Review Article

Trends in Agriculutre Science

Vol.2, Issue 1, January, 2023, Page: 20-32

Mangrove restoration: Novel technique to growing new mangrove plants in degraded areas of India

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https://doi.org/10.5281/zenodo.7572010

Abstract

Mangrove restoration has drawn a lot of interest globally for a number of reasons. First, numerous mangrove locations throughout the world have shown the ecological and environmental benefits of mangrove forests. Second, mangrove forests' natural resources are heavily relied upon for subsistence. Additionally, there have been significant losses of mangroves all over the world, which has resulted in coastal erosion, a drop in fish stocks, and other environmental effects, some of which require immediate care. Last but not least, governments around the globe are demonstrating their commitment to the sustainable use of mangrove ecosystems. The activities of mangrove restoration and management are discussed in this article. The ecology, structure, and operation of the mangrove ecosystem have all been the subject of much research. Mangrove forests continue to be over-exploited, turned into aquaculture ponds, and polluted throughout the world as well as India because the findings have not been integrated into a management framework. We fervently contend that connections should be made between research and sustainably managed mangrove ecosystems.

Introduction

Mangroves are forest ecosystems that have evolved to thrive in difficult environments between the sea and the shore. They are high productivity and biologically diverse ecosystems. Trees, plant groups, and an ecosystem that has adapted to tidal zones are all referred to as "mangroves" in the English language. "Salt-tolerant evergreen woods found at protected beaches, shallow-water lagoons, estuaries, rivers, or deltas" is how mangroves are described. They are mostly found in subtropical intertidal regions of the world (Sarhan and Tawfik, 2018). In terms of ecology, restoration rarely entails restoring an ecosystem back to its original condition, but rather, it typically entails getting it back to a state of efficacy. Morrison (1990) offers the following practical definition of restoration: "Restoration is the re-introduction and re-establishment of community-like groupings of native species to sites which can reasonably be expected to sustain them, with the resultant vegetation demonstrating aesthetic and dynamic characteristics of the natural communities on which they are based." Field distinguished between rehabilitation, defined as "the partial or full replacement of the ecosystem's structural and functional qualities," and restoration, defined as "the act of restoring an ecosystem to its original condition" (Kairo *et al.,* 2001).

Mangroves, which are sometimes referred to as "Coastal woodland," "Oceanic rainforest," and "Tidal Forest," are the only "blue carbon" forests in the ocean. Only 73 tree species make up this uncommon sort of forest, which covers 15.2 million hectares across 123 nations. Ecologically significant and economically valuable are mangrove forests. They support coastal livelihoods worldwide and offer ecosystem services worth at least US$ 1.6 billion annually. They are used by crabs, prawns, mollusks, finfish, birds, reptiles, and mammals as nidification, feeding, and breeding grounds (Kathiresan, 2018). The world's mangroves comprise 1,50,000 square kilometres in total. The majority of the world's mangroves are found in Asia. 6.8% of the world's mangrove covers lies in South Asia. India contributes 45.8% of the region's total mangrove cover. In order to maintain a balance between the economic, social, and ecological elements of development, the notion of sustainability of mangrove forest management requires criteria and indicators. This will provide the community as a whole what it needs. The effective enforcement of laws and regulations in coastal areas, as well as cooperation between scientists, legislators, governments, and stakeholders, will decide how well mangrove management policy is implemented. Environmental counseling and education of the community, strategic development planning that takes into account the carrying capacity and carrying capacity of mangroves, the development of tourism involving local communities, wisdom, and waste management and pollution control are all necessary for successful mangrove management policies (Arfan *et al.,* 2021).

