The impact assessment encompassed nine (9) duly recognized People's Organizations (POs) operating within the Caraga Region, Philippines. These organizations were purposively selected based on their direct involvement in community-based resource management and conservation initiatives. The participating POs include: (1) Bonifacio Reforestation People's Organization (BORPO); (2) Marcos Calo Farmers Multi-Purpose Cooperative (MACAFA-MPC); (3) Balungagan Reforestation Farmers Association (BARFA); (4) Lawigan Farmers and Fisherfolk Association (LAFFA); (5) Opong/Fabio Dwellers Mangrove Association (OPFADMA); (6) San Isidro Coastal Dwellers Association, Incorporated (SICDAI); (7) Iligan Tribal Farmers Community Development Association, Incorporated (ITFCDAI); (8) Singanan Upland Farmers Producers Cooperative (SUFPCO); and (9) Tigpanalipod sa Katunggan nan Magasang (TIKAMA).

The geographical distribution of these POs and the corresponding number of project beneficiaries engaged during the assessment are presented in Figure 1 and Table 1. In total, 129 project beneficiaries participated in the assessment.

Assessment Framework and Instrumentation

The assessment applied FMB Technical Bulletin No. 9, the Department of Environment and Natural Resources' standard tool for evaluating the impacts of Community-Based Forest Management projects under the Comprehensive Agrarian Reform Program

