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# Mangrove community-based management in Eastern Africa: experiences from rural Mozambique

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**Introduction:** This study investigated a community-based management model in a mangrove-dependent community in central Mozambique and its adequacy as a management tool for conservation.

**Methods:** Satellite images were used to map changes in mangrove cover between 1996 and 2017. Individual interviews and Focus Group Discussions were conducted with community members to understand the mangrove restoration processes and management models.

**Results and discussion:** After unsustainable exploitation that led to mangrove deforestation, the local community engaged in a restoration and management program that started in the late 1990s. Local norms were delineated by the Natural Resources Management Committee (NRMC) aiming at (1) reducing extractive uses by introducing alternative income generating activities; (2) awareness and mangrove planting and (3) law enforcement. Ten hectares of forest were rehabilitated. However, the management system fails to exclude illegal cutters and to enforce regulatory and sanctioning mechanisms, due to resource limitations. More involvement from government authorities and other stakeholders is needed to enhance law enforcement and explore opportunities for carbon trading, tourism and payment for ecosystem services. Additional recommendations are to develop a community management plan and create alternatives to mangrove products and income. Mangrove community-based management is increasingly advocated in many developing countries to promote sustainable utilization of resources and conservation. Understanding the reasons behind the limited success and lessons learnt at this site will guide similar programs elsewhere in Mozambique and other parts of the globe.

KEYWORDS

**mangrove restoration, law enforcement, management of commons, natural resources sustainable management, community engagement**

# 1 Introduction

Despite its high ecological and social-economic importance (Kovacs et al., 2008; De Souza et al., 2017; Mozumder et al., 2018; Machava-Antonio et al., 2020) mangroves are globally threatened by several factors, such as overexploitation, urban development, pollution, aquaculture and climate change (Nfotabong-atheull et al., 2011; Banerjee et al., 2016; Li et al., 2016; Phong et al., 2017). In most developing countries, overexploitation of resources is the greatest threat, along with conversion to agricultural uses, coastal development, and natural extreme events such as floods and droughts as documented at the Volta Estuary (Ghana), Senegal, Mombassa (Kenya) and Mozambique (Rubin et al., 1999; Sakho et al., 2011; Bosire et al., 2014; Macamo et al., 2016; Feka and Ajonina, 2017).

Several global and local initiatives are being adopted to counteract these trends, among them protection of mangroves in different types of conservation areas and the restoration of degraded areas (Esteban, 2008; de Almeida et al., 2016). These measures however may not be effective in the long term if the primary causes of degradation are not tackled, thus new management approaches need to be adopted in the protected or restored areas (de Almeida et al., 2016). Community involvement in natural resources management is increasingly advocated giving its socio-economic and ecological outcomes (Leach et al., 1999; Abou-zeid et al., 2007). There are several examples across the globe of community based management, with varying levels of community involvement in the decision making process, law enforcement and community autonomy (Leach et al., 1999; Lynam et al., 2007; Datta et al., 2012; Bown et al., 2013). However, the outcomes of most of these initiatives were below expectations (Datta et al., 2012) because the collective management of resources is a very complex process, where success or failure depends on a great multiplicity of factors, many of which are totally specific to each site (Leach et al., 1999; Datta et al., 2012).

According to (Agrawal, 2003) the critical conditions for sustainable management of common resources include the characteristics of such resources, the characteristics of the community, the institutional arrangements and the external environment (Figure 1). Mangrove forests match all five resource characteristics that are critical for successful community-based management, but the risk of failure lies on the characteristics of the community, institutional framework and external environment (Ostrom, 1999). argues that having a larger numbers of participants in the management of common resources (particularly if with different cultural backgrounds and interests) may hamper the process of community organization and decision making, because the more diverse a group, the more difficult it is to find common interests and agreements. For instance, a community in a municipal village in the Honduras earned its livelihood from the exploitation of forest resources, with at least eight distinct groups of stakeholders with different interests and perceptions of resource uses – loggers, farmers, resin tapers, handicraft women, municipality, firewood and charcoal producers, a municipal corporation for forest development and a community forest association (Nygren, 2005). The conflicts arose at almost all levels, and the same group of stakeholders could be in conflict with more than one other group. This illustrates how important it is to understand the social and political processes through which the multiple actors interrelate and to promote community participation for effective management of the resources (Nath et al., 2017).

Many community-based models also fail because the relationship between costs and benefits does not encourage the participation of some groups, as seen in Tanzania, were poor groups had a much lower net benefit when compared to middle and rich classes (Meshack et al., 2006). The costs may include time and effort to participate in activities and attend community meetings, while benefits are usually ecosystem goods and services.

Community-based management of common goods also requires the existence of legal institutions that can intervene in favor of the community by controlling external factors that are beyond the jurisdiction of the community, as well as providing additional support for law enforcement and sanctioning (Agrawal, 2003; Berkes, 2006). For example, in the mangrove dependent

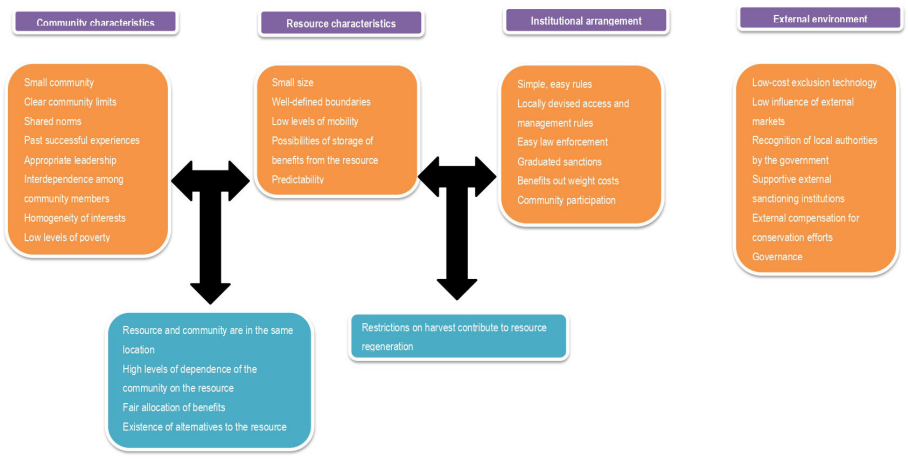


FIGURE 1
Critical conditions for successful; community-based management of common resoiurces. Modified from Agrawal 2003.

community of Koh Sralao (Cambodia), the community managed to organize themselves in a natural resources management committee, creating locally designed rules to protect the forests against illegal harvest of resources, destructive fishing gear and promoting environmental education and mangrove planting. The community also created a reserve area and imposed limits of the mesh size in swimming crab fishing to allow crabs to grow (Berkes, 2006). However, the community did not have appropriate mechanisms to enforce the local regulations to people from other nearby locations, or to exclude incompliant groups of users, even though they had the support from local NGOs and their institutions were recognized by the local authorities. This resulted in the collapse of a community-based management model that had significant outcomes.

