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Opinion

Mangrove-Based Carbon Market Projects: 15 Considerations for Engaging and Supporting Local Communities

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Abstract: Mangroves provide numerous ecological, social, and economic benefits that include carbon sequestration, habitat for biodiversity, food, recreation and leisure, income, and coastal resilience. In this regard, mangrove-based carbon market projects (MbCMP), involving mangrove conservation, protection, and restoration, are a nature-based solution (NbS) for climate change mitigation. Despite the proliferation of blue carbon projects, a highly publicized need for local community participation by developers, and existing project implementation standards, local communities are usually left out for several reasons, such as a lack of capacity to engage in business-to-business (B2B) market agreements and communication gaps. Local communities need to be engaged and supported at all stages of the MbCMP development process to enable them to protect their ecological, economic, and social interests as custodians of such a critical ecosystem. In this paper, we provided 15 strategic considerations and recommendations to engage and secure the interests of local communities in the growing mangrove carbon market trade. The 15 considerations are grouped into four recommendation categories: (i) project development and community engagement, (ii) capacity building and educational activities, (iii) transparency in resource allocation and distribution, and (iv) partnerships with local entities and long-term monitoring. We expect our study to increase local participation and community-level ecological, social, and economic benefits from MbCMP by incorporating equitable benefit-sharing mechanisms in a B2B conservation-agreement model.

Keywords: blue carbon; carbon credits; carbon trading; local livelihoods; IPLCs; coastal ecosystems

1. Introduction

The term "blue carbon" refers to the carbon that is specifically stored in marine and coastal ecosystems such as mangroves, seagrass meadows, and saltmarshes, occupying

0.2% of the globe [1–3]. The soils in these blue carbon ecosystems sequester and store 10-fold more carbon than terrestrial ecosystems [3]. Mangrove forests can sequester, on average, 6 and 8 Mg CO_2e/ha per hectare annually, and this rate is two-to-four-fold higher than that of mature tropical forests [2,4–6]. Restoring one hectare of mangrove forest has, on average, a carbon capture and storage capacity that exceeds that of the same area of restored terrestrial forest by more than five-fold [2]. Due to their carbon sequestration potential, conserving, protecting and restoring mangroves provide a very effective method of mitigating climate change [6,7]. Thus, as a blue carbon market project investment, mangroves are among the most effective natural climate solutions to build climate-resilient coastal environments [3].

Mangrove-based carbon market projects (MbCMPs) involving conservation, protection and reforestation efforts, have been increasingly developed and implemented in recent years and have gained increased prominence in the global natural climate solution/blue carbon markets [2]. The contribution of MbCMP towards conserving, protecting and restoring coastal ecosystems is globally acknowledged, and the value of voluntary carbon markets' issuances exceeded USD 1 billion in 2021 [3]. The inclusion of MbCMP in the voluntary carbon markets (VCM) allows for the industrial sector (e.g., private companies and investors) to intervene and earn carbon offset credits to neutralize their carbon footprint [3]. When included in the national REDD+ strategies of countries, mangrove conservation, protection and restoration projects can help governments to meet their Nationally Determined Contribution (NDC) commitments under the Paris Agreement. The price derived from blue carbon credits is, on average, nearly three-fold more than that of REDD+ generated credits, and the surge in the blue carbon prices is expected to continue in the coming years [3]. The higher price for blue carbon credits is driven by the overwhelming demand from companies to fulfill their net-zero targets, and the increasingly limited supply of blue carbon offsets credits to meet this growing demand [3].

The growth of MbCMP is undermined by several major concerns and challenges. These include issues associated with transparency, scalability, region-specific policy implementations, methodologies for accuracy assessments, standard protocols for reporting, long-term monitoring, and initial capital investment, amongst others [8–11]. There are also critical issues related to equitable benefit allocation, negotiation of user rights, avoidance of leakage, options for alternative revenue generation, and inadequate consultation, involvement and participation of indigenous peoples and local communities (IPLCs) [9,12,13]. These challenges limit the confidence and trust of IPLCs in MbCMP, thereby hindering the expansion and adoption of these projects at scale.