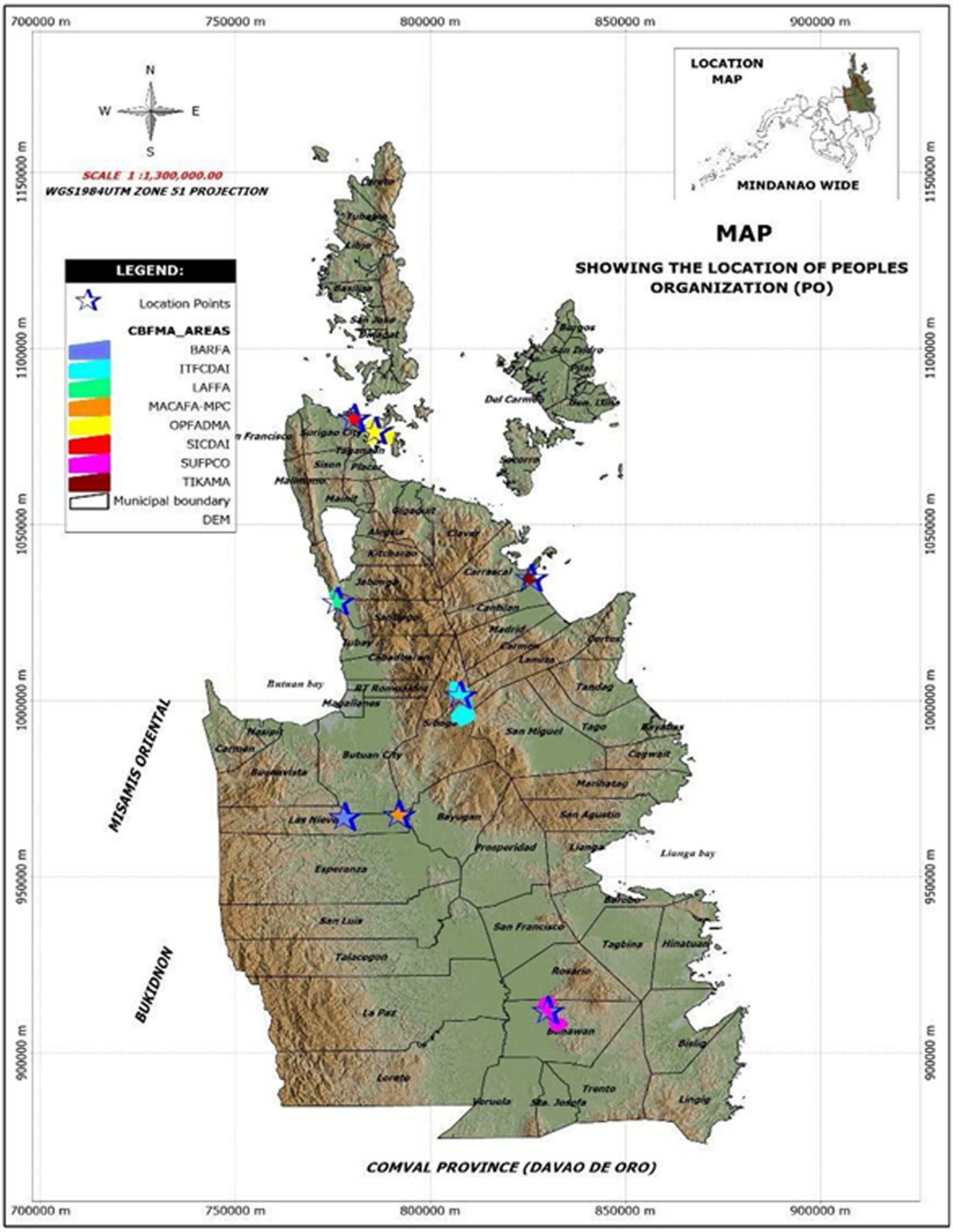

Figure 1. Location of People's Organization in Caraga Region, Philippines

Table 1. People's Organization Participants and Location

PO Name	Location	Number of Participant-Beneficiaries
Bonifacio Reforestation People's Organization (BORPO)	Barangay Bonifacio, Las Nieves, Agusan del Norte	14
Marcos Calo Farmers Multi-Purpose Cooperative (MACAFA-MPC)	Barangay Marcos Calo, Las Nieves, Agusan del Norte	17
Balungagan Reforestation Farmers Association (BARFA)	Barangay Balungagan, Las Nieves, Agusan del Norte	20
Lawigan Farmers and Fisherfolk Association (LAFFA)	Barangay Lawigan, Tubay, Agusan del Norte	11
Opong/Fabio Dwellers Mangrove Association (OPFADMA)	Brgy. Opong/Fabio, Taganaan, Surigao City, Surigao del Norte	13
San Isidro Coastal Dwellers Association, Incorporated (SICDAI)	Barangay San Isidro, Surigao City, Surigao del Norte	13
Iligan Tribal Farmers Community Development Association Inc. (ITFCDAI)	Barangay Padiay, Sibagat, Agusan del Sur	9
Singanan Upland Farmers Producers Cooperative (SUFPCO)	Brgy. San Andres and Consuelo, Bunawan, Agusan del Sur	13
Tigpanalipod sa Katunggan nan Magasang (TIKAMA)	Magasang, Cantilan, Surigao del Sur	19

(CBFM-CARP). This instrument comprises two distinct components designed to capture both socio-economic and biophysical indicators of project outcomes.

Set A of the instrument was utilized to assess the socio-economic impacts of the project, specifically focusing on changes in household income and livelihood conditions. Set B, on the other hand, was employed to evaluate the biophysical condition of the project sites, encompassing aspects such as forest cover, land use, and resource management practices.

The present study primarily concentrated on the socio-economic dimension, with particular emphasis on determining: (i) the total monthly household income before and following project implementation; (ii) the total income generated directly from the CBFM-CARP project interventions; and (iii) the net income derived from various farm-based livelihood sources.

Data Collection and Sample Selection Criteria

Data collection activities were conducted across the identified project locations, facilitated by designated representatives from the DENR Regional Office and the respective City Environment and Natural Resources Offices (CENROs) in Caraga. It is important to emphasize that project interventions varied across People's Organization (PO) members; therefore, only those members who directly received project assistance and met the eligibility requirements were invited to participate in the assessment.

Eligibility criteria for participation included the following conditions:

- The respondent must be a direct beneficiary of the CBFM-CARP project;
- In instances where the direct beneficiary was unavailable, the spouse or an immediate household member knowledgeable about the project outcomes was permitted to participate on their behalf;
- For non-literate beneficiaries, family members were allowed to assist in providing the necessary information during the interview process.

An assisted, one-on-one interview approach was utilized to elicit data from the participants, focusing on their perceptions of the economic impacts of the CBFM-CARP project. This method ensured data quality by providing clarification and assistance to respondents as needed, particularly for those with limited literacy or comprehension.