Mangroves in India: Coverage

The mangrove cover in India is 4,975 sq km, or 0.15% of the country's overall geographic area, according to the India State of Forest Report, 2019. West Bengal, Gujarat, and the Andaman & Nicobar Islands are the three regions with the largest proportion of total mangrove cover (Kathiresan, 2010). The largest mangrove forest in the world is found in West Bengal, specifically the Sundarbans. It is a part of the World Heritage List of UNESCO. The Gangetic dolphins, estuarine crocodiles, and Royal Bengal tigers all reside in the jungle mangroves in Bhitarkanika (Badola *et al.*, 2012). Bhitarkanika in Odisha, which was produced by the two river deltas of the River Brahmani and Baitarani, is the second-largest mangrove forest in India. It is one of India's most important Ramsar wetlands (Ragavan *et al.,* 2019). Andhra Pradesh, Godavari-Krishna Mangroves: The Godavari-Krishna mangroves are located between Tamil Nadu and Odisha. Mangrove forests can be found in the deltas of the Ganges, Mahanadi, Krishna, Godavari, and Cauvery rivers. Kerala's backwaters are covered in a dense mangrove forest. Mangrove trees cover a huge area of water in Pichavaram, Tamil Nadu. Numerous aquatic bird species call it home. Gujarat has 23.66% of India's mangrove cover, West Bengal has 42.45%, and the A&N Islands have 12.39% (Mitra, 2020). Based on remote sensing data, the Forest Survey of India, Dehradun reports that the mangrove coverage increased from 4046 square kilometres in 1987 to 4921 square kilometres in 2017. In the past 30 years, the mangrove cover has decreased in Andhra Pradesh and the Andaman and Nicobar Islands at 0.61% and 0.34% per year, respectively, while it has increased in all other locations, including Gujarat, Maharashtra, Tamil Nadu, Odisha, Goa, Karnataka, Kerala, Daman and Diu, and Puduchery, by 168%, 117%, 113%, 26 folds, 10 folds, and Daman and Diu. The Sundarbans saw a slight growth of only 1.83% at a rate of 0.061% annually. Over 30 years, at an average rate of 0.72%, the mangrove cover expanded overall by 21.63% year in India (Kathiresan, 2018).

Table 1: Different types of Mangroves distributed along the Indian Coast and their area (Source: Singh et al., 2012).

Sr No.	**State**	**Total (Km^2)**
1.	Andhra Pradesh	352
2.	Goa	22
3.	Gujarat	1058
4.	Karnataka	3
5.	Kerala	6
6.	Maharashtra	186
7.	Orissa	222
8.	Tamil Nadu	39
9.	West Bengal	2155
10.	Andaman & Nicobar	617
11.	Daman & Diu	1.56
12.	Pondicherry	1
Total		**4662.56**

History of mangrove restoration

In Southeast Asia, mangrove planting and management have a long history. The Sundarbans may have the longest documented history of mangrove management for timber. Mangrove management has existed in the 6000 km2 Sundarbans region of Bangladesh and India since 1769. The 40 000 ha of Malaysian mangroves in Malang that have been managed for the production of fuel wood since 1902 serve as a comparable example. The business generates a sizable number of local jobs, and the usage of mangrove wood products for timber and charcoal significantly boosts the economy of Peninsular Malaysia's west coast. Mangrove cultivation and management have a long history in Southeast Asia. The management of mangroves for timber may have been practiced in the Sundarbans for the longest time. Since 1769, mangroves have been managed in the 6000 km2 Sundarbans region of Bangladesh and India. A comparable example is the 40 000 ha of Malaysian mangroves in Malang that have been managed for the purpose of producing fuel wood since 1902. The enterprise creates a considerable number of local jobs, and the west coast of Peninsular Malaysia benefits economically from the use of mangrove wood products for the production of charcoal and timber.

Factors affecting the restoration process of mangrove

Mangrove forests are endangered ecosystems, as was shown above. Their devastation is caused by a variety of human-induced pressures, including resource overuse, land reclamation for fish farming, and pollution consequences. Natural disasters have also caused mangroves to perish. The mangrove stands are frequently permanently lost, however in some cases, the woods can recover or be repaired. New places can also be established for mangrove growth in extremely unusual circumstances. Soil stability and flooding patterns need to be given special consideration when mangrove rehabilitation is being thought about. Site elevation, salinity and fresh water runoff, tidal and wave energy, propagule availability, propagule predation, spacing and thinning of mangroves, weed eradication nursery techniques, monitoring, community involvement, and overall cost of restoration procedures are all factors to consider. Finding planting locations for successful mangrove restoration is challenging since it depends on the local environment and the species that will be planted. The hydrologic regime is generally acknowledged to be the single most significant overall site factor influencing the survival and subsequent growth of the mangrove seedlings. The planting of mangroves must take place in low-energy zones with less coastal erosion. In order to determine the best locations for various species, knowledge of mangrove species zonation is crucial. Species zonation in mangroves is a result of environmental tolerance and physiological preferences of the specific species, it was noted when commenting on the distribution patterns of mangroves. Each mangrove species has a certain spectrum of environmental tolerance. For instance, *Sonneratia alba* will grow on the seaward margin due to its inability to withstand significant variations in salt content. On the landward edge of the intertidal zones, *Ceriops lagal* and *Avicennia marina* can sustain high saline levels. Because of this, *Sonneratia* should be grown in low, muddy places that are nearer to the water. It is possible to plant species like *Ceriops* and *Avicennia* on the dry, marginal landward side (Kairo *et al.*, 2001).

