Science-based and community-centred approach to restore and sustain mangrove wetlands of India

V. Selvam[1,*] and P. Thamizoli[2]

[1]M.S. Swaminathan Research Foundation, 3rd Cross Street, Taramani Institutional Area, Taramani, Chennai 600 113, India
[2]No. 14, 6th Avenue, Ashok Nagar, Chennai 600 083, India

Mangroves of India remained degraded for many decades, and attempts to restore them yielded no appreciable results. Systematic studies revealed for the first time that changes in the biophysical condition due to past unscientific management practices are the real causes of mangrove degradation rather than utilization of mangrove resources by the local communities. Based on this finding, a simple and cost-effective method that improves the soil and hydrological conditions of the degraded areas to support the growth of mangroves has been developed and demonstrated. For upscaling, a community-centred joint mangrove management approach was developed and piloted in major mangroves along the east coast of India. Replication of this approach by government agencies resulted in a large-scale increase in Indian mangrove forest cover. Present issues relating to the participatory management of mangroves are also discussed in this article.

Keywords: Local communities, mangrove restoration, participatory research, science-based approach, tidal flushing, village-level institutions.

APART from protecting the lives and properties of coastal communities from cyclonic winds and storm surges, mangroves play a vital role in safeguarding the livelihood and food security of millions of artisanal fishing families through supporting fishery production. A review of the fisheries associated with mangroves indicates that annually 1 ha of mangrove produces fishery resources worth USD 106 (ref. 1). Communities living around the mangroves have been utilizing these resources traditionally, and through this process gain knowledge about the intricate ecosystem structure and function. These values and functions were brought to the notice of forest administrators and managers only in the 1980s when UNESCO implemented a major mangrove research and management-cum-training programme. Prior to that mangroves were considered a wasteland by the administrators and cleared on a large scale to expand agriculture. For example, between the 1790s to 1870s, nearly 280,000 ha of mangrove forest of Bengal was cleared by the British for rice cultivation[2]. Later, the Imperial Royal Forest Department of British India considered mangroves as a source of good-quality firewood and started exploiting them in the late 1880s. According to the Annual Administration Reports of the Forest Department of the Bengal and Madras Presidencies published from the 1880s and 1940s mangrove trees in thousands of acres were clear-felled and supplied as firewood to railways, steamers, as well as for consumption in nearby areas. This practice was continued by the State Forest Departments after independence. Large-scale organized felling of mangrove trees was stopped only in 1980 when the Indian Forest (Conservation) Act was passed.

Restoring mangroves in the clear-felled areas was a major challenge for foresters of both colonial and independent India. Attempts to restore mangroves during the colonial period yielded limited results, and the British foresters blamed uncontrolled grazing by cattle as the major factor that affected restoration efforts. During the post-colonial period, Indian foresters tried to restore degraded mangroves but with little success. This issue was discussed in detail in 1957 when the Central Board of Forestry, Government of India (GoI) organized the first symposium on mangroves in the country[3]. The working plans of mangroves prepared by the State Forest Departments in the 1960s and 1970s show that no serious efforts were made and finally efforts to restore degraded mangrove areas were abandoned in the 1980s.

At this juncture, in 1988, M. S. Swaminathan (Director General, International Rice Research Institute, Philippines) in a lecture at the International Symposium on the Human Response to Global Change, explained far-reaching consequences of sea-level rise due to climate change and suggested the initiation of anticipatory research to utilize the mangrove ecosystem and its genetic resources to enhance adaptive capacity to rising sea level[4]. In the same year, the M.S. Swaminathan Research Foundation (MSSRF) was established in Chennai, with conservation, management and sustainable utilization of mangrove as one of its major programmes. This article provides an account of (i) how the technical issues of mangrove restoration, which eluded both the British and Indian foresters for many decades,

*For correspondence. (e-mail: vselvam45@hotmail.com)

were resolved through participatory research, (ii) what kind of community-centric approach was followed to engage and enhance the capacity of the local communities to play a lead role in mangrove restoration and management, and (iii) how policy interventions played a key role in large-scale replication of the restoration model. The challenges faced at various stages are also discussed in this article.

