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Sustainability Evaluation of Mangrove Forest Management System of Tagbanua Tribe in Bgy. Manalo, Puerto Princesa City, Palawan, Philippines

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ABSTRACT

Community-based forest management agreement in the country is a needed instrument in attaining sustainability of mangrove management. Sadly, there is no assurance that the system implemented in the mangrove forest management is sustainable. So, evaluating the mangrove management sustainability of the local tribe is a viable avenue for the appropriate management. In this study, the sustainability of the mangrove management system of the Tagbanua tribe in Bgy. Manalo, Puerto Princesa City, Palawan was evaluated. The study utilized various criteria with relevant indicators of sustainable mangrove forest management in assessing the mangrove forest management system. Focused group discussions were conducted to identify the relevant sustainable mangrove forest management C & I and verifiers. Each indicator was rated using the formulated verifiers in the form of the rating scale. Through household interviews, FGD, KII, mangrove assessment, and secondary data analysis, this study also used a mathematical model on the Sustainability Index for Individual Criteria (SIIC) to evaluate the scores for individual criteria and the Overall Sustainability Index (OSI) of the community. As a result, there are a total of seven relevant criteria, and 35 relevant indicators for Mangrove Management in Barangay Manalo. Based on the individual rating of seven criteria, the overall rating of the sustainable mangrove management system is 1.80, which implies a fairly sustainable mangrove management system. Also, the computed overall sustainability index is 0.26, which is fairly or moderately sustainable. Each criterion has strengths and weaknesses and needs to be improved to have a highly sustainable mangrove management system.

Keywords: Mangrove management system; Relevant criteria and indicators; Mangrove sustainability index

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1. Introduction

Mangrove forests are coastal ecosystems that offer numerous benefits to humans. They play a crucial role in stabilizing coastlines, safeguarding coastal communities against severe weather events, providing essential habitats for numerous animal species, and sequestering substantial amounts of carbon [1]. They are home to a diverse range of life forms, including terrestrial and marine animals, as well as humans [2]. Mangroves have been used as a source of building materials and charcoal in some areas [3]. In addition to their direct benefits, mangrove forests also provide important indirect benefits. For example, they can offer protective services by absorbing wave energy and serving as natural buffers against storms [4]. Mangroves have the ability to filter water by trapping sediments and pollutants with their roots, which prevents these materials from being disposed to the sea [5]. They serve as a habitat for a diverse range of bird and marine species and can serve as important nurseries and spawning grounds for aquatic life, such as shrimp and milkfish. Furthermore, the detritus food chain which is supported by the organic matter produced by mangroves provides a source of food for many marine animals [4].

Effective ecosystem management, such as the mangrove ecosystem, is essential for achieving sustainability and guaranteeing sustainable health and productivity of these ecosystems. One approach to achieving this is through co-management and community-based mangrove forest management, which involves collaboration between local communities and government agencies to develop and implement sustainable management practices [6,7]. While co-management between local government and community and sole management of mangrove forests by the community can be effective in promoting sustainability, it is important to recognize that not every management system is sustainable [8,9]. In this case, sustainability evaluation of the management system of the mangrove ecosystem is a practical approach to ensure the proper management of natural resources [7].

In Palawan, there are ongoing Mangrove Forest Management Systems, including the sole mangrove management of the community in Barangay Manalo, City of Puerto Princesa, Palawan. The management of this 40-hectare mangrove forest is being overseen by the Manalo Tribal Organization, an Indigenous Cultural Community (ICC), as well as the local government of Bgy. Manalo and Puerto Princesa City Government. However, the management of the forest faces several challenges, including illegal cutting of mangrove trees, land title disputes, inadequate monitoring and law enforcement, and unsustainable aquaculture practices. Therefore, it is essential to assess the sustainability status of various mangrove management approaches to ensure proper management of these valuable resources. This study aims to assess the perception and awareness of the respondents towards criteria and indicators of sustainable mangrove management and to assess the sustainability of the mangrove forest management system of the Tagbanua tribe in Bgy. Manalo, Puerto Princesa City, Palawan, considering these challenges and opportunities for improvement.

2. Materials and methods

2.1 Research locale

The research was carried out in Barangay Manalo, Puerto Princesa City, Palawan, which is located at 9°58'30"N and 118°48'30"E, approximately 40 km from Puerto Princesa City proper as shown in **Figure 1**. The study focused on a 40-hectare mangrove forest within this area.