Mangrove Restoration: When is it necessary?

A management tactic to make up for lost and damaged ecosystem products and services is mangrove restoration. It might expand the mangrove resource base, give locals a job, safeguard brittle tropical coastlines, and improve biodiversity and fisheries output. Mangrove restoration initiatives are currently underway on a wide scale in several nations, including Bangladesh, India, Vietnam, and Malaysia, primarily to give protection in typhoon-prone areas and to directly benefit the populace economically. For instance, higher diversity forests have replaced low diversity plantings in Kenya, providing the newly planted area is not harvested. In order to accomplish the goals of sustainable mangrove management, mangrove restoration can be employed as a method to restore the lost forest. When an ecosystem has been damaged to the point where it can no longer self-correct or self-renew, restoration is advised. In many locations, natural regeneration is nearly impossible without human intervention to restore the physical and biological traits, depending on the intensity of human demands. So, direct planting of propagules, transplanting of wildlings/saplings, or nursery raised seedlings to the appropriate areas have all been part of mangrove restoration. Most of the WIO region's mangrove regeneration efforts have utilized propagules, saplings, or wildlings from the Rhizophoraceae family (*R. mucronata*, *C. tagal*, and *B. gymnorhiza*), as well as *A. marina, S. alba* has only occasionally been planted (Kairo, 2020).

Typology of Mangrove Restoration

Natural regeneration: This method restocks degraded locations using naturally occurring mangrove propagules (or seeds). In this instance, regeneration is caused by direct, freely falling, and distributed mangrove propagules, and the species composition of the regenerated forest is dependent on the species kinds and combination nations of the surrounding forest. For instance, in the family Rhizophoraceae, propagules with pointed hypocotyls can either be stranded and planted away from the parent plant or they can fall freely from the parent and plant themselves in the mud. The species mix of the surrounding population determines how the regenerated species will be composed in the Rhizophoraceae family. Propagules with pointed hypocotyls can either be stranded or planted far from the parent plant or they can fall freely from the parent and plant themselves in the mud. Depending on the forest conditions, mangroves may spread by self-planting or by stranding (cut or not cut) the stability of the soils and the tides.

When a forest is overharvested, the soil becomes less stable, which allows propagules and seedlings to be carried away with the tides and prevents natural regeneration. It is advised that parental mangrove trees (standards) be kept during harvesting operations to serve as seed bearers for the following generation and to promote natural regeneration in Malaysia, a nation with a long history of mangrove management. Twelve trees per hectare (the minimum number required) should be deliberately kept in regions with low regrowth. In Thailand, a strip clear-felling system has taken the role of standards since it has been shown to provide for appropriate regeneration. Natural regeneration versus synthetic regeneration: advantages and disadvantages (Kairo *et al.,* 2020).

Artificial regeneration: Mangroves can be artificially regenerated by manually planting suitable saplings and propagules in a chosen intertidal region. Mangrove planting has been successful in Malaysia. India. Vietnamese and Filipino (cited above). The Rhizophoraceae, Aviceniaceae, and Sonneratiaceae groups have been used for the majority of planting effort. Artificial regeneration has a number of benefits including the ability to control species composition and distribution, the introduction of genetically enhanced stocks, and the management of pest infestation. Although artificial regeneration offers a way to revive the devastated mangrove ecosystems, it has significant drawbacks. In locations where the hydrological regime has been altered, artificial regeneration can be expensive. The long-term loss of ecological productivity, which is demonstrated by the streamlining of the systems from mixed to monoculture plantations, is another drawback of artificial regeneration.