Science-based mangrove restoration method

The development of a science-based and cost-effective mangrove restoration method was initiated first in the Pichavaram mangrove in Tamil Nadu. In 1990, the Forest Department, Government of Tamil Nadu (TNFD) and MSSRF joined together to establish a 50 ha Mangrove Genetic Resources Centre in the Pichavaram mangrove in Cuddalore district. Of this, mangroves in about 20 ha were totally degraded. TNFD also wanted MSSRF to develop and demonstrate suitable methods and strategies to restore the degraded mangrove areas.

Participatory research and identifying the real cause of mangrove degradation

As a first step, consultative meetings were held with the primary stakeholders, artisanal and small-scale fishing and farming communities and managerial and field-level officials of TNFD, to identify the causes of degradation of mangroves and options available for restoring degraded areas. Officials of TNFD emphasized that grazing by cattle from nearby villages and illegal felling of trees by local people were the primary causes of degradation. Such was the conviction that foresters held for a long time as Venkatesan[5], Forest Working Plan Officer in 1965 wrote: 'though man is largely responsible for the deterioration of mangroves by his illicit cuttings, greater damage is done by the cattle which eat away the seedlings and thus prevent the establishment of natural regeneration'. On the other hand, both fishing and farming communities denied that these factors were the lead causes of mangrove degradation. To support their arguments they informed that (i) only dead wood and twigs were collected from the mangroves for domestic use, that too only by a small number of families, (ii) none was eking out a living by selling mangrove wood, and (iii) cattle were grazed only in the periphery of the mangroves, where previously the Forest Department allowed grazing on a fee. Further, they claimed that mangroves were severely degraded only in the interior parts, which were not accessed by the local communities and cattle.

Since the claims by the primary stakeholders on the causes of degradation were contradictory, joint visits to mangroves with members of the local communities and field staff of TNFD were organized by MSSRF to verify their claims. During field visits, it was found that degradation was severe in the interior parts of the mangroves as informed by the community. In the degraded areas, the presence of a large number of stools was observed, and in many places, there was stagnation of tidal water (Figure 1). Stagnation of tidal water is an uncommon feature in mangroves; free flushing of mangrove forest by tidal water is a prerequisite for a healthy mangrove. Hence, observation of stagnant tidal water in degraded mangrove areas led to the hypothesis that some changes might have occurred to the topography, causing stagnation of saline tidal water and finally degradation of mangroves. To test this hypothesis, the relationship between topography, tidal inundation, groundwater and soil salinity and health of the mangroves was evaluated.

The microtopography of the mangrove was measured in eight randomly selected transects following the method described by Emery[6], with four transects each in healthy and degraded mangroves. The lowest low tide level was taken as 0 and from this benchmark, topographic readings were taken at 5 m intervals, covering the entire length of each transect. The frequency and extent of tidal flushing of different parts of each transect were observed for a whole tidal cycle. Groundwater was collected using a PVC extractor with a porous metal tip, as described by Gordon[7]. Soil samples were collected in all the transects at three depths, viz. 0–5, 20–30 and 40–50 cm, and soil salinity was measured using saturated soil past technique[8]. All the data were collected during the peak months of April and May.

Figure 2 *a* and *b* shows the typical profile of microtopography of healthy and degraded mangrove areas respectively. In the healthy mangrove areas, microtopography was smooth and flat, and land elevation was about 20–45 cm above zero level. As a result, it was observed that tidal water entered freely into the healthy mangroves during high tide and drained completely during low tide. In contrast, the topography of the degraded mangroves was 'trough'-shaped with elevated margins and a sunken middle portion, and the depth of the troughs varied from 12

Figure 1. Clear-felled mangrove area with stools and stagnant tidal water.