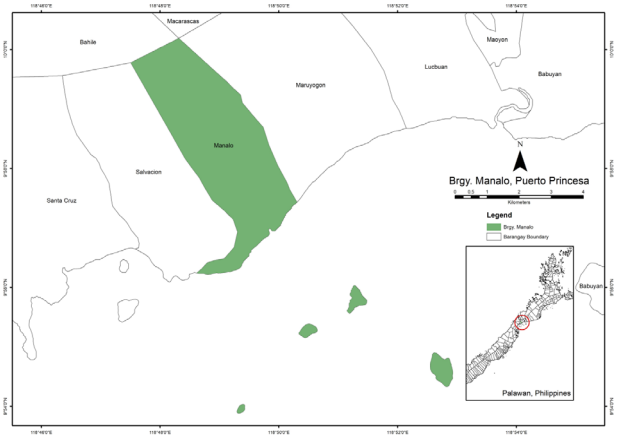

Figure 1. Map of Barangay Manalo.

2.2 Research design and instruments

The adopted research design is a mixed method which is a combination of both qualitative and quantitative research methods. The qualitative part of the study includes the identification of the relevant C & I existing management style. Meanwhile, the quantitative part of the method includes the assessment of the sustainability status of the existing management approach.

There are seven criteria and 57 indicators of forest management sustainability set by the Forest Management Bureau (FMB) to assess the sustainability status of the existing management approach. Note that the set C & I originate from the International Tropical Timber Organization (ITTO) [10]. To determine the applicable Sustainable Mangrove Forest Management Criteria and Indicators, this study utilized a Focus Group Discussion (FGD) approach. The FGDs were conducted with 12-15 participants and were guided by a set of questions, a recorder, and visual aids. In total, three FGDs were conducted as part of the study, including a validation process to ensure the relevance and applicability of the identified criteria and indicators [7,11,12].

Once the applicable criteria and indicators were identified, the study proceeded to verify the verifiers for each criterion and indicator. The verifiers were established in collaboration with the community and researchers, using a rating scale of 1 (poor), 2 (fair), and 3 (good) for individual indicators identified. The verifiers were established through a process of FGDs and KII, which involved a diverse group of stakeholders [12]. Three FGDs of at least 15 participants were conducted to formulate and validate the verifiers for each indicator that is applicable. The researchers performed validation and consultation on the developed rating scale. The participants for the FGD were multi-sectoral, which included community leaders, fishers, tour guides, leaders, members of Indigenous People (IP), farmers, women, the elderly, and community members [11,12].

Each indicator was rated using the formulated verifiers (rating scale) through household interviews (HHI), FGD, KII, mangrove assessment, and analysis of existing and available secondary data. Also, the local community's awareness of applicable criteria and indicators is rated on a scale of 1 to 5. One signifies a very low awareness (below 20% awareness). Meanwhile, a value of two is rated for low awareness (with 21%-40% awareness), three for moderate awareness (with 41%-60% awareness), four for high awareness (with 61%-80% awareness), and five for very high awareness (81%-100% awareness) [12]. The local community's perception of the importance of applicable criteria and indicators was evaluated using a rating scale of 1 to 5. One is very insignificant, two (insignificant), three (no opinion), four (significant), and five (very significant).

The study implemented 50-meter transect lines with 10 m × 10 m quadrats along each transect to assess present mangrove species composition, population density, and DBH.

2.3 Research sample

The study used Robert Slovin's formula to decide the sample size for the HHI, based on 0.05 marginal error and a 95% confidence level. The computed sample size was 40 which was computed from the total number of households (n = 48) of the Manalo Tribal Organization. Included in the HHI are the members and officers of the said organization. For the Focus Group Discussions (FGDs), community leaders and members were selected as participants in each area. The sampling frame used in selecting the samples was the household list in each area, and random sampling was conducted using the Microsoft Excel random generator. Through these methods, the study was able to collect representative data from a sample of households and community members in the study area.

2.4 Data analysis

Descriptive statistics was used to analyze the socioeconomic characteristics of the respondents and the biophysical conditions. Furthermore, an FGD was implemented, and the resulting transcriptions were analyzed to determine the appropriate C & I for

forest management sustainability [11]. To assess the management sustainability of the mangrove forest, other criteria were developed by the community, utilizing a rating scale. This scale was applied to each indicator. The data collected included ordinal data from the rating scale, as well as nominal and ratio data from socioeconomic characteristics such as household income, educational attainment, gender, age, and length of residence in the area. Spearman correlation test and Point-Biserial correlation analysis, conducted through SPSS software, were used to determine the relationship between the socioeconomic characteristics of the households and their perceptions [13,14].