Mangrove restoration in conjunction with alternative livelihoods Increased community support and sustainability of mangrove restoration programmes result from assistance with livelihood activities. Integrating restoration work with IGAs to neighbouring communities lessens over-reliance on humans and the pressure that has a knock-on effect on the mangrove environment and its resources. Where applicable, it is advisable to promote the use of energy-efficient stoves, aquaculture (fish farming and crab fattening), mangrove eco-tourism, and beekeeping (Zhongming *et al.*, 2020). Artificial regeneration methods typically use propagules, occasionally use saplings (trees under 12 metres tall), and in very rare cases use small trees (of up to 6m high). Although these techniques have essentially not altered, they are constantly being rediscovered globally as the foundation for restoration. When propagules are in season, mangrove planting should be planned. Mangrove propagules that are mature are gathered from the mother tree, from the ground beneath trees, or from rank on beaches. Rhlzophora and Ceriops species' hypocotyls display a distinctive cotyledonary hue that distinguishes juvenile propagules from adult ones. Mature propagules of Avicennia species detach from the parent with a slight hand twist and without the calyx (Maina *et al.,* 2021).

Other methods include air-layering Rhizophora mangle *Avicennia germinans* Stearn and *Laguncularia racemosa* as well as aerial planting with Rhizophora propagules. The potential of the air-layering technology is that it can produce stock plants for transplanting without removing mangrove saplings from the source area. The difference between *Xylocarpus granatum* Koenig (4.4%) and 36.5% was statistically significant. Artificial regeneration has various benefits, including the ability to manage species composition and distribution, introduce genetically enhanced stocks, and reduce insect infestation.

Step by Step Procedures for Mangrove Restoration:

Only a small number of mangrove restoration projects have been successful in WIO countries, despite numerous efforts. Mangrove regeneration has frequently been accomplished through the simple direct planting of propagules, wild saplings, and in rare instances, nursery-raised saplings, without sufficient site evaluation and consideration of the site quality (Kairo *et al.*, 2001).

Step 1: Realizing the problem: Campaigns for restoration should begin with the problem identification. The eventual success of the restoration programme depends on understanding and recognizing the extent of mangrove degradation, which has resulted in the loss of mangrove products and services, as well as the need for and desire to take action. Understanding the issue related to the destruction and loss of mangrove forests may call for quick field consultations with important parties, such as communities. This practice is crucial for quickly grasping the values and advantages of mangroves, as well as for prioritizing, choosing, and supporting their restoration (Benkenstein and Chevallier, 2021).

Step 2: Identifying the Goal: There is frequently a lack of formal stakeholder consensus on the definition and phrasing of the objective of carrying out a restoration project in sites where restoration work has been done. Experiences show that even when a purpose has been developed, it is frequently not clearly understood by all stakeholders, particularly in terms of how it fits with the local or national conservation priorities. This makes it more challenging to assess the effectiveness and results of the restoration projects. Experiences and fieldwork lessons show that restoring degraded mangrove regions is possible as long as the why, where, when, how, and by whom concerns are properly addressed (Zhongming *et al.*, 2020).

Step 3: Understanding governance: institutional and jurisdictional contexts: Successful mangrove restoration depends on user and access rights to land and resources. Mangroves are managed under laws and regulations in the majority of the nations where they occur. Therefore, authorization from the relevant regulatory bodies may be needed for any actions (including restoration) within mangroves. Additionally, many nations have laws requiring compensatory measures (nowadays commonly referred to as "biodiversity offsets") in cases of anticipated environmental impacts from development projects where there is a loss of biodiversity, such as known areas of specific habitats, such as coral reefs or mangroves. Therefore, as a compensatory action by a developer, mangrove restoration at a site might be required. However, many mangrove restoration projects tend to skip this crucial step of developing the governance arrangements to ensure and secure commitments and manage expectations due to the governance frameworks in the individual nations (Amone-Mabuto *et al.*, 2022).

Step 4: Analysis of stakeholders: Mangroves are multipurpose systems that offer a variety of resources to numerous consumers. This frequently results in a number of conflicts, necessitating effective stakeholder identification, consultation, and engagement to guarantee that the interests of each group are taken into account cooperatively and consensually. In order to assess stakeholder interests and expectations and, in turn, where restoration interventions are most practical, beneficial, and acceptable, it is crucial to involve stakeholders appropriately, particularly local ones (UNEP, 2020).