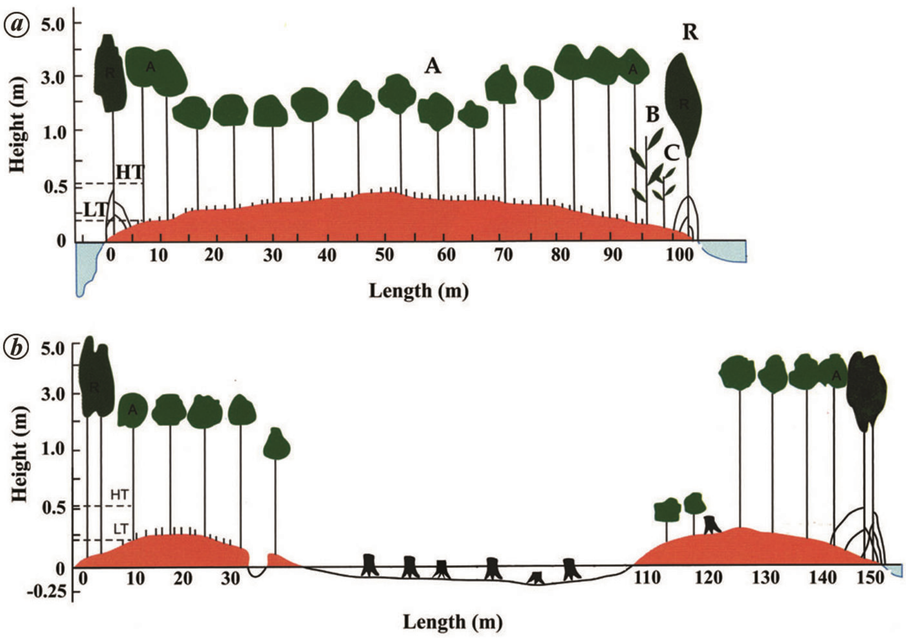

Figure 2. Profile of the topography and vegetation structure in (***a***) healthy and (***b***) degraded mangrove areas.

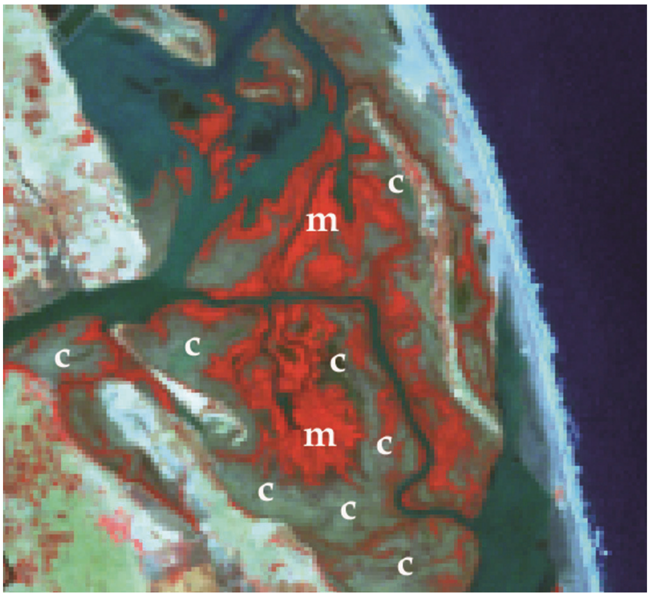

Figure 3. Satellite imagery of the Pichavaram mangrove (Landsat 5 TM of 1986) showing healthy mangroves (m) and trough-shaped, clear-felled degraded areas (c).

to 48 cm below the level of low tide. As a result, tidal water which entered into the trough-shaped area during high tide was unable to drain out during low tide due to elevated margins, resulting in stagnation. During summer, the stagnant tidal water evaporated, resulting in an increased level of groundwater as well as soil salinity. In the healthy mangrove areas, groundwater salinity varied from 22‰ to 64‰, whereas in degraded areas it varied from 70‰ to 120‰. The average value of 32 samples was 93‰, which is lethal to even high saline-tolerant mangrove species[7]. Soil salinity was also high in the degraded areas (46‰ to 104‰) and low in the healthy mangroves (12‰ to 24‰)[9]. Such high soil salinity in the degraded mangrove areas of Pichavaram was also recorded by Blasco *et al.*[10]. The above observation clearly showed that the development of hypersaline condition due to stagnation of tidal water, which was a result of the development of trough-shaped topography, was the primary reason for the degradation of Pichavaram mangroves. This conclusion was well supported by remote sensing data (Figure 3).