In this study, a mathematical model known as the SIIC was employed to assess the scores of individual criteria, as well as the OSI [7]. This was used to compare the level of sustainability for each criterion and overall.

$$SIIC = \frac{Sum\ of\ Weighted\ scores\ of\ indicators}{number\ of\ indicators\ in\ the\ respective\ criteria}$$

$$OSI = \frac{Sum\ of\ SIIC}{Number\ of\ Criteria}$$

Source: Pokharel et al. [7].

3. Results and discussions

3.1 Mangrove species composition in Bgy. Manalo, Puerto Princesa City

The mangrove species composition in Barangay Manalo, Puerto Princesa City, is shown in **Figure 2**. The most abundant species is *Rhizophora apiculate,* which comprises 34% of mangroves identified. Next is *Rhizophora mucronata* (29%) and *Xylocarpus granatum* (25%). Other mangroves species present are *Sonneratia alba, Rhizophora stylosa, Bruguiera cylindrica, Bruguiera gymnorrhiza, Avicennia alba, Ceriops tagal,* and *Lumnitzera granatum*.

3.2 Awareness and perception levels of respondents to applicable criteria and indicators

There are seven criteria, and 35 indicators are applicable to Mangrove Management in Bgy. Manalo. **Table 1** shows the awareness and perception of the respondents on the enabling condition of SFM. Except for item 1.5, it can be seen that the respondents have a high level of awareness of all the other items with weighted means of 3.825, 3.825, 3.525, 3.8, 4.025, and 3.85, respectively. Item 1.5 gained a mean of 3.275 which means that the respondents have moderate awareness of the procedures for for planning sustainable forest management. Similarly, the respondents were moderately aware of the process of regular monitoring, monitoring, evaluation, and progress feedback. The average of all the means is 3.73, which can be interpreted that the respondents have a high level of awareness of the enabling condition of SFM.

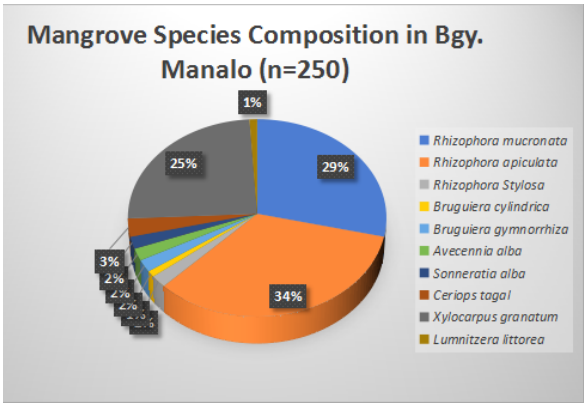

Figure 2. Mangrove species composition in Brgy. Manalo, Puerto Princesa City.

Regarding the perception of the respondents to the enabling condition of SMF, the table shows that they perceived that all the items are significant with averages of 4.175, 4.125, 3.85, 4.05, 4.05, 4.025, and 3.925, respectively. The overall mean of 4.02 reveals that the respondents perceived that the enabling condition of SFM is significant.

Table 2 presents the awareness and perception of the respondents on the extent and condition of the forest. It is indicated that the respondents have a high awareness of (a) the area and proportion of land area under the CLUP, (b) the area of forest allotted to production and protection, (c) the area and proportion of total land area under each forest type, and the (d) changes in a forested area with means of

4.025, 3.675, 3.925, and 4.125, respectively. Meanwhile, the respondents have moderate awareness of the forest condition, as interpreted from the mean of 3.4. The overall average is 3.83, which signifies that the respondents have a high awareness of the forest's extent and condition.

Table 1. Awareness and perception of the respondents on the enabling condition of SFM.

	Indicator	***Awareness***	***Interpretation***	***Perception***	***Interpretation***
1. Enabling situation of SFM	1.1 Presence of structure for laws, policies, and regulations.	3.825	High	4.175	Significant
	1.2 Forest Tenurial Instrument	3.825	High	4.125	Significant
	1.3 Amount of investment and reinvestment in forest management, administration, research, and human resource development	3.525	High	3.85	Significant
	1.4 Existence of, and ability to apply, appropriate technology to practice SFM and the efficient utilization and marketing of products.	3.8	High	4.05	Significant
	1.5 Capacity and mechanisms for planning SFM and for periodic monitoring, evaluation, and feedback on progress	3.275	Moderate	4.05	Significant
	1.6 Public participation in forest management planning, decision-making, data collection, monitoring, and assessment.	4.025	High	4.025	Significant
	1.7 Existence of Forest management plans	3.85	High	3.925	Significant
	Average	**3.73**	**High**	**4.03**	**Significant**

Legend:

4.51-5.00	*Very high**	*Very significant***
3.51-4.50	*High**	*Significant***
2.51-3.50	*Moderate**	*No opinion***
1.51-2.50	*Low**	*Insignificant***
1.00-1.50	*Very low**	*Very insignificant***

Table 2. Awareness and perception of the respondents on the extent and condition of forest.