Step 5: Community involvement: Engagement should continue throughout the whole restoration process to guarantee that the interests of the surrounding communities are understood, valued, and protected. Additionally, the process ought to be iterative so that modifications can be made in response to new facts, unforeseen problems, or the interests of stakeholders who weren't present at the initial sessions. Community perceptions and understanding of the relative benefits of conversion to other uses versus preservation of intact mangrove forest ecosystems, legal recognition of the mangrove resources in terms of rights to access and use, and land use governance defined by the institutional, economic, socio-cultural, and property rights dynamics are just a few of the crucial issues that must be taken into account in incorporating and addressing community interests (Hattam *et al.*, 2020).

Step 6: Site assessment and preparation: In the WIO region, choosing a restoration site is more theoretical than practical, especially when restoration is community-driven and communities deliberately set out to only restore local areas that are deteriorated in their locals. The place that needs to be restored should typically be accessible and free of large waves. Planting should only be done in regions with vegetation when the forest has been damaged or lost (Kirui *et al.*, 2013).

Step 7: Establishing a nursery: A mangrove nursery establishment comprises a number of operations, thus the supervisor needs to make sure that everyone is aware of what they do each day. The intertidal zone, close to streams with drainage systems, should be chosen as the location for the nursery. The area should be enclosed and the water should be of good quality to avoid human or animal disturbance. To lower the expense of transporting seedlings from the nursery to the restoration site, it should be conveniently located (Jenoh *et al.*, 2016).

1. Infantry layout: A typical mangrove nursery sketch, showing the essential cubbies. The design should be square or rectangular to facilitate building. The ideal mangrove nursery should have the following sections (Chanda, 2022).

a. Seed germination bed: Sunken beds should be built by digging out troughs where the seed pots, which are normally plastic potting bags, will be organised, to assist preserve soil moisture and prevent the pots from tumbling over, in order to protect the soil from movement. Natively, wooden supports and planks might be used to anchor the pots in rocky soil by being driven into the ground. The troughs should be at least 34 the height of the pots, depending on the size of the pots. The germination beds may need shade where the chosen site is open, which can be made by draping thatch material and branches over a straightforward frame. The resulting sheds contain two sunken beds that are each 10 m by 1 m with a minimum of a 1-m walkway, facilitating simple operations.

b. Potting shed: This is a covered shed made for the safety of the employees as they fill potting bags or polybags with soil on hot or wet days. The shade should not be smaller than 3 m by 4 m and can be constructed from 4 to 6 mangrove pole pieces. It is preferable to build the potting house underneath a large mangrove tree to further avoid direct sunlight.

c. Hardening off beds: As long as the seedlings are not moved until they are ready for out-planting, germination beds can also be utilised as hardening beds. To get the seedlings used to more sunshine exposure, artificial shedding needs to be eliminated one month before out-planting.

d. **Soil medium:** To fill the potting bags, only muddy, clayey soil should be utilised. Before adding mud to the bags, the soft clayey mud that is available in the mud flats at low tide needs to be gathered and cleared of all trash.

2. Filling pots: Raising seedlings in polybags is ideal for the majority of species. Different species need different sized pots. For example, little seedlings of A. marina can be grown in 12.5 x 20 cm polybags, whereas giant seedlings of *R. mucronata* need large bags that are at least 15 x 30 cm. The following factors need to be considered in order to maximise the germination rate and survival of seedlings in pots: To prevent water from standing on top of the pot, fill potting bags to the brim with soft clayey mud from the mangrove forest. To let the pots harden. To position the pots in a dug-trough so that at least 34 of their height is below ground level.

3. Guidelines for collection, transportation and sorting: Since the majority of mangrove species have distinct fruiting peak seasons, year-round propagule/seed production may not be possible. Therefore, it is essential to be aware of the propagule/seed production peaks for each of the mangrove species chosen for replanting in a specific location. Peak fall for mangrove propagules typically falls during the wet season from April to June in the WIO region. Figure 10 depicts propagules and seedlings of common mangrove species in WIO. To make transportation easier, mature propagules should be gathered from a forest close to the intended planting location.

Propagules should be separated after collecting to ensure high-quality planting materials. In the hypocotyls of R. mucronata and C. tagal, a unique cotyledon colour is a reliable sign of propagule maturation. Mature propagules of A. marina have a dark-blue seed coat and can twist slightly to separate from the parent plant without the calyx. Planning for direct planting of propagules should take into account their peak fall. A. marina has a single flowering time and produces propagules just once a year, unlike many species that flower frequently and produce propagules all year long with peak periods.