The conclusion arrived from the present study has raised an important question: why did the middle portion of the degraded areas become trough-shaped instead of being flat as in the healthy mangroves? Again the clue came from the community, who informed that in most of the degraded areas, mangrove trees were clear-felled by the Forest Department in the past. Although the Pichavaram mangrove was notified as a Reserved Forest in 1893, organized exploitation of mangrove trees by the Forest Department was introduced only in 1949. The system adopted was clear-felling with 40 years rotation, and the method of treatment followed was simple coppice[11]. That is, the mangrove forest will be divided into 40 plots (called annual coupes) of more or less equal size. In the first year, trees in the first plot will be clear-felled. During the felling of trees, the lower portion of the stem with roots (stools) will be left undisturbed for the formation of new shoots. This method of regeneration is termed simple coppice. In the second year, mangrove trees in the second coupe will be clear-felled with stools for regeneration. This will continue until the mangrove trees in the 40th annual coupe are felled during the 40th year of rotation. In the 41st year, the first coupe will be ready with a stock of trees of 40 years old for the second felling cycle.

According to this system, the Pichavaram mangrove forest was divided into 40 annual coupes, which varied in size from 24 to 40 acres[11]. The mangrove trees in the first coupe were felled in 1949–50, and this continued till clear-felling was completed in the seventh coupe in 1955–56, when it was noticed that regeneration of mangroves from stools was not satisfactory. Hence in 1956, another treatment method, i.e. simple coppice with standards was introduced[12]. According to this treatment method, 15 mother trees were retained per acre of clear-felled areas for regeneration from seeds. With the second treatment method, clear-felling in the eighth coupe commenced in 1956–57, which continued till clear-felling was completed in the 16th coupe in 1963–64. During this time, it was observed that regeneration from stools and seeds was not satisfactory and clear-felling was stopped in the mid-1970s. This clear-felling system of management was found to be the primary cause of mangroves degradation. Since nearly 80% of the mangrove soil is water, clear-felling of mangrove trees exposed the mangrove soil to sunlight, causing evaporation of soil water which caused subsidence of sediment in clear-felled areas. Subsidence of sediment is common in wetland soils, which are exposed to prolonged solar radiation[13,14]. Due to this, topography in the clear-felled areas had become trough-shaped, causing stagnation of tidal water. Its subsequent evaporation led to the failure of regeneration of mangroves species in the clear-felled areas. Since the foresters of both the colonial period and independent India were not cognizant of the above chain reaction triggered by the clear-felling system of management, their attempts to restore mangroves in clear-felled areas were not successful[15].

Tidal-water canal system for mangrove restoration

Having understood that development of hypersaline condition in the clear-felled areas as the primary cause of degradation, it was hypothesized that these trough-shaped, degraded, clear-felled areas could be easily restored if facilities were provided for regular flushing by tidal water. To test this hypothesis, a 10 ha degraded area was selected jointly with TNFD and the local people. The topographic map of this area was prepared and on the basis of the topography, a canal system was designed and established to ensure free flow of tidal water in and out of the degraded areas during high and low tide. The canal system consisted of the main canal with 3 m (upper width) × 1.8 m (bottom width) × 1 m (depth) dimension, and feeder canals with 1 m × 0.60 m × 1 m dimension. The feeder canals were aligned at 45° to the main canal (Figure 4). The main canal, in turn, was connected to a deep natural channel located close to the degraded areas. The canal system was established before the onset of the northeast monsoon season, expecting that during the monsoon low-saline water or freshwater will flood the degraded areas, which would help in reducing the salinity level rapidly.