	Indicator	***Awareness***	***Interpretation***	***Perception***	***Interpretation***
2. Area and situation of forest	2.1 Area and Proportion of land area under the comprehensive land-use plan (CLUP)	4.025	High	4.625	Very significant
	2.2 Area of forest allotted to production and protection.	3.675	High	4.025	Significant
	2.3 Area and proportion of total land area under each forest type	3.925	High	4.175	Significant
	2.4 Changes in the forested area	4.125	High	4.475	Significant
	2.5 Forest Condition	3.4	Moderate	3.525	Significant
	Average	**3.83**	**High**	**4.165**	**Significant**

Legend:

4.51-5.00	*Very high**	*Very significant***
3.51-4.50	*High**	*Significant***
2.51-3.50	*Moderate**	*No opinion***
1.51-2.50	*Low**	*Insignificant***
1.00-1.50	*Very low**	*Very insignificant***

Moreover, the respondents perceived that the land area covered in the comprehensive land-use plan (CLUP) is very significant, based on the mean of 4.625. Furthermore, they perceived that the (a) forest area intended for production and protection, (b) areal extent of each forest type, (c) variation in the area covered by forest, and (d) forest condition are significant with 4.025, 4.175, 4.475, and 3.525, respectively. The overall mean for perceptions is 4.165, which means that the respondents perceived that the extent and condition of the forest are significant.

Table 3 shows the awareness and perception of the respondents on forest ecosystem health. Respondents generally have a high level of awareness for both indicators of Criterion 3, with means of 3.9 and 4.375, respectively. The average of the means is 4.14, which states that the respondents have a high awareness of forest ecosystem health.

The respondents perceived that the extent and nature of forest encroachment, degradation, and disturbance due to human interventions are significant. At the same time, they do not agree on the area and nature of forest depletion and disturbance caused by natural means, according to the calculated means of 3.9 and 3.5, respectively. The overall average of 3.7 signifies that the respondents perceived that the forest ecosystem health is significant.

Table 4 presents the awareness and perception of the respondents on forest production. The respondents have a high level of awareness of indicator 4.1 (mean = 3.925) and indicator 4.3 (mean = 4.1). However, they have a moderate awareness indicator 4.2. Despite that, the overall average is still 3.71, which states that the respondents have a high awareness of forest production.

Table 3. Awareness and perception of the respondents on forest ecosystem health.

	Indicator	***Awareness***	***Interpretation***	***Perception***	***Interpretation***
3. Health of forest	3.1 The area and nature of forest encroachment and disturbance affected by human	3.9	High	3.9	Significant
	3.2 The area and nature of forest depletion and disturbance caused by natural causes.	4.375	High	3.5	No opinion
	Average	**4.14**	**High**	**3.7**	**Significant**

Legend:	*4.51-5.00*	*Very high**	*Very significant***
	3.51-4.50	*High**	*Significant***
	2.51-3.50	*Moderate**	*No opinion***
	1.51-2.50	*Low**	*Insignificant***
	1.00-1.50	*Very low**	*Very insignificant***

Table 4. Awareness and perception of the respondents on forest production.

	Indicator	***Awareness***	***Interpretation***	***Perception***	***Interpretation***
4. Forest production	4.1 Area and proportion of forest which inventory and survey measures have been applied to assess the quantity of the primary forest products.	3.925	High	4.025	Significant
	4.2 Actual yield of wood and non-wood forest products	3.1	Moderate	3.275	No opinion
	4.3 Harvest Composition	4.1	High	3.375	Significant
	Average	**3.71**	**High**	**3.56**	**Significant**

Legend:	*4.51-5.00*	*Very high**	*Very significant***
	3.51-4.50	*High**	*Significant***
	2.51-3.50	*Moderate**	*No opinion***
	1.51-2.50	*Low**	*Insignificant***
	1.00-1.50	*Very low**	*Very insignificant***

In terms of the respondent's perception, the area and proportion of forest for which inventory and survey measures have been applied to assess the quantity of the forest products and composition of harvest are perceived to be significant, as revealed from their means of 4.025, and 3.275, respectively. Nonetheless, the participants in the study have no opinion about wood and non-wood forest products (mean = 3.275). The overall mean of 3.56 reveals that they perceived that forest production is significant.