Many studies on community-based management models focus on the assessment of only a few of the critical conditions for the success of the model, instead of using more holistic approaches that also try to understand the interrelations between such factors and the implications of the parts on the overall context (Leach et al., 1999; Meshack et al., 2006; Stone et al., 2008). Assessments also rarely detail the community's experience and perception of the outcomes of the management programs (Nguyen et al., 2016).

The aim of this study was to describe the community experience and critically analyze a mangrove community-based management model being implemented in a rural community in central Mozambique. By looking at its failures and success also in terms of the point of view of the community and program managers, the study identifies successful strategies and interventions for improvement that can be replicated elsewhere. The peculiar characteristics of the site include it being one of the few successful mangrove restoration programs in the country (Bandeira and Balidy, 2016), the community experienced traumatic impacts of mangrove degradation and engaged in a mangrove rehabilitation program (by their own initiative) in an area that is vulnerable to wood demands from a nearby town. The study also combines remote sensing techniques to assess the ecological outcomes of the management actions. Understanding the factors behind success and failure of mangrove rehabilitation programs is important in the regional and global context as mangrove rehabilitation and community based management is increasingly used as mangrove conservation and management tools, but few examples of success are known globally (Romañach et al., 2018).

# 2 Materials and methods

## 2.1 Description of the study area

This study was conducted at the Nhangau Administrative post, located in central Mozambique, some 30 km away from the second largest town of the country (Beira). Nhangau, with an estimated population of 3 000 inhabitants, features several rural characteristics despite administratively being part of Beira municipality. Agriculture, fishing and small-scale trade are the main economic activities. Nhangau is also a major provider of fishing products to Beira city. The restoration was conducted in Njalane (including Txondja neighbourhood), which is part of Nhangau administrative Post (Figure 2).

The area is part of the Mozambique Channel EBSA (Ecologically or Biologically Significant Marine Area), given its high productivity and species diversity which includes threatened and endangered species (https://www.cbd.int/ebsa/). The climate is tropical, with a rainy season from November to March and a dry


FIGURE 2
Location of the study area, showing Njalane.

season in the rest of the year. The average monthly precipitation is 121.9 mm, and mean temperature 25°C (Estatistica. Estatisticas do Distrito da Beira 2018 -2022. (2023)). Eight mangrove species occur in the area: *Avicennia marina* (Forssk.) Vierh., *Bruguiera gymnorhiza* (L.) Savigny, *Ceriops tagal (Pers.) C.B.Rob.*, *Heritiera littoralis* Aiton, *Lumnitzera racemosa* Willd.(1803), *Rhizophora mucronata* Lam., *Sonneratia alba* Sm., and *Xylocarpus granatum* K.D.Koenig. Marine species in the area include panaeid shrimp *Fenneropenaeus indicus* (H. Milne-Edwards, 1837) and *Metapenaeus monoceros* (Fabricius, 1798) (Gammelsröd, 1992; de Sousa et al., 2006); and sea turtles *Dermochelys coriacea* (Vandelli, 1761) and *Caretta caretta* (Linnaeus, 1758) (Robinson et al., 2016).

## 2.2 Mapping

High resolution images from the satellite Digital Globe repository on Google Earth were used in its digital format to identify and delineate natural and planted mangrove stands using a participatory approach with community members, members of the local Natural Resources Management Committee and government officials in a meeting (Aheto et al., 2016). The image covered the area between Ladrão and Mutamba Rivers. The participants identified the planted areas and respective year of planting, and all data were recorded. Mangrove planted areas are easy to identify due to the characteristic square-like shape. The geographical coordinates of the limits of each planting block were collected, as well as 50 randomly selected validation points in planted and natural areas. A field visit to all mangrove planted stands and natural areas was conducted afterwards with the same group of people for data validation. Most planted sites had indicative plates with information on the year of plantation, which helped with data validation.

Image processing and supervised classification followed by visual interpretation was carried out using ArcGIS 10.2 and ENVI 5.1. Data validation was done through field work based on the classes produced in the supervised classification. This allowed the correction of misclassifications generated by the supervised classification algorithm. The procedures for accuracy assessment were applied through random validation points from field sampling using a confusion matrix, which shows the proportion of misclassified and well classified pixels in a matrix. Based on this, the calculated overall accuracy and k coefficient were 72.97 and 0.45 respectively. The natural area was mapped as dense and sparse mangrove area and planted mangrove stands that were identified for different years since 1996.

## 2.3 Mangrove uses, restoration and forest management

Participatory rural appraisal methods were used to collect historical information on causes of mangrove degradation, current and historical uses of mangroves, the restoration process, and details on the management actions for mangrove sustainable use. The data collected were also used to identify the strengths and weaknesses of the Nhangau mangrove replantation and management program. The study incorporated a mixed approach, combining semi-structured questionnaires used to guide open interviews with key informant and focus group discussions (FGDs), and reports available at government institutions.

Focus group discussions were conducted with several members of the community separated by age, gender and main occupation. Some members of the community were interviewed individually when it was not possible for them to attend the formal group discussions (such as mangrove charcoal producers who were unwilling to participate in these discussions). Questions asked were about people's perception of change in mangrove condition, levels of exploitation, provision of goods and services, engagement in management and replantation activities, functioning of the natural resources management committee, assessment of the community management systems, strengths and challenges, among others. Semi-structured interviews were also conducted with key informants on similar subjects (local leaders, managers, NGOs).

The FGD and individual interviews aimed at four main target groups: members of the local Natural Resources Management Committee (NRMC); Managers and key informants (influential people from the community; government, NGO representatives and local authorities); local community (common mangrove users), and community rangers. Within the community, the main user groups were identified with the help of the NRMC. These were fisherman, fish traders, women (fuel wood and invertebrate collectors), mangrove pole cutters, mangrove charcoal producers, honey producers and students (members of the local environmental club). Key informants included the elderly from the village, the head of Nhangau Administrative Post, project managers from NGOs, government officials who participated in the program from the beginning and influential community members. All villages were visited, and 78 people were interviewed in total.

This flexible approach was useful for data validation and triangulation, and also created opportunities for traditionally more reserved groups to speak such as women, youth and illegal cutters (Asante et al., 2017; Nath et al., 2017). Data processing primarily involved interpreting the qualitative information provided by community members to document all mangrove restoration processes and the community-based management program implemented in Nhangau.