In the 10 ha demonstration site, 4800 propagules of *Rhizophora* spp. and 28,000 of *Avicennia marina* were planted according to the distribution of these species in healthy mangroves. The growth performance of the plantation was observed for three years continuously and also at the end of six years (Table 1). The survival of *Rhizophora* and *Avicennia* plantations was 66% and 72% respectively, in the first year. However, from the second year onwards, a large number of propagules of these species were brought into the demonstration site by tide currents and started establishing themselves. Before setting the tidal-water canal system, the soil of the demonstration site was unsaturated with water, and hence groundwater was collected from six points; its salinity varied from 82‰ to 94‰. After tidal flushing was established, the soil was saturated with water and hence pore water was collected in five randomly selected points after a period of one year and its salinity showed values ranging from 17.8‰ to 53‰. The observation of natural regeneration, good growth and reduced level of salinity in soil water clearly showed that the canal system is an effective method of restoring degraded clear-felled areas of the Pichavaram mangrove[16,17]. Since the field staff of TNFD and local people were involved from the beginning, they were also engaged in regular monitoring of the restoration demonstration.

Community-centred joint mangrove management approach

The results of the study on the real cause of mangrove degradation and scientific method of restoration were communicated and shared with all the stakeholders,

Figure 4. A typical canal system established in the degraded areas for regular flushing by tidal water.

Table 1. Growth performance of *Avicennia marina* propagules planted in the restoration demonstration site

Parameters	Months 8	12	18	24	36	72
Survival (%)	84	78	77	72	72	72
Net increment in height (cm)	35.16 ± 1.54** (22–58)***	61.65 ± 2.66 (44–82)	137.1 ± 2.66 (92–165)	163.86 ± 5.61 (102–214)	262.85 ± 5.72 (196–345)	415.06 ± 13.20 (324–488)
Number of internodes/plant	7.03 ± 0.31 (4–12)	11.37 ± 0.43 (9–18)	22.5 ± 0.66 (14–30)	25.43 ± 0.82 (17–35)	29.13 ± 1.05 (16–44)	No data
Number of branches/plant	8.7 ± 0.46 (3–12)	10.93 ± 0.62 (6–21)	25.33 ± 0.99 (16–40)	27.56 ± 0.98 (18–48)	32.83 ± 1.21 (17–56)	No data
Diameter of first internode (cm)	0.82 ± 0.05 (0.4–1.5)	1.12 ± 0.07 (0.6–2.1)	2.16 ± 0.78 (1.3–3.6)	2.78 ± 0.09 (1.9–3.9)	3.71 ± 1.33 (1.8–5.8)	6.38 ± 0.39† (4.56–8.99)

**Mean with standard error; ***Minimum and maximum; †Diameter at breast height.

including higher officials of TNFD and leaders of the local community, through formal and informal meetings and by organizing field visits to the demonstration site. During these interactions, the following three important questions were raised by the stakeholders: (i) How do we upscale mangrove restoration efforts? (ii) How will the canal system for tidal flushing, which is artificial and prone to siltation, be maintained? (iii) How will social pressure, if any, on restored and other healthy mangroves be handled?

In response to the above concerns, a community-centred joint mangrove management (JMM) approach was worked out in the Pichavaram mangrove on the lines of the joint forest management principles. The primary aim of the approach was to engage and empower stakeholders, particularly the local communities, socially, technically and organizationally to restore and sustain and manage mangrove wetlands. To achieve this, the following process which consists of several steps was employed.

Situation analysis

The purpose of situation analysis was to understand (i) land use and land cover within and near mangroves, (ii) degree and causes of mangrove degradation, (iii) assessment of forestry and fishery resources associated with mangroves, (iv) degree of dependency of the local community on mangroves, (v) the traditional and changing systems of resource utilization and their perception about the past and present status of the resources, (vi) current management practices and (vii) level of participation of the community and other stakeholders. A combination of scientific and participatory tools was used to analyse the situation.