Table 5 portrays the awareness and perception of the respondents on biological diversity. They have a high level of awareness for indicator 5.1. The respondents are also highly aware of the quantity of endangered and threatened forest-reliant plants and animals, measures of in situ, and ex-situ of the genetic variation within the commercial, endangered, rare, and threatened species of forest plants and animals, and the presence and enactment of procedures for safety and monitoring of plants and animals species in the production zone of forests, with means of 3.9, 3.975, 3.875, and 4.2, respectively. The overall mean of 3.99 suggests that the respondents have a high level of awareness of biological diversity.

Regarding their perception of biological diversity, they perceived that the presence and enactment of procedures to classify and guard endangered and threatened species of forest plants and animals, the number of endangered, rare, and threatened forest-dependent species. The measures of in situ and ex-situ of the genetic variation within the commercial, endangered, rare, and threatened species of forest flora and fauna are all significant with means 4.225, 4.025, and 4.1, respectively. Furthermore, they perceived that the presence and enactment of procedures for safeguarding and checking biodiversity in the production zone of forest area is very significant, having an average of 4.7. The whole mean of 4.26 indicates that their perception of biological diversity is significant.

Table 5. Awareness and perception of the respondents on biological diversity.

	Indicator	***Awareness***	***Interpretation***	***Perception***	***Interpretation***
5. Biodiversity	5.1 Presence and enactment of procedures to identify and safeguard endangered and threatened species of forest plants and animals.	3.9	High	4.225	Significant
	5.2 Quantity of endangered and threatened forest-dependent species	3.975	High	4.025	Significant
	5.3 Measures of in situ and ex-situ of the genetic variation within the commercial, endangered, rare, and threatened species of forest flora and fauna	3.875	High	4.1	Significant
	5.4 Presence and implementation of procedures for protection and monitoring of biodiversity in production forests	4.2	High	4.7	Very significant
	Average	**3.99**	**High**	**4.26**	**Significant**
Legend:	*4.51-5.00* *Very high** *Very significant***				
	3.51-4.50 *High** *Significant***				
	2.51-3.50 *Moderate** *No opinion***				
	1.51-2.50 *Low** *Insignificant***				
	1.00-1.50 *Very low** *Very insignificant***				

Table 6 presents the awareness and perception of the respondents on soil and water protection. The respondents have a high level of awareness of the procedures to guard downriver catchment and measures to maintain the productivity of soil and the capability of the soil to hold water inside a production zone of forests, as implied by means 4.225 and 4.4, respectively. However, there is a moderate level of awareness of the procedures for forest engineering based on the mean of 3.375. The combined means resulted in an average of 4, which translates to high awareness for soil and water protection.

The respondents perceived that the processes in safeguarding downstream catchment values, productivity of soil and water holding capacity, forest industry and engineering are all significant, having an average of 4.2, 4.25, and 3.85, respectively. They perceived that soil and water protection is significant from the overall average of 4.1.

Table 7 shows the awareness and perception of the respondents on the economic, social, and cultural aspects. It can be interpreted from the table that the participants of the study have a very high level of awareness for the participation of the indigenous cultural community, local people, and other forest inhabitants, in forest management capacity building, discussion, decision-making, and implementation (mean = 4.65). Moreover, the respondents have a high level of awareness of (a) the forest products industry organization and effectiveness (mean = 3.6), (b) the presence and enactment of conflict resolution procedures for solving disagreements between interested parties (mean = 3.775), (c) the number of community members depending on forests for their occupation (mean = 3.825), (d) the area of forests use for traditional and customary lifestyles (3.825), (e) the area of forest sites allotted and accessible for research and instruction, and recreational activity (mean = 3.9), (f) the quantity of significant cultural, and spiritual sites discovered and safeguarded (mean = 3.9), (g) the level to which user rights of the indigenous cultural community over publicly owned forests are acknowledged and practised (mean = 3.85), and (h) the indigenous knowledge is utilized in forest management planning and implementation (mean = 3.725). In addition, they have a moderate level of awareness for (a) the worth of produced wood, and non-wood forest products in the market (mean = 3.375), and (b) the coaching, capacity building, and workforce development programs for forest workforce (mean = 3.325). The overall mean of 3.84 signifies that the respondents have a high awareness of the economic, social, and cultural aspects.

On the other hand, the overall mean of 4.06 for the perception suggests that the study's respondents perceived the economic, social, and cultural aspects as significant. Specifically, they perceived that the worth of produced wood, non-wood forest products in the market (mean = 3.525), the forest products industry organization and effectiveness is significant, the presence and enactment of conflict resolution procedures for solving disagreements between interested party

Table 6. Awareness and perception of the respondents on soil and water protection.