# 3 Results

## 3.1 Mangrove uses

From the FDGs and individual interviews with the community members, it was demonstrated that mangroves played an important role in the provision of resources for the community (Table 1). These forests are the main source of poles of all sizes such as "laca-laca" (up to 5 cm wide), small poles (5-9 cm wide), medium poles (9-14 wide) and large poles (more than 14 cm wide), which are used for house construction and domestic utensils. The forests also provide fuelwood and wood to produce furniture, doors and window frames. Women also reported medicinal uses of some

TABLE 1 Mangrove goods and services used by the communities at Nhangau.

| Mangrove product/service | Uses |
|---|---|
| Wood resources | Furniture, construction, domestic utensils<br>Firewood and charcoal |
| Medicine | Stomach ache |
| Food | Fish, crab, mangrove snail, honey |
| Ecological services | Coastal protection, temperature regulation, nursery habitat |
| Other uses | Traditional ceremonies<br>Traditional Christmas meal |

mangrove species, such *X. granatum* fruit used for stomach ache, and general use of mangrove species by traditional healers. Food collection is common in and around mangroves forests, and this includes fishing, invertebrate collection (crab *Scylla serrata* and mollusc *Cerithidea decollata* locally known as "mandombe"), and collection of *Sesuvium portulacastrum* for a traditional plant dish only cooked for Christmas (also known as *mpfixiri*). Many fishing products are sold to middle men from Beira town. Mangroves are also used for honey production, which is sold in Beira town. Community members have more than 10 beehives in the mangroves. The honey is commercialized in local markets and fairs with the brand name "Mel de Mangal de Nhangau" (Mangrove Honey from Nhangau) at the price of USD 8 per 0.5L. The communities also reported that mangrove forest provide protection of the coastline, therefore specific restrictions were instated to reinforce protection of seaward mangroves. The community also mentioned that mangrove forests reduce erosion and protect houses from strong winds. It was also mentioned that the mangroves protected properties of the communities living closer to the coastline during cyclone Idai, which made landfall in the area in 2019. Subsequent cyclones and storms (namely Chalane and Eloise in 2020 and 2021, respectively) were less impactful.

## 3.2 From forest degradation to building community management structures: the history of the mangroves of Nhangau

The Nhangau community divides the last 45 years in two periods. The first period refers to the late 1980 up to 1996, coinciding with the end of the civil war that prompted an increase of unemployed people (mainly former soldiers) that cut and sold mangroves for subsistence. After deforestation the communities experienced a drastic reduction in fish, shrimp and crab stocks, severe coastal erosion, high temperatures, strong winds and whirlwinds (that destroyed many houses) and reduced availability of wood resources, such as poles for house construction and fish. The second period started in 1996 with mangrove planting and re-establishment of some ecological services, such as temperature regulation and shoreline protection from wind and wave erosion. The community also reported an increase in fish stocks and improvement in their lives in general after mangrove plantations because whirlwinds became less frequent and less destructive.

Mangrove restoration was initiated by the local government and intended to address the impacts of forest degradation on the community's social and economic life. Mangrove restoration started in the late 1990's and was primarily carried out by the then Ministry of Agriculture, who was responsible for the management of the mangrove forests in Mozambique; later continued by new entities with the same role namely MICOA (Ministry of Coordination of Environmental Affairs) until 2014, and PD-TADER (Provincial Directorate of Land, Environment and Rural Development) from 2015. Propagules of *R. mucronata*, *B. gymnorhiza* and *C. tagal* and germinating seedlings of *A. marina* were planted directly in the soil without the intervention of a nursery. The selection of sites and species to be planted on each site was based on the community ecological knowledge of the site. No hydrological restoration was carried out, and the system did not seem to require it.

The mangrove planting was conducted by the local community assisted by the PD-TADER, which provided much of the technical capacity. According to key informants, the community was initially organized into a small group dedicated particularly to planting activities. Later on, NGO's (KULIMA and ADEL-Sofala) and civil society (schools, volunteers and others) were also involved, and the government promoted planting campaigns involving several actors (such as local leaders, government representatives and other influential figures) (Table 2). Meanwhile, the community group (assisted by the government and ADEL-Sofala) was converted into the Natural Resources Management Association of Nhangau (NRMC), a registered community association with legal rights and recognition. Currently the NRMC is in charge of all mangrove restoration activities, and the community is working to build a nursery with the collaboration of several partners, such asMozambES project (a partnership between Eduardo Mondlane University, UniLicungo and Lisbon Nova School of Business) and the SWAMP Project supported by the United States Forest Services International Program. Eduardo Mondlane University is also providing technical support for the establishment of the nursery.

All activities of the NRMC were done on a volunteering basis, but government and NGOs provided 2 monthly basic groceries to NRMC members of the main social bodies. They also provided uniforms for the six community rangers and some basic equipment such as gloves and plastic bags for the nursery. No salaries or other monetary incentives were paid.

According to the members of the NRMC and government officials, the propagules were collected in the dense mangrove

TABLE 2 Mangrove restoration history in Nhangau.

| Period | Events | Impacts/Outcomes |
|---|---|---|
| 1996-1997 | Agriculture Ministry visits | Pre-planting studies (ecological and socio-economic studies)<br>Initial planting activities with community participation |
| 1997-1998 | KULIMA (NGO) interventions | Financial support to the community (boats, fieldwork equipment) |
| 2001 | Mangrove restoration in Nhangau becomes permanently part of the annual agenda of MICOA | Annual government funding for replanting activities (field work equipment; 2-monthly basic groceries for nursery workers) |
| 2006/7 – 2016 | ADEL-Sofala (NGO) interventions | Improved stoves<br>Alternative and complementary income generating activities<br>2-monthly basic groceries for NRMC workers |
| 2010 | MICOA minister visit to Nhangau mangroves program | Increased national visibility of the program |
| 2016 | Extremely high tides (Njalane and Txondja) | Flooding in areas were mangroves had been cleared, highlighting the protective role of mangroves |
| 2016 | Legal registration of NRMC and opening of a bank account | NRMC meets legal requirements to apply for funds from the Government and NGO's; and to receive a percentage of fines collected |

areas and then transported and planted in the degraded areas during low spring tides. The preferred species for planting were *C. tagal*, *R. mucronata* and *B. gymnorhiza*, which were also more successful given the predominantly muddy conditions in the area. Some *A. marina* was planted particularly on sandier substrates, but with less success.

The community estimated that 500 ha had been planted, however this study only found 10 ha planted between 1996 and 2017 (Figure 3). Non-quantified natural regeneration in degraded sites has also been identified (Figure 4).

The NRMC has representatives from the three villages of the Nhangau Administrative Post: 14 from Njalane, 10 from Nhangau Sede and 10 from Txondja, to ensure that the particular interests of the three sites are represented. Membership is voluntary upon the payment of a joining fee of 50 MZN (USD 0.8) and monthly fee of 10 MZN (0.16 USD). The association aimed at promoting sustainable management of natural resources and local development, coordinate and supervise community projects implemented by partners and promote self-employment within the community. The committee meets ordinarily once a year or extraordinarily on the request of Fiscal Council or 30% of the members. These meetings are the main platform for the community to discuss their concerns and find common ground to solve arising issues. Community members that are not part of the NRMC and