Selection of project hamlets

Hamlets rather than revenue villages were selected as the social unit to implement mangrove restoration and conservation activities because in hamlets (i) the community is mostly homogenous, (ii) traditional controlling system is dominant rather than the political system, (iii) there is trust among different groups of the community and (iv) decision-making and conflict resolution are comparatively easier. For selecting the hamlets, socio-economic backwardness, intensity of utilization of mangrove resources and willingness to take active participation in JMM were used as the criteria.

Participatory rural appraisal

In the project hamlets, a set of participatory methods such as social mapping, historical timeline, seasonality calendar, organizing transect walk in the mangrove wetland, resource mapping, livelihood analysis, matrix rankings, etc. was used. These methods ensured active participation of both women and men in the appraisal, and to express their perceptions and perspectives relating to the complex inter-relationships between mangrove environment and livelihood of local people, governance and dynamics in the resource availability and management of mangroves[18]. It also helped in the identification and prioritization of major concerns of the mangrove-dependent communities that need to be resolved to improve the socio-economic condition of the communities, and conservation and sustainable management of mangroves. The participatory rural appraisal (PRA) also provided ample opportunities to establish a rapport with the men and women of the hamlets, which was an unintended result but provided a strong base to mobilize the people to form a community-based organization.

Setting up a community-based institution

A gender-balanced, community-based organization called Village Development and Mangrove Conservation Council (VDMC) was set up in each of the identified hamlets. It provided a platform for all the stakeholders to jointly discuss the major concerns identified through PRA and take a collective decision to address them. The structure of this village-level organization included a General Body in which one adult male and female from each willing family were enrolled as members. It functioned as the decision-making body. The second tier of this institution was an Executive Committee in which, apart from the local community other stakeholders such as the Forest, Fisheries, Rural Development Department and MSSRF also participated as members. It was made compulsory to give 33–50% representation in the Committee to women. The Executive Committee functioned as the planning and implementation body. The kinship ties, shared lineage and socio-economic, homogenous nature of the hamlet community formed a good basis for this institution to embark on collective actions.

The VDMC helped engage the people as active participants. Community engagement in the intervention planning and implementation of the activities is essential to ensure effective and equitable socio-economic development, and long-term conservation and management of mangroves. The VDMCs were created primarily to prioritize issues to be solved, arrive at a consensus as the basis for action, and ensure that all sections of the community are participating in the planning and implementation. The VDMC also provided an opportunity for women, and other marginalized and powerless sections of the community to become part of the decision-making structure and process.

Mangrove management unit

For each participating hamlet, a mangrove management unit was identified jointly by the community and the Forest Department. This management unit is an area of the mangrove wetland which was traditionally utilized by the people of that hamlet for livelihood and subsistence before the mangroves were declared as Reserved Forests. The identified unit consisted of both degraded and healthy mangroves.

Preparation of a micro-plan

For each hamlet that participated in the JMM, micro-plans were prepared jointly by the community and the stakeholders. In this process, responsibilities were delegated to the communities, which created an opportunity for them to take informed decisions about local issues related to their livelihoods and management of the mangrove resources.

The plan contained details of the actions to be taken to solve the issues relating to mangrove restoration and conservation, and interventions needed to address the socio-economic concerns of the community identified and prioritized through PRA. In some villages, mangrove restoration was not the foremost priority of the communities. There were other more pressing economic and social concerns which the communities wanted to address first, and as a principle of participatory development, it was accepted, and plans were prepared according to the priority list made by the community. In some villages, socio-economic concerns and issues relating to mangrove restoration and conservation were addressed simultaneously. The plan helped in mobilizing funds from internal and external resources, and manpower from the hamlets. The micro-plan also provided details of the timeline, and the roles and responsibilities of each stakeholder in its implementation.

Implementation of the micro-plan

The Executive Committee implemented activities according to the micro-plan with support of stakeholders; MSSRF facilitated the process. Funds obtained according to the micro-plan were directly deposited in the accounts of the community-based institution, which took responsibility for proper utilization of the funds. The active participation of local people in decision-making, planning and taking responsibilities in the activities always improved the effective implementation of the plan, enhanced the results and reduced the time and investment required in the long term.