4. Propagule sowing: Depending on the species, different sowing techniques are needed for seeds and propagules. The hypocotyl should be put into large propagules at a depth of between 4-5 cm (Ceriops and Bruguiera) and 7-8 cm (Rhizophora). The radicle portion of Avicennia and Xylocarpus seeds must be pushed roughly (about one-third of the seed) into the soft mud. In order to prevent incidents of insect pest assault, seedlings can occasionally be raised in a thin netting screen house. To speed the opening of fruits and, in the case of Sonneratia alba and A. marina seeds, the splitting of their seed coats, overnight water soaking is recommended. Fruits from H. littoralis should be immersed in fresh water for one to two weeks. Before planting, the husk can be split by hand Mangrove propagules and seedlings, R. mucronata and A. marina, morphology.

Step 8: Out planting: For mangroves in the Rhizophoraceae family, direct planting of propagules is common (*Rhizophora, Ceriops* and *Bruguiera*). This family of species produces broad, pointed propagules that can be buried in mud. Experience has revealed that transplanting saplings has a lower survival probability than mature propagules taken from mother trees or those that have just fallen. Additionally, using propagules is three times less expensive than transplanting saplings. Methods of reproduction for various mangrove species (Abib and Appadoo, 2021).

Step 9: Reaction and modification: The belief in the majority of restoration operations has been that mangroves will grow unchecked once they are replanted. Mangroves are dynamic ecosystems that are touched by stresses both inside and outside the system; hence this is likely to fail. Involved with numerous mangrove restoration initiatives failing, as well as lessons learned from monitoring that can be used to drive changes made during the planning and implementation stages. There are detailed methods and instructions for carrying out a restoration plan. The rehabilitation of oil spill-impacted mangrove areas is a rather uncommon case in the area that may require specialist expert monitoring (Jones *et al.*, 2016).

Conclusion

A lack of understanding of mangrove silviculture, the potential for multiple uses of resources, and the methods of natural regeneration and reforestation compound the sectorial approach to managing mangrove resources, the lack of community input into management efforts, the poverty status of many indigenous coastal communities, and the lack of awareness among decision makers about the true values of these management problems. Little has been done to rehabilitate the region's deteriorated mangrove systems aside from plantation experiments for the rehabilitation of deforested mangroves. Mangrove restoration has the ability to significantly expand mangrove resources, give locals work, safeguard vulnerable tropical coral reefs, and potentially even improve biodiversity and fisheries output. In Bangladesh, India, and Vietnam, mangrove a forestation is being place on a huge scale primarily to give protection in typhoon-prone areas and to benefit the underdeveloped coastal people economically. The limited availability of mangrove wood products and maintaining the general balance of coastal ecosystems are problems that artificial mangrove planting in Asia and the Pacific region has the potential to resolve. Restored mangroves may grow into mature forests with many of the structural and functional traits of a mature mangrove system, even if plantation production has been found to diminish over many years. For instance, higher diversity forests have replaced low diversity plantings in Vietnam, providing the newly planted area is not harvested. For several places, the connection between mangroves and fishing productivity has been studied. According to these estimations, a semi-intensive shrimp farm needs a mangrove area that is 35–190 times bigger than the pond's surface area. Clearly, there is an urgent need for integrated management of mangrove forests and fisheries. There are significant prospects to build mangrove-friendly aquaculture that might be truly sustainable in East Africa, where aquaculture and mariculture activities are only starting (as previously mentioned).

References

Abib, S. and Appadoo, C., 2021. Local people and mangroves: Ecosystem perception and valuation on the south west coast of Mauritius. *Western Indian Ocean Journal of Marine Science*, *20*(1), pp.11-19.

Amone-Mabuto, M., Hollander, J., Lugendo, B., Adams, J.B. and Bandeira, S., 2022. A field experiment exploring disturbance-and-recovery, and restoration methodology of Zostera capensis to support its role as a coastal protector. *Nordic Journal of Botany*, p.e03632.

Arfan, A., Side, S., Maru, R. and Juanda, M.F., 2021. Mangrove forest management model as sustainable production forest of post COVID-19 in South Sulawesi, Indonesia. *Asian Journal of Conservation Biology*, *10*(2), pp.234-239.