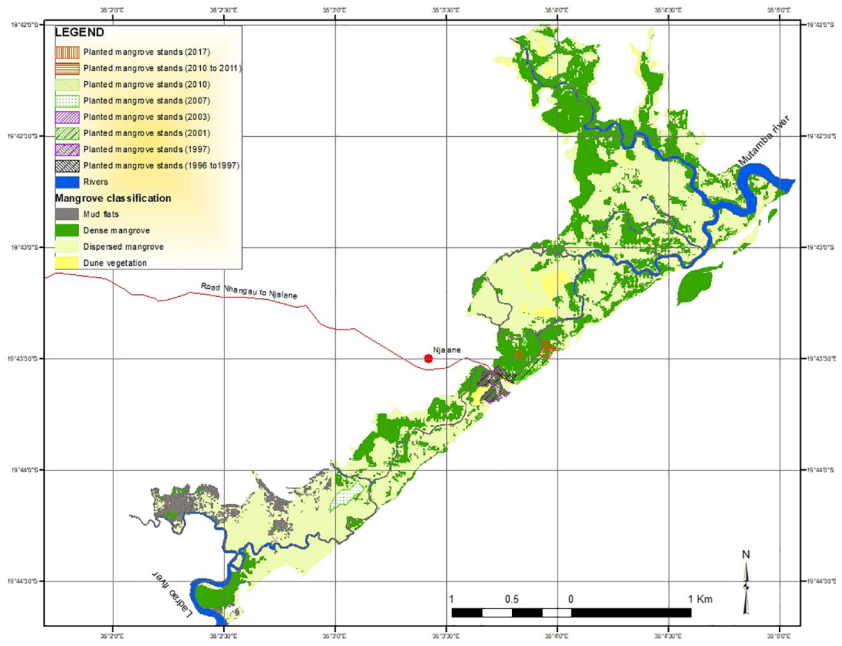


FIGURE 3
Restored mangrove areas and the respective year of plantation.


FIGURE 4
Mangrove restoration facilitated natural regeneration in nearby areas.

that have issues pertaining the mangrove activities can also approach the NRMC members, and if needed, meetings can be organized. The meetings are also used to communicate community concerns to the local authorities and other supporting partners. The structure of the organization is: a general assembly, a fiscal council, a management council (all composed of a president, vice-president and secretary). It also includes an executive council, constituted by a director, coordinator, manager, head of administration; and a financial department, which deals with human resources and finances; and a logistics department. The coordinator and manager are responsible for leading the management, conservation and environmental education department, communication and marketing department, hygiene and calamity department. With this structure, the NRMC intends to provide conservation services to neighbourhood communities, such as providing mangrove propagules and seedlings, training and mangrove restoration. The committee also intends to conduct income generating activities that will benefit the community and support mangrove conservation.

## 3.3 Management measures

Mangrove cut is allowed for community members only. When in need of mangrove poles for construction, for example, a community member must submit a request to the committee, which will indicate a person to accompany the applicant to the mangrove forest and harvest the poles observing sustainable procedures. For instance, in order to protect the coast line against erosion, seaward mangrove cut is prohibited. Communities are also stimulated to cut trees partially, and not the main trunk. Depending on the amount of cut poles, the cutter may be requested to plant a similar amount in a degraded area, or to replace naturally dead plants in planted areas. If a non-authorized person is found with mangrove poles, he/she will either take a penalty from the Committee (if a member of the community), for example working for the committee for several days or paying a fine varying from 0.8 USD to 1.6 USD; or will be handed to the local authorities and prosecuted (if from another community). The community is also allowed to collect fuelwood (wood debris) for domestic consumption only. Mangrove cut in replanted sites and mangrove charcoal production is not allowed in Nhangau, and this goes in accordance with the national legislation. The national legislation also prohibits commercial exploitation of mangrove poles.

The community rangers indicated by the NRMC are also responsible together with the government-employed rangers, to collect a fee from wood loggers and charcoal producers from nearby terrestrial forests (1.0 USD for each bag of charcoal), as commercialization of mangrove poles and charcoal is forbidden by law. Despite this, it is known that mangrove poles and charcoal is produced illegally in Nhangau. When caught by rangers, mangrove poachers are handed to local authorities and charged a fine. The

illegal products are kept by authorities and donated. Twenty per cent of the fees and fines should return to the community and be used in community works. The other sources of income to the NRMC are monthly fees from members, 50% of the fines charged for transgressions reported by the committee and entrance fee (50 USD) charged to students, tourists and other visitors to the Nhangau mangrove restoration area. The NRMC is also providing mangrove restoration services to support conservation activities, such as the construction of the new headquarters of the NRMC.

The management measures at Nhangau can be synthetized in three main components:

i. Reduction of extractive uses

Implemented through the introduction of alternative and complementary income-generating activities (IGA), and alternative sources of domestic firewood. NGOs KULIMA and ADEL-Sofala played a key role in promoting demonstrative alternative IGA such as beekeeping, aquaculture, natural medicine gardens and seedling production. According to our interviews, beekeeping and the natural medicine garden provided complementary source of income to more than 50 people altogether. The NGOs also promoted the production of improved energy-efficient stoves. These stoves are made with local clay, and have a specific structure that slows down firewood burn, therefore lasting longer. This activity was encouraged both as an alternative source of income (stoves were sold within the community and to other areas) and as a means to reduce charcoal consumption. ADEL-Sofala also encouraged the community to plant casuarinas (*Casuarina equisetifolia*) as an alternative source of domestic fuelwood. This project is currently interrupted due to lack of funding to pay salaries to nursery workers and other consumables such as plastic bags.

All actors (government, NGO, NRMC and community in general) agree that mangrove cut has reduced significantly within the community, but they point out that there are illegal cutters from outside the community cutting mangroves in the natural and planted stands. The community struggles to control the invasion of such groups due to the lack of human, material and financial resources.

ii. Continuous awareness and planting

Both government and NGOs were involved in the initial stages of community awareness and in building community capacity on mangrove and environmental related issues. The NRMC invites the community for regular meetings, where people discuss and are informed of the legal procedures for mangrove exploitation and sanctions that are applicable to offenders. Local regulations for mangroves and other natural resources exploitation are also discussed in these meetings (for example mangrove cut near the houses is not allowed) (Table 3). These meetings are also a platform where the community can voice their concerns and discuss the solution to problems that arise.

As a result, the community had a very strong awareness of the importance of mangroves (for example, all interviewees from the community could mention at least three mangrove goods or ecological services), and passes the message to each other and to newcomers. The NRMC coordinates most of the planting and other activities among the community and local schools, with the support of ADEL-Sofala and government institutions, or autonomously.

iii. Law enforcement

The local government works closely with the NRMC and its community rangers for the enforcement of the regulations and procedures, however anyone from the community can denounce offenders. The institutions involved in law enforcement include the Provincial Directorate of Sea, Inland Waters and Fisheries and DP-TADER in collaboration with the coastal police. The authorities have reported the seizure of thousands of mangrove poles and charcoal bags confiscated inside mangrove areas as well as along the road linking Nhangau to Beira town. One of the most relevant actions of the municipal authorities was the dismissal and prosecution in 2017 of the then chief of the Administrative Post of Nhangau, accused by the NRMC of ordering the clearing of 1.5 ha of planted mangrove for personal purposes (Mauricio, personal communication).

According to the decree 12/2002, illegal products and means used for extraction and/or transport must be confiscated by competent entities (including the NRMC) and a fine must be charged. At Nhangau confiscation was applied only to the products. Confiscated products are donated to schools, hospitals, orphanages and other state institutions, or sold by public auction.