Data Analysis

The study utilized a quantitative research design to assess the economic status of selected project beneficiaries, with particular emphasis on income derived from CBFM-CARP projects and other farm-based livelihood sources. Descriptive statistical methods, including the computation of means, standard deviations, frequencies, and percentages, were employed to summarize and describe the key characteristics of the data. Wilcoxon Signed-Rank test, a non-parametric statistical analysis appropriate for paired observations, was conducted to evaluate changes in household income before and after project implementation.

3 Results and Discussion

The decline of forest cover and degradation of its resources are often attributed to poverty, high upland population growth, de facto management, and open access (Guiang et al., 2001). The recognition of this problem has led to the proclamation of Presidential Executive Order (EO) No. 263 as a national strategy to ensure the sustainable development of the country's forestland resources. EO 263 legitimates the respective people's organization, on which their livelihood depends, as resource managers of the nation's forest.

People's Organization Profile and Project Awarded

Caraga has one-hundred twenty-six (126) CBFM Agreements (CBFMA) as of 2013. This agreement is entered into by and between the government and the local community, represented by the PO, as forest manager. Table 1 shows the list of POs assessed in this study which has approved funding from 2012 to 2015. Six POs are in an upland ecosystem, while three are in a coastal ecosystem. Project in the upland includes agroforestry planting of rubber, falcata, fruit trees, cacao, and banana, while mangrove rehabilitation and mud crab fattening projects in the coastal area. The project with a greater number of members has the highest funding attributed to the number of individuals who can implement the work plan activities (Table 2). Among the POs that have the highest funding are BORPO, MACAFA-MPC, and SUFPCO, which have a total members of 561, 121, and 118, respectively. These POs received more than one (1) million pesos in funding. BORPO and MACAFA-MPC are both in the municipality of Las Nieves and have the same project - Rubber Plantation Development with Banana and SUFPCO with Rubber and Falcata Development project. In contrast, the project with less funding is on the coastal area that involved mangrove rehabilitation. This project has fewer activities and materials needed compared to upland projects.

Respondents Socio-Economic Profile

Socio-economic data helps understand actual conditions in the community. This study can help identify POs with limited education, fewer employment opportunities, and low income, which can be used as a basis for targeted measures to reduce poverty and bridge inequality gaps.

The average age of members across POs ranges from 47.37 years to 57.67 years, indicating a relatively mature aging population actively involved in these organizations (Table 3). In terms of educational attainment (measured as years in school), it varies between 7.22 and 9.74 years, which suggests that some participants may have completed elementary to early level, and others have slightly higher educational exposure. Training and capacity building conducted by various national government agencies under respective programs from the Department of Environment and Natural Resources (DENR), the Department of Agriculture (DA), the Department of Social Work and Development

Table 2. Peoples Organization Profile and Project Awarded Details

PO's Name	Total Area (hectare)	Total No. of PO Members	CBFM No. and Date Awarded	CBFM-CARP Project	Year Approved for Funding (Php)	Project Cost
BORPO	242	561	70030 / October 19, 2005	Rubber Plantation Development with Banana	2012	1,088,506.25
MACAFA-MPC	356	121	70029 / October 19, 2005	Rubber Plantation Development with Banana	2012	1,088,506.25
BARFA	399	86	70033 / October 19, 2005	Rubber Plantation Development with Cacao	2013	827,700.00
LAFFA	267	58	70028 / October 20, 2005	Rubber and Fruit Trees Plantation Development	2013	492,055.00
OPFADMA	1,401.50	81	72009 / June 24, 2003	Mangrove Rehabilitation	2013	254,330.00
SICDAI	324	24	72005/ December 22, 2000	Mangrove Rehabilitation	2015	512,350.00
IITFCDAI	2,639.75	41	71005 / December 31, 1998	Rubber and Falcata Plantation Development	2012	808,629.00
SUFPCO	1,037.00	118	71019 / July 29, 2002	Rubber and Falcata Development	2014	1,056.537.00
TIKAMANA	53.0	38	73031 / August 6, 2011	Mangrove Rehabilitation and Mud Crab Fattening	2012	151,425.00

(DSWD), and others have helped them acquire learnings that could improve their well-being.