The design of community-led MbCMP prioritizes broad community benefits, climate resilience, and biodiversity conservation, protection and restoration, along with direct financial gains to individuals. These projects are most likely to be successful when they include IPLCs who are custodians of the mangroves and land and live within and around these forests. Research describing how carbon markets impact IPLCs will provide insights into how best the interest of this important stakeholder can be secured and enhanced. Previous studies have reported how the mangrove carbon market has influenced changes in economic development, cultural aspects, and ecosystem enhancement with biodiversity [14–16]. The benefits of MbCMP to IPLCs are mostly reflected in the salaries of NGO managers, the individual recruits and financial incentives to planters in the form of food and/or daily stipend provision during days of fieldwork. Community benefits, such as improved social amenities (e.g., water, education, and health) and enhanced biodiversity, have also been found to indirectly boost household incomes by freeing up time for livelihood activities and improving fisheries production. However, in many cases, inadequate consultation, involvement, and participation of IPLCs, in combination with a lack of co-benefit monetization, have undermined community development, economic resilience, and social empowerment.

The main objective of this study is to provide strategic recommendations for engaging and supporting local communities associated with MbCMP. The study findings

were derived from the literature related to mangrove-based carbon markets, which stated challenges and benefits associated with transparency and governance [17–22], risk management [23–25], capacity building and education [9,26–28], securing land tenure [29,30], establishment of partnerships [26,31], accessing information [21], the understanding of cultural value [20], conflict management [32,33], gender inclusivity and empowerment [22,24], and long-term monitoring [31]. These findings were supplemented with knowledge of experts in the field, ranging across academia, industry, public and private sectors in areas of blue carbon market projects, economy, policy, community livelihoods, and mangrove forest management. The study also integrates our own experiences when working with blue carbon market project developers, implementing NGOs, and local communities involved in MbCMP.

We categorized the strategic recommendations into four groups: (i) project development and community engagement; (ii) capacity building and educational activities; (iii) transparency in resource allocation and distribution; and (iv) partnerships with local entities and long-term monitoring. The 15 considerations we outline under the above four groups of recommendations (Figure 1) can be used to encourage mangrove blue carbon project developers, blue carbon market stakeholders, researchers, practitioners, lawmakers, governments and NGOs to encourage investors to integrate local communities at all levels of project development and carbon pricing. It must be noted that several of our recommendations and considerations are based not on theoretical limitations in existing carbon market standards but on practical experiences with MbCMP. They are aimed to improve implementation practices so that the ecological, social, and economic co-benefits are equitably shared with IPLCs, particularly in terms of income and capacity building. This approach is intended to secure long-term IPLC engagement and participation and ensure the success and sustainability of these nature-based solutions (NbS) projects. Ultimately, we hope that the propositions made here will help increase global acceptance and adoption of MbCMP and assist with the successful and sustainable implementation of these projects by local communities.

Figure 1. Recommendations and considerations for engaging and supporting local communities in mangrove-based carbon market projects.

2. Considerations for Engaging and Supporting Local Communities

MbCMP needs to ensure that local communities are supported in an equitable way and that they are engaged and participate in all the major stages of the operations to attain global credibility. The prescribed methodologies of the existing standards for MbCMP, such as Plan Vivo and the verified carbon standard (VCS) of Verra, recognize the role of local communities in the MbCMP. The Plan Vivo standard highlights the importance of pricing under co-benefit schemes [34,35], community participation, stakeholder consultation, and informing the community about the indirect cost and benefits (climate, communities, and biodiversity credits) of MbCMP [14]. This plan also emphasizes the importance of establishing the rights and responsibilities of the parties involved in the project [20], the scientific and technical capacity of project parties [26], and enabling communities to plan and have alternative sources of livelihood [36]. On the other hand, the VCS standard stresses a key point: the critical role of monitoring, reporting, and verification (MRV) activities of any carbon project, entailing data requirements and data-collection capacity (capacity-building requirement) [36]. Likewise, the Free, Prior, and Informed Consent (FPIC) principle (often inherent in customary laws) is a crucial component of these projects as it ensures that IPLCs are adequately informed, consulted, and voluntarily agree to the project's terms before it begins [37].