However, the implementation of the legislation remains a challenge for the NRMC. Issues include the lack of alternative resources for the community, as one member of the NRMC said herself: “We talk to people about not cutting mangroves, but even us, members of the NRMC, we struggle when we need poles to fix our houses”. The NRMC also struggles to act over people from outside the community. Nhangau is part of Beira municipality and relatively close to it. The demand for poles for house construction from Beira is high, and sometimes involves people with more resources that NRMC. Another member of the community reported episodes were mangrove cutters had cars, boats and even machetes that made her feeling threatened. “What could I have done, as I was alone and had no means to call for help?”, she said.

TABLE 3 Local rules for mangrove exploitation in Nhangau.

| Institutional arrangement | Prohibitions | | Permissions |
|---|---|---|---|
| | Activities | Sanctions | |
| National law or regulation | Commercial exploitation of mangrove poles or wood | Fine (167 USD); confiscation of goods and equipment | • Customary exploitation of wood products |
| | Production of mangrove charcoal | | |
| Local rules | Cutting/ transporting more than 35-40 poles | Fine 0.8 – 1.7 USD or compulsory planting | • Sustainable cut in designated areas<br>• Cut for bridge construction in widened mangrove creeks<br>• Compensatory mangrove replanting for illegal cutters |

## 4 Discussion

The results of this study indicate that 10 ha of mangrove have been replanted in 21 years (average 0.47 ha planted every year) at Nhangau. This reforestation rate is smaller than that of the Limpopo Estuary, where more than 26 ha were replanted between 2010 and 2015 (Bandeira and Balidy, 2016); but similar to that of the Mikoko Pamoja Program in Kenya, where 10 ha have been restored and 0.4 ha are planted every year (Abdalla et al., 2017; Mangrove, 2017). It is significant that the latter is a site where Payment for Ecosystem Services has occurred. Meanwhile additional information is required to fully assess the ecological outcomes of the restoration and management initiatives at Nhangau. For example, satellite images from the region show that mangrove planting has promoted natural regeneration of nearby mangroves in an area that was not estimated by this study. Passive restoration is a process where mangrove planting creates conditions for other parts of the forest to regenerate naturally (Lewis, 2005 ; Corbin and Holl, 2012). It has been documented elsewhere (such as at the Limpopo Estuary in Mozambique, Gazi Bay in Kenya and Pichavaram in India) that this may account for more than 30% of the total recovered area in a forest (Bosire et al., 2003; Selvam et al., 2003; Bandeira and Balidy, 2016). This information is important to assess the outcomes of the management system and to what extent the conservation goals are being met.

When looking at the critical enabling conditions for successful management of natural resources as described by (Agrawal, 2003), one can see that the mangrove management system of Nhangau possesses several key elements of success and that the weaknesses of the model lie in the "External environment" criteria (Figure 5).

There are several positive aspects about the system at Nhangau that have also been seen in successful models across the globe such as Gazi Bay (Kenya), Trang (Thailand) and Lyngayen Gulf (Phillipines) (Table 4). One of the key elements of success is community awareness on the importance of mangroves (Shunula, 2002), in this case possibly highlighted by the impacts experienced after mangrove deforestation in the area. This awareness gave the community a high sense of responsibility reflected in the continuing replanting, self-awareness raising and self-enforcement. The community also feels empowered by the fact that they were able to institute and enforce measures on their resources. These aspects are crucial to achieve community support for mangrove sustainable management and conservation (Shunula, 2002). The fact that mangrove restoration as well as restoration of mangrove ecological services was successful also encouraged the community to engage and maintain sustainable practices of mangrove exploitation.

The external and prolonged assistance provided by the government and NGOs (who worked in partnership) was almost permanent and consisted of technical, financial and moral support to the community, in addition to community training and basic tools for conflict resolution. The lack of alternative IGA is often pointed as one of the main impediments for communities to abandon unsustainable practices of mangrove exploitation (Damastuti and De Groot, 2017). At Nhangau there has been demonstration of various activities, beekeeping and a medicinal garden in particular contributing significantly to the income of several families. There has also been a gradual transfer of responsibilities in the leadership of the mangrove planting, awareness and law enforcement to the communities. However, the communities need more support to increase the number of families working in such activities, and to get involved in new ones. The community expressed interest in aquaculture, for

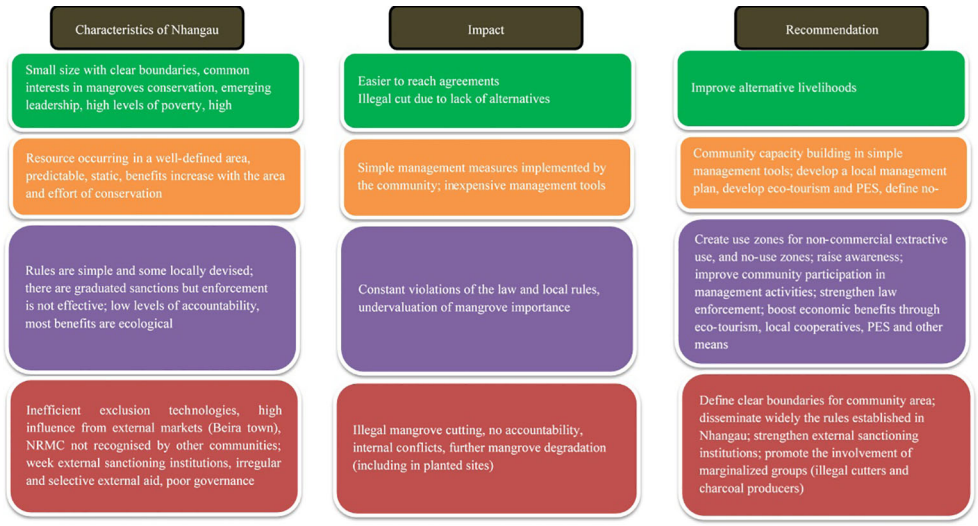


FIGURE 5
Analysis of the critical enabling conditions for natural resources management (Agrawal 2003) and recommendations for improvement for the Nhangau community-based management system. Green: Community characteristics; Orange: Resource characteristics; Purple: Institutional arrangements; Maroon: External environment.

TABLE 4 Factors contributing to success or failure of community-based mangrove management initiatives.

| | | Where seen |
|---|---|---|
| **Positive aspects** | Clear limits of community area | Trang |
| | Existence of mangrove reserve area | Trang; Gazi Bay |
| | High social capital and local autonomy | Trang |
| | Bottom-up decision making | Surodadi |
| | Conflict management | Trang |
| | Community awareness and appropriation | Trang; Gazi Bay; Lingayen Gulf; Surodadi, Limpopo |
| | Mangrove rehabilitation | Gazi Bay; Surodadi; Limpopo |
| | Adequate external assistance | Trang; Gazi Bay; Surodadi; Limpopo |
| | Successful (pilot) livelihood projects | Lingayen Gulf; Surodadi; Limpopo |
| | Carbon trade and ecotourism | Gazi Bay |
| | Law enforcement | Lingayen Gulf; Limpopo |
| Negative aspects | Low community involvement | Mida Creek, Braganca |
| | Community unequal representativeness | Lingayen Gulf |
| | Poor relationships between stakeholders | Mida Creek |
| | Poor local leadership | Bragança |
| | Lack of financial and technical support | Lingayen Gulf; Kien Giang |
| | Poaching and poor enforcement | Mida Creek; Kien Giang, Brangança; |
| | Lack of IGA | Mida Creek; Bragança |
| | Political conflicts | Bragança |
| | Legislation conflicts | Bragança |
| | Poor decision making | Kien Giang |

Green and red indicate positive and negative aspects identified at Nhangau respectively.

instance, which would reduce fishing pressure and provide livelihood. High investment is necessary as a starting point, and the community has no means at the moment.