The POs' household size ranges from 4.20 to 6.23, indicating moderately large family sizes, which is typical of rural or agrarian communities. Some household children who are married still stay with their parents, making the household size large. Results of the number of earning family members suggest that only about two members contribute to the family income. This may reflect underemployment or limited job opportunities in their respective area. While interview results indicate that some members of the household work abroad and help augment household income. In terms of income, there is a significant disparity where the lowest income is reflected in the members of LAFFA and the highest in the members of TIKAMANA. High-income variation for POs like TIKAMANA, SUFPCO, and MACAFA-MPC implies a large income gap within their memberships, reflecting unequal access to livelihood opportunities or diversified income sources. On the other hand, POs like LAFFA, SICDAI, and OPFADMA have low household incomes with relatively smaller standard deviations, indicating economic homogeneity characterized by subsistence living and limited livelihood options.

Income derived from CBFM-CARP Projects

The funds granted by the CBFM-CARP projects provided the organization with materials needed in agroforestry and rehabilitation activities such as establishing a nursery, procuring seedlings and organic fertilizer, and planting. Over time, plantation and rehabilitation could reap many benefits from the direct provision of additional income from agricultural and forestry products and improve ecosystem service of mangroves that contribute to increased fisheries production (Ellison et al. 2020). Such products are expected to account for substantial shares as known sources of food and construction materials (Wiebe et al. 2022). The average monthly income of all POs before the project implementation falls between poor and low-income classes based on the indicative range of monthly family incomes in the Philippines (Albert et al. 2018). Before the project, every household could earn an average monthly income of PHP 15,000.0 or below (Figure 2).

On the other hand, a significant income increase can be seen from the figure, except for the case of SICDAI, which shows a relatively decreased trend after the project was implemented. Four POs namely BORPO, ITFCDAI, SUFPCO, and TIKAMANA have improved their income classification as a low middle-income class with average monthly income falling between PhP19,040.00 and PhP38,080.00. This increase in income can be attributed to project revenues and benefits, where a higher percentage of the households' earnings came from CBFM-CARP projects (Figure 3).

Approximately 62.5% of the total monthly income of SUFPCO beneficiaries is derived from CBFM-CARP projects, as the majority of members rely on agroforestry as their primary source of livelihood. While other POs show a high increase in income after the project implementation, such as TIKAMANA yielded from Php14,989.00 to PhP29,889.00 average earnings, some other POs remained at the poor income classification, such as BARFA, LAFFA, and SICDAI, which should be given more attention. In the case of LAFFA, with the lowest percentage (24.1%) of earnings from the project, the organization resorted to other means of living since most of the project's activities were not fully attained. This is after finding some planting failures during the project implementation and other inevitable factors, such as the biophysical characteristics of the study location. Generally, the

Table 3. Socio-economic profile of participants from nine participating POs

PO Name	Age	No of years in School	Household Size	Number of earning family members	Total Household Monthly Income (in peso)
BORPO	54.46 ± 12.69	9.38 ± 4.01	6.08 ± 2.47	1.92 ± 0.95	59,704.00 ± 76,421.99
MACAFA-MPC	57.67 ± 12.99	7.73 ± 2.55	5.47 ± 2.61	1.87 ± 0.92	141,101.33 ± 121,722.20
BARFA	54.40 ± 12.24	7.28 ± 4.35	5.8 ± 2.89	1.67 ± 0.91	76,965.00 ± 76,686.56
LAFFA	51.00 ± 16.01	8.20 ± 3.08	4.20 ± 1.75	1.88 ± 1.13	9,661.73 ± 5,080.87
OPFADMA	57.31 11.43	9.62 3.80	6.23 ± 2.95	1.70 ± 0.95	14,575.64 ± 20,592.29
SICDAI	51.38 ± 8.76	8.85 ± 2.38	5.62 ± 2.10	1.92 ± 1.26	10,103.85 ± 7,637.35
ITFCDAI	49.00 ± 20.32	7.22 ± 4.52	5.7 ± 2.2	2.22 ± 0.97	22,566.48 ± 22,126.76
SUFPCO	53.69 ± 13.51	8.31 ± 3.79	4.23 ± 1.33	2.15 ± 0.99	253,584.62 ± 221,225.46
TIKAMA	47.37 ± 9.24	9.74 ± 2.60	6.21 ± 1.78	2.32 ± 1.34	358.666.95 ± 447,219.9