Although certified MbCMP under organizations like Plan Vivo and VCS are designed to ensure that a significant portion of revenue from carbon credit sales benefits local communities with transparent allocation through community meetings, meeting all their requirements can be challenging. For example, projects certified under Plan Vivo, like Mikoko Pamoja in Kenya, faced challenges related to limited livelihood and income opportunities for community villagers due to low carbon prices at the project's inception [14]. Additionally, Wylie et al. [9] pointed out that certain projects did not consider the impacts of sea level rise and climate change in the planning stages, which was related to MRV deficiencies, highlighting the requirement for MRV training and capacity building within the local communities involved. In the case of the Tahiry Honko project, there existed a lack of project governance, unclear roles and responsibilities of national authorities, and insufficient technical knowledge and skills training in remote areas such as Baies in Madagascar [26]. In this project, no carbon credit certificates were issued due to the country's policy and legislative framework, which assigns carbon rights to the government and lacks a mechanism for transferring these rights to another entity [26].

However, adopting or revising existing national policy frameworks relevant to specific projects could be a constructive step forward. For example, Kenya had amended its climate change act for the Mikoko Pamoja and Vanga Blue Forest projects, incorporating carbon markets with strict regulations on community involvement and equitable benefit sharing [9]. Initiatives such as the India Sundarbans mangrove restoration project under the VCS faced issues related to deforestation, livestock grazing, and aquaculture [9], which led to loss in newly planted mangroves, reflecting the lack of awareness and need for community education. Several gaps, such as inadequate consultation and due diligence, power imbalance, lack of genuine participation, transparency issues, unclear benefit-sharing mechanisms, complexity of administrative processes, and missing channels for resolving disputes, often exist in the implementation of FPIC projects [37].

This section offers a comprehensive overview of 15 key considerations grouped under four recommendations (Figure 1) that can help with the integration and engagement of local communities as primary stakeholders into MbCMP development initiatives. Through implementing these recommendations and associated considerations, blue carbon developers can accomplish appropriate benefit-sharing goals by monetizing co-benefits, fostering community involvement, and boosting the overall impact of mangrove restoration, protection, and conservation efforts in MbCMPs.

2.1. Project Development and Community Engagement

The MbCMP development cycle consists of three main stages that include project/program design, carbon development, and carbon monetization [3]. These carbon projects undergo pre-feasibility assessments, project implementation, MRV and carbon credit sales [38]. In this case, multiple stakeholders are involved, including carbon project developers, local communities, independent third-party auditors, and buyers of offset credits [3,39].

2.1.1. Involvement from Early Stages

Local communities, as primary custodians of mangrove forests, should lead (or at the very least be actively involved in every stage of) MbCMP development, especially during the pre-feasibility assessment [38]. Such involvement should be formalized through signed Memorandum of Understanding (MoUs), conservation agreements, and/or business-to-business (B2B) agreements [40,41]. Additionally, these agreements should be signed between the carbon project developer and the local communities, funder(s) and local communities, international implementing NGOs and local implementing NGOs, and local communities and decentralized government agencies. The agreements should provide clear tasks, responsibilities, a co-benefit sharing scheme, long-term management, and the sustainability of the project, among other essential terms [42]. The MoUs and B2B agreements will serve as legally binding documents between local communities and the external stakeholders from the very start and should protect the rights and benefits (ecological, economic, and social development) of local communities. Our insights from grassroots organizations recommend the establishment of a B2B agreement between carbon developers and community-based entities/enterprises/cooperations.

2.1.2. Clear Project Development Plan in Advance

A clear project development plan of action should be developed for each phase across all the stages of the MbCMP development. For example, a clear plan for the project design, stakeholder engagement, project implementation, MRV, carbon credit sale, and long-term project management phases should be schemed and made public for review, revision, and approval by local communities [38]. MbCMPs (such as Mikoko Pamoja in Kenya, markets and mangroves in Vietnam, the Sundarbans mangrove restoration project in India, and blue forests in Madagascar) analyzed by Wylie et al. [9] demonstrated the benefits of a well-defined project design (e.g., sustainable shrimp farming, empowerment of local women, etc.) that integrates livelihood aspects and involves community members in multiple stages of planning and implementation. Another example is the Yagasu project in Indonesia, where people from local communities were involved in tree planting, monitoring tree mortality activities, and patrolling to prevent illegal activities in mangrove areas [14].

The plan of action should also include local capacity development, protection of rights around decision-making and negotiation of carbon pricing, and the envisaged benefit-sharing scheme to retain and sustain local community participation. Local community involvement from an early stage should also involve a clear plan on material and financial provisions and the employment of members of IPLCs that have local skills and ecological knowledge as a livelihood improvement component [9]. The development of a clear project development plan that is locally binding increases local and public belief, trust, transparency, and support for MbCMP.