		Awareness	***Interpretation***	***Perception***	***Interpretation***
6. Protection of soil and water	6.1. Processes to assure protection of downstream catchment values	4.225	High	4.2	Significant
	6.2 Processes to safeguard soil productivity and water retention capacity within production zone of forest area	4.4	High	4.25	Significant
	6.3 Processes for forest engineering	3.375	Moderate	3.85	Significant
	Average	**4**	**High**	**4.1**	**Significant**

Legend:			
	4.51-5.00	*Very high**	*Very significant***
	3.51-4.50	*High**	*Significant***
	2.51-3.50	*Moderate**	*No opinion***
	1.51-2.50	*Low**	*Insignificant***
	1.00-1.50	*Very low**	*Very insignificant***

(mean = 4.1), the quantity of community members depending on forests for their occupation (mean = 3.875), the coaching, capacity building, and workforce development programs for forest workforce (mean = 3.925), the area of forests use for traditional and customary lifestyles (mean = 4.05), the area of forest sites allotted and accessible for research and instruction, and tourism activity (mean = 3.975), the quantity of significant cultural, and spiritual sites discovered and safeguarded (mean = 4.175), the level to which user rights of indigenous cultural community over publicly owned forests are acknowledged and practiced (mean = 4.45), and the indigenous knowledge is utilized in forest management planning and implementation (4.0) are all significant. Besides, they have perceived that the participation of indigenous cultural community, local people, and other forest inhabitants, in forest management capacity building, discussion, decision-making, and implementation is very significant, having a mean of 4.80.

Table 7. Awareness and perception of the respondents on the economic, social, and cultural aspects.

		Awareness	***Interpretation***	***Perception***	***Interpretation***
7. Economic, social, and cultural	7.1 Worth of produced wood, non-wood forest products in the market	3.375	Moderate	3.525	Significant
	7.2 Forest products industry organization and effectiveness	3.6	High	4.1	Significant
	7.3 Presence and enactment of conflict resolution procedures for solving disagreements between interested party.	3.775	High	3.875	Significant
	7.4 Quantity of community members depending on forests for their occupation	3.825	High	3.925	Significant
	7.5 Coaching, capacity building, and workforce development programs for forest workforce.	3.325	Moderate	3.825	Significant
	7.6 Area of forests use for traditional and customary lifestyles.	3.825	High	4.05	Significant
	7.7 Area of forest sites allotted and accessible for research and instruction, and tourism activity.	3.9	High	3.975	Significant
	7.8 Quantity of significant cultural, and spiritual sites discovered and safeguarded.	3.85	High	4.175	Significant
	7.9 Level to which user rights of indigenous cultural community over publicly owned forests are acknowledged and practiced.	4.425	High	4.45	Significant
	7.10 Indigenous knowledge is utilized in forest management planning and implementation.	3.725	High	4	Significant
	7.11 Participation of indigenous cultural community, local people, and other forest inhabitants, in forest management capacity building, discussion, decision-making, and implementation	4.65	Very high	4.8	Very significant
	Average	**3.84**	**High**	**4.06**	**Significant**

Legend:			
	4.51-5.00	*Very high**	*Very significant***
	3.51-4.50	*High**	*Significant***
	2.51-3.50	*Moderate**	*No opinion***
	1.51-2.50	*Low**	*Insignificant***
	1.00-1.50	*Very low**	*Very insignificant***

3.3 Relationship between socioeconomic characteristics and awareness of applicable criteria and indicators (C & I) of the community in Bgy. Manalo, Puerto Princesa City

The relationship between socioeconomic characteristics and awareness level on the suitable C & I in Bgy. Manalo was analyzed using the non-parametric Spearman correlation test, except for gender, where the point-biserial correlation was applied. **Table 8** shows that livelihood has a p-value of 0.030 and a positive coefficient. The p-value is less than 0.05 alpha level (0.030 < 0.05). Therefore, the livelihood and awareness level on the relevant C & I significantly correlates (positive correlation). Also, income has a p-value of 0.000 and a negative coefficient. The p-value is less than 0.01 and 0.05 alpha level (0.049 < 0.01 < 0.05). Therefore, the income and awareness level on the suitable C & I significantly correlates (negative correlation).

Table 8. Socioeconomic characteristics and awareness level on the suitable C & I in Bgy. Manalo.