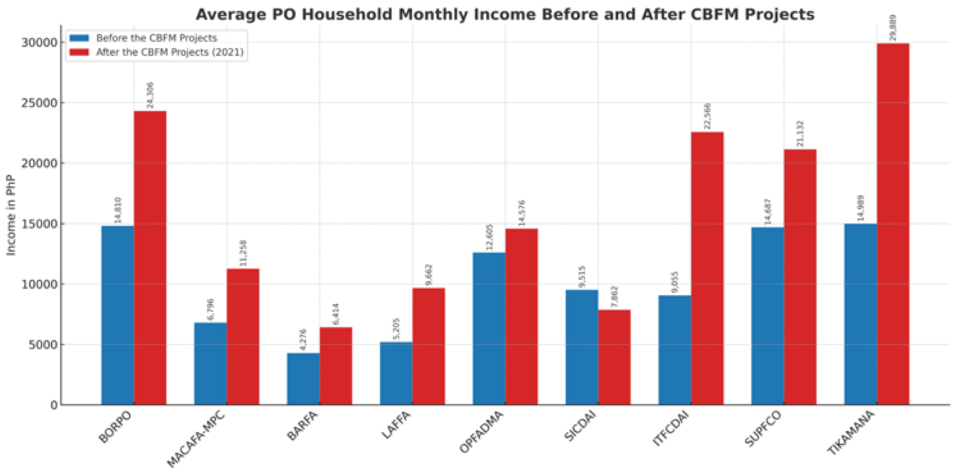

Figure 2. Estimated average total household monthly income of PO Members

CBFM-CARP projects awarded for these POs help in the income generation of its beneficiaries.

Income derived from other Farm Sources

Figure 4 shows the net income derived from farm sources before and after the implementation of the CBFM project. These were from fruit trees, crops, non-timber forest products, forest trees, livestock, and aquaculture activities. Data shows that the income of MACAFA-MPC, BARFA, LAFFA, SICDAI, SUFPCO, and TIKAMANA increased during the year 2020-2021, attributed to increased production and prices of fruits, crops, trees, and other farm produce. CBFM encourages the beneficiaries to develop various income-generating activities in addition to the sustainable harvesting of forest products. Communities may see increased revenues due to this diversification of income sources. Community-managed Forest areas might have better access to new markets for forest goods or timber products that are certified as sustainable. Also, communities can do away with middlemen or intermediaries by handling the harvesting and selling of forest products themselves. This practice may increase revenue and profits from using forest resources (Carandang & Wilson 2005, Tacconi & Kaimowitz 2019). For communities, this may open new revenue options. Aside from economic benefits, the communities also increased social capital, which can lead to greater cooperation and coordination within the organization. In addition, the enhanced skills and knowledge acquired are beneficial for the group. However, BORPO, OPFADMA, and IFTCDAI net income decreased due to pest attacks and natural calamities.

During the phase of the implementation period, members of these organizations refused to raise livestock such as swine due to high inputs and African Swine Fever (ASF) disease. Many countries also experienced major price volatility of pigs in the market due to the ASF outbreak resulting from scaled backing of the operations (Xu et al. 2022). Certain community members may have better access to resources than others in some instances where the distribution of forest resources under CBFM is not equitable. Increased production of forest products due to CBFM may result in overproduction and lower prices in local markets. For communities that depend on the sale of forest products, this may mean lower incomes (Iversen & Chhetri 2011, Poudyal & Baral 2011). Community-based financial management (CBFM) communities may be exposed to outside forces including natural disasters, shifting economic conditions, and governmental regulations. These elements may have an adverse effect on income levels and local.