2.1.3. Understanding of Local Cultural Values

During pre-feasibility assessment in the project development stage, it is essential to carefully research and account for local culture, values, traditions, belief systems, and practices. These elements are pillars of community identity and are important for the success of MbCMP development and sustainability [33,43]. Where local cultural values, traditions, and belief systems are not recognised, community members do not see carbon

sequestration as a valid strategy [44]. This highlights the importance of proactivity in community education, communication, and preparation before implementation. Cultural respect also promotes social cohesion and community involvement. When projects align with local cultural values, it is more likely that they will gain support and participation. In turn, long-term success becomes more achievable if the project is supported and sustained by those whose lives are most affected by it. Understanding and respecting cultural values is a responsibility [44]. Communities have the right to maintain identity and autonomy as projects are implemented [45]. Integrating cultural values into project planning respects community values and strengths, which is the foundation for successful implementation [33]. Natural capital accounting can be applied to quantify cultural values as assets managed by IPLCs, thereby enhancing the overall value of the mangrove ecosystem.

2.1.4. Secure Land Tenure and Create Awareness of Individual Rights

Land tenure is a significant bottleneck for investment in MbCMP, particularly in mangrove-rich developing countries, where land tenure systems are multifaceted, involving many stakeholders [3]. During pre-feasibility assessment studies of the carbon project development cycle, securing land tenure rights and respecting individual land ownership rights is paramount to sustainable land management efforts. Therefore, mangrove restoration (afforestation/reforestation), protection, and conservation efforts must prioritize, from the very start, the securing of community land tenure rights and authorisation for activities such as mangrove planting. This requires genuine negotiation, effective communication, and official land tenure agreements with the communities and decentralized government agencies involved. Undertaking a robust process at this stage ensures that the land used for such an initiative does not disrupt local livelihoods, lives, rights, and practices. Secure land tenure assures communities that their land ownership, access, control, due compensation, and resource user rights are secured and protected [46]. Where land tenure rights are not secured and protected, the loss of livelihoods relating to the harvesting of dead mangrove wood for fuelwood and collection of fish, clam, oyster, and shrimp can be exacerbated [47].

Where several implementing NGOs intervene in the same landscape, such as in the Sine Saloum estuaries/deltas of Senegal, each implementing NGO must secure official land tenure rights and clearly demarcate their area of intervention as GIS (Geographic Information System) polygons to avoid potential conflict among stakeholders. Increasing awareness and knowledge of individual and community land tenure rights is crucial, such that MbCMP does not come at the cost of local land tenure rights and cultural practices [14,48]. It is important to provide local leaders, who are key decision-makers, with the necessary support in applying FPIC frameworks, especially since some IPLC groups have previously misunderstood the legal consequences of land transfers to external parties [37]. Alternative tenurial systems where the local communities have an opportunity to manage ecosystems owned by government or private entities should also be explored.

2.1.5. Protocols for Conflict Resolution

The MbCMP development process might lead to conflict between stakeholders across various phases and stages, especially during project implementation, MRV, carbon credit sale, and benefit sharing. Conflicts can result when local people and the implementing NGOs believe that their local ecological knowledge, material and financial support for project implementation, and agreed rights and economic benefits are overlooked by the carbon project developer and/or other technical NGO partners. Conflicts can also occur when the carbon project developer and/or funder believes that local people and implementing NGOs are misappropriating and mismanaging project funds and not meeting agreed targets, deliverables, and deadlines. Such conflicts should be anticipated, and a fair and equitable conflict resolution plan and protocol should be formulated in advance to guide conflict reporting [48]. In a similar vein, it is important to ensure that the FPIC approach, when implemented, includes measures to prevent the perpetuation of existing

inequalities, as power imbalances may exist within local communities and/or between different cultural groups [37].

Conflicts should be resolved through dialogue in scheduled meetings with all the stakeholders concerned in an open and amicable manner without any bias, pre-conceptions, or pre-conditions. The conflicting parties should be bound by a contract to report their accrued grievances to official partners (carbon project developers, NGOs, funders, local communities, government agencies, etc.) in a signed written document that forms the basis for fair deliberations made in good faith [49,50]. Resolutions should be made and shared with the conflicting parties for effective and judicious implementation to avoid a repeat of similar conflict and sustain the progress of the project. Project stakeholders should be required to resolve conflicting situations as soon as possible to ensure the conflict does not deteriorate or become irreversible. Robust leadership involving trust, respect, and transparency among the project stakeholders and team members should be demonstrated to minimize and avert potential conflicts. Conflicts with state agencies, carbon project developers, implementing NGOs, and local communities on the ground can be resolved following the same protocols [51].