Level of awareness	Coefficient	P-value
Age	–0.306	0.055
Gender	0.273	0.088
Civil status	–0.060	0.713
Educational Attainment	–0.115	0.478
Livelihood	0.343*	0.030
Income	–0.528**	0.000
No. of years living in the community	0.112	0.493
***Significant correlation at the 0.01* **.Significant correlation at the 0.05*		

3.4 Relationship between socioeconomic characteristics and perception of the importance of applicable criteria and indicators (C&I) of the community in Bgy. Manalo

Similarly, statistical treatments were applied to determine the relationship between socioeconomic characteristics and perception of the importance of the suitable C & I in Bgy. Manalo. **Table 9** shows that age obtained a p-value of 0.021 and a positive coefficient. Therefore, the age and perception of the importance of the relevant C & I have a significant correlation (positive correlation). Gender, livelihood, civil status, educational attainment, livelihood, and income have a weak negative correlation, while the number of years living in the community has a trivial positive correlation.

Table 9. Socioeconomic characteristics and perception on the importance of relevant C & I in Manalo.

Perception to importance of applicable C & I	Coefficient	P-value
Age	0.363*	0.021
Gender	–0.233	0.147
Civil status	–0.155	0.339
Educational Attainment	–0.163	0.316
Livelihood	–0.175	0.280
Income	–0.032	0.844
No. of years living in the community	0.116	0.475
*. Correlation is significant at the 0.05 level (2-tailed).		

3.6 Evaluation of sustainability

The evaluation of the mangrove management sustainability is mainly based on the mean scores of each criterion [15], presented in **Table 10**. Verifiers through a Likert scale of 1-3 (1 = Poor, 2 = Fair, 3 = Good) were used to quantify each indicator for each criterion. The meaning of 1.29 on Criterion 1 translates to poor condition. Reasons such as lack of policy implementation for mangrove management, no awarded tenurial instrument to the community, no available funding for mangrove forest management and protection, no existing adopted technology for the management, and low capacity of the community in mangrove management planning may be associated to the result of the assessment. Meanwhile, Criterion 2 has a mean score of 2.20 or fair condition. Note that there have been neither significant good nor bad changes in the mangrove area for the last five years. Only 70% of the mangrove area is in good condition. The mangrove management system garnered a mean of 2.50 (Fair Condition) on Criterion 3.

An estimated 10% of the total area was degraded and disturbed caused by human activities. Also, an estimated 2% of the total area was damaged or affected by natural calamities. Criterion 4 has a mean score of 1.67 or fair condition. During the focus group discussion, it was found that there is no existing inventory system of harvested products (wood and non-wood) from the mangrove area.

Criterion 5 has a mean score of 1.25, which is considered poor condition. There are no implemented procedures to protect the wildlife in the area. Also, Criterion 6 has a rating of 1.67 (fair condition). The management has procedures to protect water, soil productivity, and water retention capacity within the production forest but has not implemented them. In terms of forest engineering, there is no existing plan or implemented plan provided. Lastly, Criterion 7 has a mean score of 2.00, under poor conditions. Their existing management has no structure for forest product industry efficiency and no available forest site for recreation, research, and educational use. The community has an existing conflict resolution mechanism but has not implemented it. In addition, there is a high level of involvement of the indigenous cultural community in the management. The traditional practices of Tagbanua were adopted in their management system. In the case of Tagpait, Aborlan mangrove, indigenous people use traditional practices in implementing ecotourism to protect mangroves and generate income [16]. Sustainable forest management practices provide welfare impact like in the case scenario presented in Sabah, Malaysia where the reduction of harvested area or control of harvest of natural resources and increase in market access may provide higher social benefits [17].

Based on the individual rating of seven criteria, the overall rating of the sustainable mangrove management system of Bgy. Manalo is 1.80, which implies a fairly sustainable mangrove management system.

In addition, the Sustainable Index for Individual Criteria (SIIC) and the Overall Sustainability Index (OSI) were applied to the mean scores of each criterion further to assess the status sustainability of the management approach. These are mathematically expressed as:

Table 10. Mean of scores for each criterion.

Criteria	Score
C1 enabling situation of SFM	1.29
C2 area and situation of forest	2.20
C3 forest health	2.50
C4 forest production	1.67
C5 biodiversity	1.25
C6 protection of soil and water	1.67
C7 economic, social, and cultural	2.00
Grand mean	**1.80**
Note: If > 2.5 (Good); > 1.5 ≤ 2.5 (Fair); ≤ 1.5 (Poor)	

$$SIIC = \frac{Sum\ of\ Weighted\ scores\ of\ indicators}{number\ of\ indicators\ in\ the\ respective\ criteria}$$

$$OSI = \frac{Sum\ of\ SIIC}{Number\ of\ Criteria}$$

Source: Based on Pokharel et al., 2015.