The main negative tipping point in the community-based management system at Nhangau is little law enforcement and compliance, and in this matter, Nhangau represents much of what has been seen elsewhere in the WIO Region and other developing countries (Machava-Antonio et al., 2020). At Nhangau there is both lack (or weak) institutional capacity, and political issues which provide conditions for non-compliance with local laws and regulations, mostly without liability of violators. Nhangau is part of the Beira Municipal District, under the governance of a different party from that of the provincial government, thus many decisions are taken in view of short-term political benefits rather than conservation and long-term well-being of the population. There is a weak follow-up of the cases when seizures are made by the police or other enforcement entities. Offenders are released shortly afterwards and without penalties. The NRMC also lacks the means of policing and authority over outsiders and even some members of their own community. Being located close to a major urban center, Nhangau supplies charcoal and mangrove poles to Beira town. As a result, mangrove wood and pole cutting did not cease and there is an illegal mangrove charcoal market known to the authorities. At the institutional level, there is poor communication between government institutions with overlapping jurisdiction over mangroves (for example provincial directorates of MTA and the Ministry of Sea, Inland Waters and Fisheries – MIMAIP), and weak inter-institutional coordination resulting in redundancy of efforts. Despite being one of the first mangrove rehabilitation sites in Mozambique, the documentation was very poor, and scientific studies on ecology and socio-economy are very scarce. Therefore, the scientific basis for decision making is weak to non-existent, and there is also a risk of repetition of mistakes from the past. In addition, current activities may not be accurately monitored, as demonstrated by the disparity between the area that the community believed to have planted and the area found by this study.

Many local mangrove cutters and charcoal producers claim that their rights are being violated since this type of activity has always been tolerated in the area and that they have no alternative IGA. This position results in non-compliance and people shifting cutting sites to another one where enforcement is less rigorous and also creates a tense environment in the village between the two sides (poachers vs. law enforcers). This situation may be indicative of inadequate consultation before the implementation of management measures (Chen et al., 2005) and could be minimized with a management plan with clear zoning indicating no-use zones and multiple use zones, where mangrove cut is regulated (minimum sizes, rotational cut, closure periods and other adequate measures), as seen at Kenya and Thailand (Sudtongkong and Webb, 2008; Mangrove, 2017). Additionally, it is important to ensure that alternative sources of wood are provided. In this context *Casuarina* species. may not be adequate as it is an exotic species and may alter habitat functionality. Species such as *Thespesia populnea* have been successfully used in other places (Bandeira and Balidy, 2016; Warrier, 2010), but other fast-growing native species may also be considered. No compliance is also often a result of an inadequate management strategy for decision making (top-down vs. bottom up), and inappropriate strategies to encourage community participation (self-mobilized vs. manipulative) (Damastuti and De Groot, 2017).

There is also a need to review the incentives system in ways that the people involved in replanting and management activities feel that it is worth carrying out these activities. Incentives should be diversified, aligned with conservation objectives and satisfactory for the people involved (Dasgupta and Shaw, 2017). Granting additional rights of use of mangrove resources can be a more sustainable form of compensation in the long run instead of

the current system, which is irregular and expensive. The current system also creates friction between the community and members of the NRMC, who are seen as privileged for having additional support from the Government and NGOs. Similar systems produced the same effect at Mida Creek Kenya and other sites (Chen et al., 2005; Damastuti and De Groot, 2017). A fair incentive system and financial sustainability of the community-based management program can also be achieved by harnessing the potential of the region for the development of community and mangrove tourism, taking advantage of the fact that Nhangau is a mandatory pass for Savane beach tourists.

The NRMC lacks financial sustainability due to exiguous membership fees, few visitors and incapacity of the system to deliver their respective percentages on fines and fees. Payment for Ecosystem Services (PES), including the voluntary carbon market, is another potential source of income for community development to be considered (Locatelli et al., 2014).

The community-based management initiative at Nhangau achieved important milestones such as community awareness, engagement and successful restoration. It is certainly also a potential tool for mangrove conservation as demonstrated by the program's outcomes. However, the program is threatened mainly by poor law enforcement, finanacial constraints and alternatives for the community. Community empowerment and more involvement of the local authorities to address mangrove use at several levels (cutters, transporters and final consumers) are necessary. Nhangau is a replicable model for mangrove replantation and community involvement for the rest of the country, however the management component needs improvements before it can be reproduced.

## 5 Study recommendations

In order to increase the success of the mangrove restoration program at Nhangaau, the following recommendations are made:

- To strengthen the collaboration with the government institutions, in order to ensure that offenses to mangrove regulations are dealt with accordingly. This includes Beira Municipality, the Provincial Directorates of the Ministries of Land and Environment, the Ministry of Sea, Inland Waters and Fisheries, and other relevant entities;
- The reinforce the capacity of surveillance of mangroves, increasing the number of rangers and equipping them with the necessary tools for the job;
- To increase the fee charged over illegal producers of mangrove charcoal and poles, and reinforce other mechanisms for the implementation of local and national legislation on what regards to mangrove management;
- Create and strengthen partnerships with other institutions that can provide technical and scientific support to the program. This includes universities and other relevant research institutions. Such information must be used to support decision making;
- To conduct climate-change vulnerability assessments, in order to ensure that the restored areas will protect the most vulnerable zones; and that restoration efforts will not be nullified by the impacts of climate change;
- To develop a mangrove restoration monitoring program. Such plan shall include mangrove restoration metrics such as survival rates, growth patterns, mangrove mapping and dynamics (including UAVs techniques), community employment indicators as related with mangrove restoration, protection and derived livelihoods
- To produce a mangrove management plan, which should include mangrove zoning, indicating areas for different activities (e.g.: beekeeping, sustainable cut, degraded areas to be restored), and no-take zones. Such plan should also include specific protection measures for the recently restored areas and naturally regenerated areas;
- To work further on the development of a nursery to grow *A. marina*. This species is climate smart and key to create forest resilience, and, as it occurs naturally in the system, it should also be considered for restoration. Direct planting of *A. marina* is challenging, thus the high unsuccess rate that was reported with this species;
- To develop alternative sources of wood, other than *Casuarina* sp, *Thespesia populnea, Hibiscus tiliaceus* and other fast-growing native alternatives must be considered;
- Explore additional options for IGA, e.g.: the medicinal properties of mangrove species. Mangrove species such as *B. gymnorhiza*, *S. alba* and other non-mangrove species are used as source of food in Asian countries. Mangrove fauna species, such as gastropods *C. decollata* and *Terebralia palustris* can also be exploited commercially for food production.