2.2. Capacity Building and Educational Activities

2.2.1. Capacity Building and Skills Development

An assessment of the capacity of local communities is crucial for the success of MbCMP [52]. Conducting a thorough baseline survey and interviews with local community members during the pre-feasibility assessment phase will help evaluate their existing knowledge and skills in mangrove ecosystem management, carbon projects, and the implementation of FPIC principles [37]. Skill-set gaps can be identified and addressed through training during the carbon project development cycle [39]. Technical and professional areas of improvement for local communities usually include training around (a) mangrove planting and restoration techniques [29,53]; (b) the use of technology such as UAVs (unmanned aerial vehicles) and field-based standard operating protocols for MRV purposes [54]; (c) methods for quantifying mangrove ecosystem services (in particular, their carbon sequestration potential) [55]; (d) carbon markets and financial considerations involved in the management of these projects [11,38]; (e) awareness of local, national, and international environmental and carbon trading policies, as well as the development of skills for participating in policy advocacy and negotiations [11,56]; and (f) communication, market negotiation, and collaboration skills [29]. The provision of skills to empower livelihood alternatives or sources of income for local communities (e.g., ecotourism, fisheries farming, and sustainable aquaculture) is an invaluable means of increasing project participation, accountability, and ownership [57,58].

There should be a strong relationship between external experts and community members to enhance knowledge transfer. Robust training will empower local community members, reduce reliance on external stakeholders, lower costs, and enable more timely and frequent project activities. The development of local capability is invaluable in emergency response situations, such as during a natural hazard or a plant disease outbreak. For instance, in the Tahiry Honko mangrove carbon project, increased capacity building was recommended as project managers were not always able to depend on external support for fast-paced, knowledge-based responses to natural hazards [26]. Workshops, training, mentorship programs, and knowledge sharing by experienced community members can help locals drive and sustain their initiatives, preventing illegal practices like mangrove cutting [59].

2.2.2. Environmental Education, Internships and School Programs

Environmental education, internships, and school programs can be a tremendous influence on youth and help to build a generation of environmentally conscious citizens [60]. These three approaches can equip youth with skills and knowledge of the latest NbS (such as MbCMP) they may not acquire in other places and help them understand how to work

on environmental challenges in their communities. Education programs can provide a base of knowledge about ecosystems, conservation, climate change, the global ecosystem, and sustainability [28,61]. Internships and school programs complement education by providing an opportunity for practical use and application of the knowledge gained in the classrooms [17]. In particular, internships offer students exposure to potential career paths in the environmental sustainability sectors, perhaps piquing their interest or stimulating an already-present passion. School programs, which are run for early-age students, can do the same in terms of generating interest and providing practical opportunities and experiences [62]. Partnering with educational institutions to offer certifications or short courses to experienced individuals and newcomers is a suitable strategy to enhance mangrove education in local communities. Additionally, these approaches can facilitate the effective integration of FPIC principles into ongoing projects and help bridge the gap between understanding (knowledge) and implementing (practice) people's rights, which is an ongoing challenge within the FPIC framework [37].

2.2.3. Formation of Local Leadership Groups and Representative Committees

Local communities in mangrove-rich countries, particularly in developing countries, usually have a wide range of existing and structured leadership groups. These groups often include traditional, ethnic, women, men, youth and neighborhood groups, and mangrove management committees. Where some do not exist, they can be easily formed for the purpose of the carbon development project to strengthen effective leadership, communication, and capacity-building outcomes. Working with existing and newly formed groups in general ensures community voices are integrated in the overall process. A participatory approach is essential for emphasizing inclusivity, transparency, and representativeness. The identification of individuals for the leadership groups and representative committees should be established based on a clear protocol and criteria such as experience, knowledge, community trust, team building and cohesion, and connections with other stakeholders (e.g., local authorities, academia, and NGOs, among others) [63,64]. The group members should have a deep understanding of the community and its dynamics. During the formation of leadership groups, a third party should guarantee transparency in the election or nomination processes to ensure legitimacy and acceptance of the committees, while roles and responsibilities should be clearly defined to avoid overlaps and ensure accountability [29]. Special care should be taken to avoid the incorporation of a majoritarian approach (i.e., equating consent of the majority of committee representatives to be equal to the agreement of the entire community), which is often followed within FPIC frameworks [37] for amplifying the voices of minority groups.