The sum of scores for each indicator is presented in **Table 11**. Criterion weight and a number of criteria and indicators were utilized in the calculation. 14.28% is the criterion weight which is evenly divided into seven criteria. It is highly sustainable if the computed value of SIIC and OSI is ≥ 0.40 and ≥ 0.25 if moderately sustainable. Also, if the value is < 0.25, it is poor or low sustainable.

Table 11. The sum of scores for each indicator of the criteria for Sustainable Mangrove Forest Management.

Criterion	Sum of scores
Criterion 1	9
Criterion 2	11
Criterion 3	5
Criterion 4	5
Criterion 5	5
Criterion 6	5
Criterion 7	22

Table 12 presents the sustainability index for individual criteria of the mangrove management system of Bgy. Manalo, Puerto Princesa City. Each criterion should be improved in order to have a highly sustainable mangrove management system—the computed overall sustainability index of Bgy. Manalo mangrove management system is 0.26, which is

considered moderately sustainable.

The evaluation of the sustainability of the mangrove forest management system is a useful mechanism for sustainable mangrove forest management. In Indonesia, the evaluation of the sustainability of mangrove management was adopted as their planning and management tool for its sustainability. In the mangrove forest in Damas Beach, Trenggalek, Indonesia, the status of management is unsustainable because the ecological dimensions fall under fairly sustainable. Also, the economic, social, legal and institutional category falls under the less sustainable category due to the conversion of mangroves into coconut plantations [18]. In the case of North Sumatra, Indonesia, mangroves ecotourism was adopted as a mechanism for sustainable management of mangrove, particularly in improving ecological, social, and economic dimensions, including the local community from upland [19]. Their management, the upland ecosystem and upland communities are directly part of their sustainable mangrove management. In the case of the Matang mangrove reserve in Malaysia, the local community is aware that the mangrove provides charcoals and timber but is not knowledgeable about other services like carbon sequestration, which serves as a barrier to sustainability [20].

Table 12. SIIC and OSI values.

Criteria	**SIIC**
Criterion 1	0.18
Criterion 2	0.31
Criterion 3	0.36
Criterion 4	0.24
Criterion 5	0.18
Criterion 6	0.24
Criterion 7	0.29
(OSI)	**0.26**
Note: Highly sustainable if ≥ 0.40; moderately sustainable if ≥ 0.25 but < 0.40; poorly sustainable if < 0.25.	

4. Conclusions and recommendations

4.1 Conclusions

The sustainability of a mangrove management system is inseparable from continuous monitoring and improvement of the weak points. No monitoring tool is "one size fits all"; hence, there is a need to formulate one such that it encompasses the monitoring indicators that are appropriate to the context. After a series of data gathering, 35 indicators under the seven criteria were identified as applicable to managing mangroves in Brgy. Manalo, Puerto Princesa City. The result of the initial application of the monitoring tool concludes that there is moderate sustainability in the current mangrove management system. The management was even rated with low sustainability on four criteria. These problems, when not addressed, could jeopardize the availability of the mangroves' ecosystem services to the nearby community. Information in this study would be a call to both leaders of the organizations and the community residents to create actions that could strengthen the weak management points and reinforce the strong ones.

4.2 Recommendations

The authors of this study have created a monitoring tool that applies to the current mangrove management system in Brgy. Manalo, Puerto Princesa City. The tool is crafted to be appropriate, convenient, easy to use, and requires less technical knowledge. It is highly recommended that the governing organization adopt this tool when conducting a regular assessment of the sustainability status. This tool is also helpful in determining both the strong and weak points of the management. Leaders could now create action plans focusing on these identified points to enhance the overall sustainability status of the management approach. The academe is willing to provide technical support to the community leaders in addressing the issues related to mangrove management.

With a few modifications, the monitoring tool can be applied to other mangrove communities in the city. Using this tool would capacitate the leaders in improving the sustainability of the mangrove management so that the residents would maximize the benefits from the mangroves. It is suggested that

more research and extension activities be conducted in other mangrove areas.

Author Contributions

The first author served as the team leader, who was directly involved in proposal making, instrument development and validation, data gathering, data analyses and report writing and revisions. The second to fourth authors were directly involved in instrument development and validation, data gathering, data analyses and report writing. The rest of the authors including the last author were directly involved in instrument development and validation and data gathering, report improvement. Also, the last author was directly involved in writing and paper revision.

Conflict of Interest

There is no conflict of interest.

Data Availability Statement

Data stated in this paper can be publicly available. The use of data can be for reading and citation only. The publicly available data are only those stated in the manuscript and some data that are not allowed to be disclosed are not stated.

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