Economic Impact of CBFM Projects: Comparison of Household Income Before and After Project Implementation

In the Philippines, forest-dependent communities have experienced significant changes in household income levels following the implementation of Community-Based Forest Management (CBFM) initiatives. Results of the Wilcoxon Signed-Rank Test (Table 4), revealed a statistically significant difference ($p < 0.05$) in the total monthly household income of most beneficiary

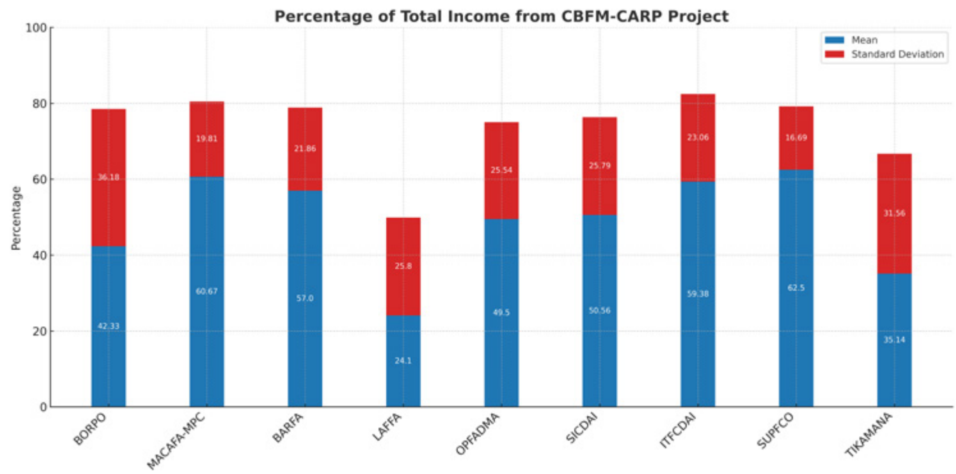

Figure 3. Estimated Percentage of total income from CBFM-CARP Project livelihoods (Tigabu & Luukkanen, 2012).

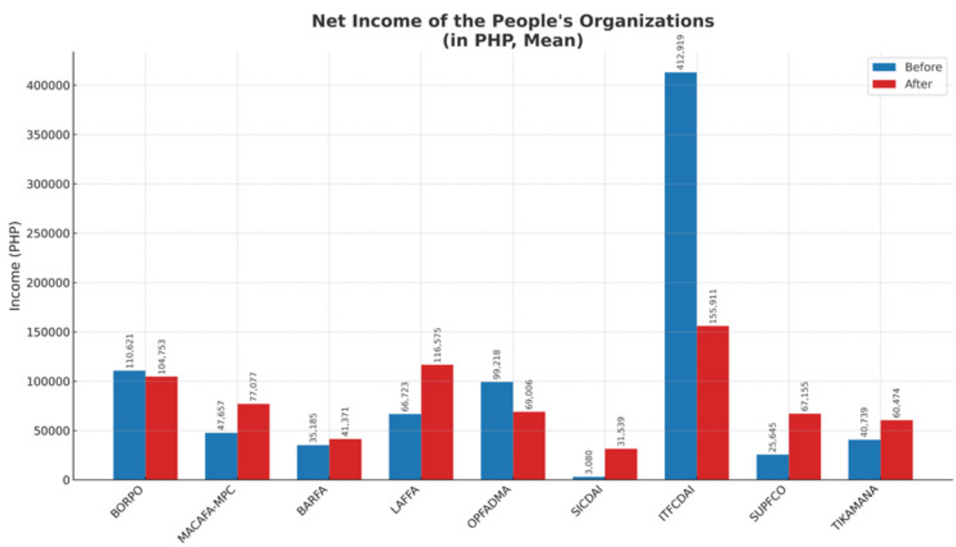

Figure 4. Summary of estimated net income derived from different farm sources before and after CBFM project implementation.

members of People's Organizations (POs) before and after project implementation. This indicates that the CBFM-CARP interventions contributed to improving household income among the majority of project participants.

However, the results for the Opong/Fabio Dwellers Mangrove Association (OPFADMA) were not statistically significant, suggesting no measurable change in the monthly household income of its members following project implementation. This may be attributed to project design, incomplete implementation of planned interventions, or external socio-economic and environmental factors, which warrant further investigation through localized case studies or process evaluations.