Leadership can be enhanced by acknowledging the contributions and role that the local community leaders play and fostering a sense of community ownership in the development of MbCMP. This harmonizes economic and environmental objectives and community commitment to the long-term actors involved. The creation of local groups that include multidisciplinary individuals with diverse representation provides a more robust handling of queries and concerns of the general community [65]. Leadership and local participation can be enhanced by offering attractive management options such as fund management, livelihood alternatives, and local community development incentives such as the provision of water, electricity, schools, roads, and health infrastructures.

2.2.4. Gender Inclusivity and Empowerment

In several MbCMP, especially in countries such as India, Indonesia, Kenya, and Madagascar, gender inclusivity was allotted specific importance to promote the empowerment of women so that they have a voice in the decision-making process of their community [9,14]. In the case of the Mikoko Pamoja blue carbon project in Gazi Bay, Kenya, women were able to earn income by planting mangroves, which increased their participation and financial empowerment [9]. Similarly, Gazi women created the "Gazi Women Mangrove Boardwalk", which provided them with an income from ecotourism that supported their

community [14]. Within the Indian Sundarbans, women were empowered through the establishment of self-help groups [65].

Allowing women to have the chance to learn more about mangroves and, most importantly, about their cultivation and preservation can contribute significantly to the success of MbCMP and address concerns related to social exclusion within FPIC frameworks [9,37]. Further research should be undertaken in this area to: (i) understand how capacity building and educational initiatives focused on promoting gender inclusivity could benefit women psychologically, (ii) identify metrics to monitor women's involvement in ongoing activities, (iii) investigate elements of the current policy framework that hinder women's inclusion in leadership roles, and (iv) identify the factors that make women feel more welcome during various stages of decision making in the MbCMP development cycle.

2.3. Transparency in Resource Allocation and Distribution

2.3.1. Equitable and Transparent Distribution of Benefits

MbCMP often faces challenges such as inadequate transparency in MRV activities, carbon accounting, carbon credit sales, and benefit sharing, which can lead to local communities being overlooked [39,66,67]. Local communities are mostly involved in the project pre-feasibility assessment, implementation, and MRV, but not in the carbon credit sale market negotiations and decision-making on benefit-sharing schemes. They only receive what they are provided as economic/financial benefits, with no decision-making or negotiation power when it comes to the market (trading carbon) or finances and benefit sharing. The carbon market is complex, with limited information flow and transparency in derived data and financial gains, especially to the local implementing NGOs and local communities [38]. As such, MbCMP should be collectively supervised during all the stages of the carbon project development cycle, and all data from baselines and project scenarios should be shared with local community stakeholders, made public in reports (whenever possible), and be open for scrutiny, discussion, and feedback. The economic benefit-sharing scheme should be equitable and transparent in terms of distribution and shared benefits to local communities and other local stakeholders. This should enable the carbon project developers and funders to build transparent, long-lasting partnerships and monetized co-benefits with local communities to retain and sustain community engagement and support for the blue carbon projects when funding ends.

2.3.2. Timely Sharing of Results and Active Interactions

Effective communication and transparency are crucial at all stages of project implementation. Timely sharing of results from baseline and project scenarios, as well as MRV, with local communities and stakeholders is crucial for fostering trust, accountability, addressing feedback, and enhancing project outcomes [68,69]. This sharing keeps all parties informed about progress and impact, while active engagement with community stakeholders provides an opportunity to listen to community opinions, concerns, and suggestions [69,70]. This approach acknowledges and respects the community interests, demonstrating a commitment to shared goals and values, and it can reassure the community that time, labor, and land are not being wasted. Moreover, issues related to simplifying the concept of "consent" (under FPIC frameworks) [38], which can render initial consent outdated with changing conditions, can be mitigated in this context.