## 6 Conclusions

This study described and analyzed mangrove co-management experiences at the Nhangau administrative post in central Mozambique. After unsustainable use of mangrove resources had caused several socio-ecological negative impacts, the community, assisted by the local government and NGOs, engaged in several best practice and sustainable management actions for mangrove restoration and conservation, through a successful mangrove restoration and conservation program. The community created a Natural Resources Management Committee, which is responsible for mangrove plantation and oversight of planted and natural areas, law and local regulations enforcement, promoting alternative income generating activities as well as continuous raising awareness. These actions resulted in the rehabilitation of 10 ha of mangrove, increased community awareness, development of (demonstrative) alternative IGA, and development of local procedures for mangrove resources exploitation. Other program outcomes include community empowerment and capacity building,

and the recovery of several ecosystem services with concomitant improvement in community well-being. Law enforcement, more alternative IGA and building robust financial sustainability to the program are the main issues to be targeted to improve the community-based management system at Nhangau. A number of recommendations to improve the restoration program were made, tackling mostly on legislation reinforcement and strengthening the management mechanisms. The study makes a global contribution to the understanding of the interface between community-based mangrove management and the role of stakeholders as well as understanding the factors behind positive and negative outcomes of such initiatives. Future studies at Nhangau should focus on baseline ecological aspects of the forest (forest structure, physico-chemical parameters, regeneration, change detection), including comparisons between replanted sites and natural stands for a better understanding of restoration of ecological services from mangrove and to support decision-making.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by Nelson Mandela University-Department of Marine Botany. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

FD: Writing – original draft. CM: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Writing – original draft. SB: Conceptualization, Validation, Writing – review & editing. JA: Validation, Writing – review & editing, Funding acquisition. HB: Formal analysis, Writing – original draft.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2024.1337678/full#supplementary-material

## References

Abdalla, S., Kairo, J., Huxham, M., and Czachur, M. (2017). 2015-2016 plan vivo annual report mikoko pamoja 1–46.

Agrawal, A. (2003). Sustainable governance of common-pool resources: Context, methods, and politics. *Annu. Rev. Anthropol* 32, 243–262. doi: 10.1146/annurev.anthro.32.061002.093112

Aheto, D. W., Kankam, S., Okyere, I., Mensah, E., Osman, A., Jonah, F. E., et al. (2016). Community-based mangrove forest management: Implications for local livelihoods and coastal resource conservation along the Volta estuary catchment area of Ghana. *Ocean Coast. Manag* 127, 43–54. doi: 10.1016/j.ocecoaman.2016.04.006

Asante, W. A., Acheampong, E., Boateng, K., and Adda, J. (2017). The implications of land tenure and ownership regimes on sustainable mangrove management and conservation in two Ramsar sites in Ghana. *For Policy Econ* 85, 65–75. doi: 10.1016/j.forpol.2017.08.018

Bandeira, S., and Balidy, H. (2016). Limpopo estuary mangrove transformation, rehabilitation and management. *Estuaries: A lifeline of ecosystem services in the Western Indian Ocean*, 227–237. doi: 10.1007/978-3-319-25370-1_14

Banerjee, K., Gatti, R. C., and Mitra, A. (2016). Climate change-induced salinity variation impacts on a stenoecious mangrove species in the Indian Sundarbans. *Ambio* 46, 492–499.doi: 10.1007/s13280-016-0839-9

Berkes, F. (2006). From community-based resource management to complex systems: The scale issue and marine commons. *Ecol. Soc.* 11. doi: 10.5751/ES-01431-110145

Bosire, J. O., Dahdouh-Guebas, F., Kairo, J. G., and Koedam, N. (2003). Colonization of non-planted mangrove species into restored mangrove stands in Gazi Bay, Kenya. *Aquat Bot.* 76, 267–279. doi: 10.1016/S0304-3770(03)00054-8

Bosire, J. O., Kaino, J. J., Olagoke, A. O., Mwihaki, L. M., Ogendi, G. M., Kairo, J. G., et al. (2014). Mangroves in peril: unprecedented degradation rates of peri-urban mangroves in Kenya. *Biogeosciences* 11, 2623–2634. doi: 10.5194/bg-11-2623-2014

Bown, N. K., Gray, T. S., and Stead, S. M. (2013). Co-management and adaptive co-management: Two modes of governance in a Honduran marine protected area. *Mar. Policy* 39, 128–134. doi: 10.1016/j.marpol.2012.09.005

Chen, D. T., Rosenstein, D. L., Muthappan, P., Hilsenbeck, S. G., Miller, F. G., Emanuel, E. J., et al. (2005). Research with stored biological samples. *Arch. Intern. Med.* 165, 652. doi: 10.1001/archinte.165.6.652

Corbin, J. D., and Holl, K. D. (2012). Forest Ecology and Management Applied nucleation as a forest restoration strategy. *For Ecol. Manage* 265, 37–46. doi: 10.1016/j.foreco.2011.10.013

Damastuti, E., and De Groot, R. (2017). Effectiveness of community-based mangrove management for sustainable resource use and livelihood support : A case study of four villages in Central Java, Indonesia. *J. Environ. Manage* 203, 510–521. doi: 10.1016/j.jenvman.2017.07.025

Dasgupta, R., and Shaw, R. (2017). Perceptive insight into incentive design and sustainability of participatory mangrove management : a case study from the Indian Sundarbans. *J. For Res.* 28, 815–829. doi: 10.1007/s11676-016-0355-6

Datta, D., Chattopadhyay, R. N., and Guha, P. (2012). Community based mangrove management : A review on status and sustainability. *J. Environ. Manage* 107, 84–95. doi: 10.1016/j.jenvman.2012.04.013

de Almeida, L. T., Olímpio, J. L. S., Pantalena, A. F., de Almeida, B. S., and de Oliveira Soares, M. (2016). Evaluating ten years of management effectiveness in a mangrove protected area. *Ocean Coast. Manage.* 125, 29–37. doi: 10.1016/j.ocecoaman.2016.03.008

De Souza, L., Rossi, S., Calvet-mir, L., Ruiz-mallén, I., García-betorz, S., Salvà-prat, J., et al. (2017). Neglected ecosystem services : Highlighting the socio-cultural perception of mangroves in decision-making processes. *Ecosyst. Serv.* 26, 137–145. doi: 10.1016/j.ecoser.2017.06.013

Esteban, J. H. (2008). A review of mangrove rehabilitation in the Philippines : successes, failures and future prospects. *Wetl. Ecol. Manag.* 16, 345–358. doi: 10.1007/s11273-008-9101-y

Feka, N. Z., and Ajonina, G. N. (2017). Drivers causing decline of mangrove in West-Central Africa: a review. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* 3732, 217–230. doi: 10.1080/21513732.2011.634436

Instituto Nacional de Estatistica. *Estatisticas do Distrito da Beira 2018 -2022. 2023.* Instituto Nacional de Estatistica, Mocambique, 36pp.