Badola, R., Barthwal, S. and Hussain, S.A., 2012. Attitudes of local communities towards conservation of mangrove forests: A case study from the east coast of India. *Estuarine, Coastal and Shelf Science*, *96*, pp.188-196.

Benkenstein, A. and Chevallier, R., 2021. Strengthening the Science-to-Policy Interface in the Western Indian Ocean Region.

Chanda, A., 2022. Blue Carbon Ecosystems of the Indian Ocean: Conservation and Management. In *Blue Carbon Dynamics of the Indian Ocean* (pp. 305-328). Springer,

Cham-Hattam, C., Evans, L., Morrissey, K., Hooper, T., Young, K., Khalid, F., Bryant, M., Thani, A., Slade, L., Perry, C. and Turrall, S., 2020. Building resilience in practice to support coral communities in the Western Indian Ocean. *Environmental Science & Policy*, *106*, pp.182-190.

Jenoh, E.M., Robert, E.M., Lehmann, I., Kioko, E., Bosire, J.O., Ngisiange, N., Dahdouh-Guebas, F. and Koedam, N., 2016. Wide ranging insect infestation of the pioneer mangrove Sonneratia alba by two insect species along the Kenyan coast. *PloS one*, *11*(5), p.e0154849.

Jones, T.G., Glass, L., Gandhi, S., Ravaoarinorotsihoarana, L., Carro, A., Benson, L., Ratsimba, H.R., Giri, C., Randriamanatena, D. and Cripps, G., 2016. Madagascar's mangroves: Quantifying nation-wide and ecosystem specific dynamics, and detailed contemporary mapping of distinct ecosystems. *Remote Sensing*, *8*(2), p.106.

Kairo, J., 2020. *Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region*. United Nations Environment Programme.

Kairo, J.G., Dahdouh-Guebas, F., Bosire, J. and Koedam, N., 2001. Restoration and management of mangrove systems—a lesson for and from the East African region. *South African Journal of Botany*, *67*(3), pp.383-389.

Kairo, J.G., Mangora, M.M., Network, W.I.O.M. and Western Indian Ocean Marine Science Association, 2020. Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region-Western Indian Ocean Ecosystem Guidelines and Toolkits.

Kathiresan, K., 2010. Importance of mangrove forests of India. *Journal of coastal environment*, *1*(1), pp.11-26.

Kathiresan, K., 2018. Mangrove forests of India. *Current science*, pp.976-981.

Kirui, K.B., Kairo, J.G., Bosire, J., Viergever, K.M., Rudra, S., Huxham, M. and Briers, R.A., 2013. Mapping of mangrove forest land cover change along the Kenya coastline using Landsat imagery. *Ocean & Coastal Management*, *83*, pp.19-24.

Maina, J.M., Bosire, J.O., Kairo, J.G., Bandeira, S.O., Mangora, M.M., Macamo, C., Ralison, H. and Majambo, G., 2021. Identifying global and local drivers of change in mangrove cover and the implications for management. *Global Ecology and Biogeography*, *30*(10), pp.2057-2069.

Mitra, A., 2020. *Mangrove forests in India* (p. 1). Springer International Publishing.

Ragavan, P., Dubey, S.K., Dagar, J.C., Mohan, P.M., Ravichandran, K., Jayaraj, R.S.C. and Rana, T.S., 2019. Current understanding of the Mangrove forests of India. In *Research developments in saline agriculture* (pp. 257-304). Springer, Singapore.

Sarhan, M. and Tawfik, R., 2018, January. The economic valuation of mangrove forest ecosystem services: Implications for protected area conservation. In *The George Wright Forum* (Vol. 35, No. 3, pp. 341-349). George Wright Society.

Singh, A.K., Ansari, A., Kumar, D. and Sarkar, U.K., 2012. Status, biodiversity and distribution of mangroves in India: an overview. *Uttar Pradhesh Sate Biodiversity Board. Marine Biodiversity: One Ocean, Many Worlds of Life*, pp.59-67.

UNEP-Nairobi Convention/USAID/WIOMSA, 2020. Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z. and Wei, L., 2020. New guidelines aim to support mangrove restoration in the Western Indian Ocean.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z. and Wei, L., 2020. Decades after devastating cyclone, mangroves are on the rebound in Mozambique.