2.3.3. Diversification of Economic Resources

The development of MbCMP that relies solely on income from carbon credits can be risky for local communities. The fluctuating prices, an underdeveloped and non-standardized market, delayed returns, and vulnerability to climate change and natural disasters all contribute to this risk. To mitigate these concerns, local communities should be provided with opportunities to diversify the economic revenue streams. Income from payment for ecosystem services (particularly ecotourism), as demonstrated by projects in Kenya, Indonesia, Malaysia, Philippines, Thailand, and Vietnam, offer fund diversification

options [71–74]. Income from fisheries, silvofishery, and aquaculture provides options for livelihood revenue diversification and has been successfully tested in countries like the Philippines and Indonesia as by-products of MbCMP that support local economic resilience [72,75]. In many regions, local communities are also heavily dependent on the sale of sustainably harvested wood for fuel and fodder [76,77]. Non-timber products (such as honey, wax, medicinal products, etc.) and agroforestry options have also been explored as by-products of MbCMP [78,79]. This kind of revenue diversification can help bring more economic resilience and minimize overall risks while increasing the confidence and motivation of investors [80]. Diversification of economic resources can be powered by novel capacity-building practices that provide access to more markets, financing options (e.g, microloans and credits, stable rural economic infrastructure, etc.) and conflict resolution training programs (as there might be opposing interests in matters of finance and sustainability).

2.4. Partnerships with Local Entities and Long-Term Monitoring

2.4.1. Partnerships and Collaborations

The success of MbCMP can be achieved through partnerships and collaborations. A collaborative management approach that integrates all stakeholders across various stages reassures local communities that their needs and interests are protected. Collaboration with NGOs can leverage people's expertise in community engagement and conservation practices. Research and academic institutions play a vital role in providing support and technical guidance, whereas the involvement of the private sector could leverage funding, resources, technology, and knowledge transfer [28,32,81]. The participation of international organizations and verification bodies such as Verra and Silvestrum provides a global perspective and approval of the MbCMP to ensure that the mangrove carbon credit can be sold in the open markets [82].

An effective way to attract stakeholders is to be assertive with the mission, intention, and processes that are meant to be applied in the project. If the involved organizations are harmonized with such integrity, the outcome is a powerful association most likely to succeed [83]. Establishing partnerships in the early stages of project implementation efforts through a multi-stakeholder platform enhances clearness and ease of access to impactful tools, statistics, and strategies. Moreover, the involvement of universities has positively impacted STEM disciplines directly focused on mangrove projects, not only by aligning efforts with the Sustainable Development Goals (SDGs) but also by improving data management, response times, and the integration of local knowledge [84].

2.4.2. Sustained Long-Term Monitoring and Validation Operations

Key priorities for long-term monitoring and management in MbCMP include ensuring the successful establishment of mangrove seedlings, removing stressors inhibiting natural regeneration, promoting healthy growth with high biomass content, and preventing the conversion of mangroves to other land uses. MRV operations are the go-to solution for mangrove initiatives as they provide both accurate information and effective forest management guidelines. Local communities are a key cornerstone for MRV of the MbCMP since they can provide regular field monitoring to ensure seedling survival and provide an early warning if any issue is occurring in the project site. Carbon developers should implement robust MRV systems to track the progress of the project by, for example, training local community members in MRV techniques to ensure continuous and reliable data collection [85]. Training programs could offer a mix of field-based (e.g., use of global positioning system (GPS), tree measurements, spotting leaf coloration, etc.), programming-based (e.g., software tools to analyze images), and remote-sensing-based (e.g., UAV mapping of regenerating forests in inaccessible areas, time series analysis of the study area using open-source satellite images, etc.) approaches. As a result, the following could be achieved: estimation of seedling counts, identification of diseases at early stages, mapping and monitoring of the mangrove extent, health and growth, carbon accounting, and identification of leakages [9,14,26]. UAVs

offer high-resolution imagery, which can be used to underpin monitoring and bolster forest management efforts [8,55,86,87]. The integration of remote-sensing technologies (especially light detection and ranging (LiDAR) and UAVs), state-of-the-art machine-learning tools, and field data can be used to provide an accurate assessment of the status of biomass content and forest health conditions [29,88–93]. This will significantly assist MbCMP, where standardized protocols for data collection and reporting need to be developed to ensure consistency and comparability over the monitoring periods.