Lewis III, R. R. (2005). Ecological engineering for successful management and restoration of mangrove forests. *Ecological Engineering* 24 (4), 403–418. doi: 10.1016/j.ecoleng.2004.10.003

Kovacs, J. M., Crona, B., Ainul, S., Walters, B. B., and Ro, P. (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquat. Bot.* 89, 220–236. doi: 10.1016/j.aquabot.2008.02.009

Leach, M., Mearns, R., and Scoones, I. A. N. (1999). Environmental entitlements: dynamics and institutions in community-based natural resource management. *World Dev.* 27, 225–247. doi: 10.1016/S0305-750X(98)00141-7

Li, R., Chai, M., and Qiu, G. Y. (2016). Distribution, fraction, and ecological assessment of heavy metals in sediment- plant system in mangrove forest, south. *PloS One* 11, 1–15. doi: 10.1371/journal.pone.0147308

Locatelli, T., Binet, T., Kairo, J. G., King, L., Madden, S., Patenaude, G., et al. (2014). Turning the tide : how blue carbon and payments for ecosystem services (PES) might help save mangrove forests. *Ambio* 43, 981–995. doi: 10.1007/s13280-014-0530-y

Lynam, T., De Jong, W., Sheil, D., Kusumanto, T., and Evans, K. (2007). A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. *Ecol. Soc.* 12. doi: 10.5751/ES-01987-120105

Macamo, C. C. F., Massuanganhe, E., Nicolau, D. K., Bandeira, S. O., and Adams, J. B. (2016). Mangrove ' s response to cyclone Eline (2000): What is happening 14 years later. *Aquat Bot.* 134, 10–17. doi: 10.1016/j.aquabot.2016.05.004

Machava-Antonio, V., Bandeira, S. O., Macamo, C. C., and Mahanzule, R. (2020). Value chain analysis of mangrove forests in central Mozambique: Uses, stakeholders and income. *Western Indian Ocean J. Mar. Sci.* 19, 1–17. doi: 10.4314/wiojms.v19i1.1

Mangrove, N. (2017) 1). Management, E. on.

Meshack, C. K., Ahdikari, B., Doggart, N., and Lovett, J. C. (2006). Transaction costs of community-based forest management: empirical evidence from Tanzania. *Afr. J. Ecol.* 44, 1–10. doi: 10.1111/j.1365-2028.2006.00659.x

Mozumder, M. M.H., Shamsuzzaman, M. M., Rashed-Un-Nabi, M., and Karim, E. (2018). Social-ecological dynamics of the small scale fisheries in Sundarban Mangrove Forest, Bangladesh. *Aquaculture Fisheries* 3 (1), 38–49. doi: 10.1016/j.aaf.2017.12.002

Nath, T. K., Puat, M., Dahalan, B., and Parish, F. (2017). Local peoples 'Appreciation on and contribution to conservation of peatland swamp forests: experience from peninsular Malaysia. *Wetlands.* 37, 1067–1077. doi: 10.1007/s13157-017-0941-1

Nfotabong-atheull, A., Din, N., Koum, L. G. E., and Satyanarayana, B. (2011). Assessing forest products usage and local residents ' perception of environmental changes in peri-urban and rural mangroves of Cameroon, Central Africa Assessing forest products usage and local residents ' perception of environmental changes in peri-urba. *J. Ethnobiol. Ethnomed.* 41, 1–13. doi: 10.1186/1746-4269-7-41

Nguyen, T. P., Van Tam, N., Phat, L., and Parnell, K. E. (2016). Ocean & Coastal Management Community perspectives on an internationally funded mangrove restoration project: Kien Giang province, Vietnam. *Ocean Coast. Manag* 119, 146–154. doi: 10.1016/j.ocecoaman.2015.10.008

Nygren, A. (2005). Community-based forest management within the context of institutional decentralization in Honduras. *World Dev.* 33, 639–655. doi: 10.1016/j.worlddev.2004.11.002

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., and Policansky, D. (1999). Revisiting the commons: local lessons, global challenges. *Science.* 284 (5412), 278–282. doi: 10.1126/science.284.5412.278

Phong, T., Thanh, T., and Parnell, K. E. (2017). Ocean & Coastal Management Existing strategies for managing mangrove dominated muddy coasts : Knowledge gaps and recommendations. *Ocean Coast. Manag* 138, 93–100. doi: 10.1016/j.ocecoaman.2017.01.016

Robinson, N. J., Morreale, S. J., Nel, R., and Paladino, F. V. (2016). Coastal leatherback turtles reveal conservation hotspot. *Nat. Publ Gr.* 6, 1–9. doi: 10.1038/srep37851

Romañach, S. S., Deangelis, D. L., Lye, H., Li, Y., Yean, S., Sulaiman, R., et al. (2018). Conservation and restoration of mangroves: Global status, perspectives, and prognosis. *Ocean Coast. Manag* 154, 72–82. doi: 10.1016/j.ocecoaman.2018.01.009

Rubin, J. A., Gordon, C., and Amatekpor, J. K. (1999). Causes and consequences of mangrove deforestation in the volta estuary, Ghana: some recommendations for ecosystem rehabilitation. *Mar. Pollut. Bull.* 37, 441–449. doi: 10.1016/S0025-326X(99)00073-9

Sakho, I., Mesnage, V., Deloffre, J., La, R., Niang, I., and Faye, G. (2011). Estuarine, Coastal and Shelf Science The in fl uence of natural and anthropogenic factors on mangrove dynamics over 60 years: The Somone Estuary, Senegal. *Estuar. Coast. Shelf Sci.* 94, 93–101. doi: 10.1016/j.ecss.2011.05.032

Selvam, V., Lakshmanan, G., and Muthu, N. (2003). Assessment of community-based restoration of Pichavaram mangrove wetland using remote sensing data Assessment of community-based restoration of Pichavaram mangrove wetland using remote sensing data. *Curr. Sci.* 794–798. Available at: https://www.jstor.org/stable/24109889

Shunula, J. P. (2002). Public awareness, key to mangrove management and conservation: the case of Zanzibar. *Trees* 16, 209–212. doi: 10.1007/s00468-001-0147-1

Stone, K., Bhat, M., Bhatta, R., and Mathews, A. (2008). Ocean & Coastal Management Factors influencing community participation in mangroves restoration: A contingent valuation analysis. *Ocean Coast Manag.* 51, 476–484. doi: 10.1016/j.ocecoaman.2008.02.001

Sudtongkong, C., and Webb, E. L. (2008). Outcomes of state- vs. Community-based mangrove management in Southern Thailand. *Ecol. Soc.* 13. Available at: https://www.jstor.org/stable/26267971https://www.jstor.org/stable/26267971

Warrier, K., Venkataramanan, K. S., Balasubramanian, T., and Singh, B. G. (2010). Thespesia populnea. *book: Manual of Economically Important Forestry Species in South India*, 495–506. doi: 10.24941/ijcr.45843.08.2023