The observed increase in income among project beneficiaries is primarily attributed to the integration of diversified livelihood commodities within CBFM sites, including the cultivation of fruit trees, timber species, and non-timber forest products. This diversified approach enhanced harvest yields and generated additional income streams for the participating communities.

Previous studies have similarly documented the positive socio-economic impacts of community-based forest management initiatives. For instance,

Table 3. Socio-economic profile of participants from nine participating POs

Peoples Organization	p-value
BORPO	0.040**
MACAFA-MPC	0.003***
BARFA	0.008***
LAFFA	0.003***
OPFADMA	0.083^{ns}
SICDAI	0.003***
IITFCDAI	0.027**
SUFPCO	0.038**
TIKAMANA	0.004***

Braganza et al. (2012) highlighted that such projects significantly enhance the economic viability and overall sustainability of resource management efforts. Fajar & Kim (2019) further reported that CBFM not only provides direct employment opportunities (e.g., through forest management, agroforestry, and ecotourism) but also generates indirect economic benefits by stimulating related enterprises, such as food establishments, accommodations, transportation services, and small retail outlets near project sites.

Moreover, CBFM initiatives have effectively broadened economic opportunities for rural communities by facilitating access to financial capital, enabling land leasing for plantation development, and establishing market linkages for value-added forest-based products such as coffee, timber, and handicrafts. The creation of Community-Based Forest Enterprises (CBFEs) has been particularly instrumental in diversifying household income and promoting sustainable resource use. Pandit et al. (2008) emphasize that such enterprises enhance economic inclusion by ensuring the participation of marginalized groups and improving access to livelihood assets. As they noted, one good practice is the provision of a revolving fund by donors that will enable the poor to buy shares in the cooperative or company. Other practices include offering labor opportunities to the poorest, and representation of the poorest and marginalized in FUG executive committees (Pandit et al. 2008). These practices underscore how CBFEs serve not only as economic mechanisms but also as social instruments that foster equity and resilience in forest-dependent communities.

Empirical research demonstrates that participation in CBFEs leads to notably higher income levels compared to non-participants. In the Philippines, a comparative study in Baybay City, Leyte, found that CBFM member households had significantly greater mean incomes than non-members, based on independent samples t-tests across agroforestry projects involving coffee, cacao, and timber crop production (Compendio & Bande 2017). The study supports the findings of Pandit et al. (2008), who evaluated 28 forest user group enterprises and found that income benefits were highest in formal companies, followed by cooperatives and networks particularly where poorer members held shares or were directly employed in non-timber forest product processing. These enterprises enhanced market access by leveraging economies of scale, improving product quality, and enabling entry into higher-value markets, thereby reinforcing their role as economic drivers of sustainable rural development.

Before the implementation of CBFM, many forest-dependent communities engaged in environmentally unsustainable livelihood activities, including slash-and-burn agriculture and illegal timber harvesting (Charnley & Poe 2007, Peralta & Lasco 2014). The introduction of CBFM has provided these communities with more sustainable, ecologically sound, and economically viable livelihood alternatives, contributing to both poverty alleviation and forest conservation objectives.

4 Conclusion and Recommendations

The utilization of forest and mangrove resources is a source of income in upland and coastal communities. The lack of policy intervention on the means to safeguard these resources can lead to exploitation and degradation that further exacerbate poverty to its users and compromise the ecosystem services it provides. The community-based forest resource management strategy is a mechanism to harmonize socio-economic activity and the health of the environment. Fund support and the capacity building of its direct stakeholders is an effective means to manage natural resources collectively. Income generated from agroforestry serves as an alternative source of income for its beneficiaries to improve their socio-economic status.

5 Acknowledgement

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6 Statement of Conflict of Interest

MV Elvira, part of the Editorial Board of JESEG abstained in the reviewing process of the article in the journal.

7 Author Contribution

JRD Apdohan drafted the extended abstract and introduction, the structural outline for the full paper and the final proofreading of the manuscript. KB Burdeos and MV Elvira wrote the methodology and collaborated with drafting the results and discussion and its revision. MAP Perodes, MC Amarille, and J Valdehueza created the study area map and contributed to the development of the introduction and the results and discussion sections. KJG Dulabay performed data analysis and interpretation.

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