The use of UAVs for the near-real-time tracking of mangrove biomass is crucial for the long-term monitoring of the dynamics of planted mangrove forests (especially under ex-ante carbon credit programs). This is plausible because UAV costs decrease over time compared to field-based and high-resolution satellite alternatives, which enable repeated and detailed surveys to generate accurate and up-to-date data for forest carbon measurement, optimization, and management [8,54,85,86]. Moura et al. [94] discuss the use of UAV imagery for species detection in regenerating forests, highlighting its effectiveness in accurately identifying small and young plants due to the ability to collect numerous data points at the tree level at a reasonable cost, something not feasible with satellite imagery. While field-based inventories can achieve similar results, they become challenging and cost-inefficient at larger scales. Previous studies in Iran [95] and China [96] have also demonstrated the use of low-cost UAVs for mapping coastal ecosystems and estimating the aboveground carbon stock (AGB) of mangroves at the tree level. Similarly, a study in Australia compared estimates from UAVs to field-based measurements for calculating canopy diameter, height, and AGB in mangrove forests, finding that UAVs saved approximately AUD 50,000 per hectare, which is a significant benefit for large-scale MbCMP [97]. Furthermore, when compared to high-resolution satellite imagery, UAVs offer better temporal resolution, especially on cloudy days, which is crucial for mangrove carbon projects in tropical regions with high humidity and frequent rain [98]. The use of UAV technology enhances project management and stewardship practices by providing detailed, real-time data that empower stakeholders and local communities to participate in monitoring activities [86,91,99].

2.4.3. Feedback Mechanisms

Various methods can be employed to collect feedback depending on the group, with each tailored to gather insights and perspectives of those participating in the project. With individual community members, personal interactions (e.g., interviews, surveys, questionnaires, etc.) can be of great use. These mechanisms allow personnel to directly engage with individuals and pursue a better understanding of concerns, preferences, and suggestions [100]. Ensuring anonymity in feedback collection is also crucial, as it encourages participation and open and honest responses. With larger groups, such as businesses and organizations, reports or larger surveys can be useful. These allow for a wider reach but still pave the way for detailed feedback on specific aspects of the project's implementation and impact. Effective communication and the use of feedback are also crucial for the task at hand. The analysis of all received feedback should be assigned to dedicated team members who can interpret it and communicate relevant information to the proper parties for later implementation [101]. Positive feedback, for example, on planted seedling survival and capacity-building outcomes delivered to local communities by the locally and internationally implemented NGOs increases social cohesion, team spirit, and local participation in community-led reforestation projects [102]. Likewise, feedback on verifiers assessing FPIC compliance is also crucial for helping IPLCs ensure that companies respect their rights and priorities under voluntary carbon market standards [37].

3. Concluding Remarks

MbCMPs are an effective NbS with immense potential for climate change mitigation while promoting coastal defense and biodiversity conservation. Nonetheless, the support of local communities is a necessity to ensure the successful implementation and long-term

sustainability of these projects. Our study underscores the importance of engaging local stakeholders from the early stages of carbon project development, ensuring transparency in management decisions, incorporating equitable benefit distribution, and fostering capacity building through educational initiatives and skills development. In this regard, we provided 15 considerations grouped under four major recommendations for engaging and supporting local communities that are grouped into four categories: (i) project development and community engagement, (ii) capacity building and educational activities, (iii) transparency in resource allocation and distribution, and (iv) partnerships with local entities and long-term monitoring. In addition to improving the success rate and scalability of projects, the adoption of these recommendations will improve the reliability and adaptability of management operations in MbCMP.

Furthermore, we acknowledge that MbCMP can be either operated by the local communities or by carbon developers. Despite the fact that both types of projects can face similar challenges in their development, we stress the relevance of the following considerations for engaging and supporting local communities in community-based mangrove carbon projects: clear project development plan in advance, protocols for conflict resolution, capacity building and educational activities (all considerations under this category), timely sharing of results and active interactions, diversification of economic resources, and partnerships with local entities and long term monitoring (all considerations under this category). On the other hand, for mangrove carbon initiatives that are operated by carbon project developers, the following considerations should be taken into account: involvement from early stages, clear project development plan in advance, understanding of local cultural values, secure land tenure and creating awareness of individual rights, protocols for conflict resolution, capacity building and educational activities (all considerations under this category), equitable and transparent distribution of benefits, timely sharing of results and active interactions, diversification of economic resources and partnerships with local entities, and long-term monitoring (all considerations under this category). The implementation of these recommendations will greatly assist the development of frameworks that promote environmental sustainability and climate change-mitigation practices while empowering local communities.

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