Piloting mangrove restoration method and Joint Mangrove Management approach

When the JMM approach was being worked out, the causes for degradation of Muthupet mangrove in Tamil Nadu; Krishna and Godavari mangroves in Andhra Pradesh and Bhitarkanika and Devi mangroves in Odisha were also analysed by participatory research. The records of the State Forest Departments showed that most of the mangrove forests of the Godavari delta such as Coringa and Upputeru, and the Krisna delta such as Yellichettidibba, Nachugunda and Sorlagondi were declared as fuel Reserved Forest during 1886–87 (ref. 19). The large-scale clear-felling of mangrove trees in these mangroves was started immediately after their notification as Reserve Forest. In all these mangroves, as in the case of the Pichavaram mangrove, clear-felling was the system implemented to exploit the trees. For example, during 1893–94 and 1894–95 mangroves trees in 5130 and 3358 acres respectively, were clear-felled in the Krishna mangroves and the felled trees were supplied as firewood to railways, cotton mills, brick kilns and for consumption in nearby towns. In the clear-felled areas of Muthupet, the Godavari and Krishna mangroves soil subsided as in the case of the Pichavaram mangrove causing the topography to become trough-shaped, resulting in the development of hypersaline condition and failure of regeneration of mangrove species[20].

Table 2. Area of degraded mangroves restored and healthy mangroves brought under conservation during pilot testing of the joint mangrove management (JMM) approach

State	Mangrove	Area restored (ha)	Healthy mangroves under JMM (ha)	No. of villages that participated	Total no. of families that participated in JMM
Tamil Nadu	Pichavaram	250	200	4	697
	Muthupet	375	800	4	506
Andhra Pradesh	Krishna	355	2600	4	930
	Godavari	165	6840	6	884
Odisha	Devi	257	1560	10	1435
		1402	12,000	33	4452

Since the primary cause of degradation of most of the mangroves of the east coast of India was similar to that of the Pichavaram mangrove, it was decided to extend the mangrove restoration method and JMM approach developed and demonstrated in Pichavaram to these mangroves on a pilot scale. As shown in Table 2, the mangrove restoration method was pilot tested in 1400 ha with participation of the local communities and State Forest Departments of Tamil Nadu, Andhra Pradesh and Odisha. Apart from restoration, healthy mangroves of about 12,000 ha were also brought under participatory management[21].

Challenges

The canal method of mangrove restoration faced limited challenges. When the mangrove restoration method was developed, it was predicted by the stakeholders that the artificially dug canals would collapse in due course of time, which may again restrict free tidal flushing of the degraded areas. However, silting of canals was not observed in areas with clayey soil and wherever feeder canals are aligned about 45° to the main canal. In fact, in many places, the breadth of the canals was found to have increased. Though this increase in breadth of the canals was due to erosion of the banks, the silt thus generated was removed out of the canal by tidal currents. In sandy soil, both primary and feeder canals collapsed within a short period because of the loosely arranged sand grains, indicating that this method is not appropriate in sandy areas. Similarly, wherever feeders were aligned at or near 90° to the main canal, the speed of flow of water was reduced, which resulted in the deposition of silt[22].

In the community-centric approach, many challenges were encountered, particularly in establishing village-level organizations and balancing the socio-economic aspirations of the community and objectives of mangrove restoration and conservation. Each hamlet, where the pilot-scale, community-centric mangrove restoration and conservation activities were implemented, has its own traditional controlling system with an established line of leadership, norms for functioning and decision-making processes. It usually focuses on keeping peace and harmony within the hamlet, maintaining a cordial relationship with other hamlets, organizing festivals and rituals for village deities, etc. The leaders of this traditional controlling system considered that establishing a new institution at the hamlet level would undermine their power, and roles and responsibilities and hence, refused to provide consent to develop a multistakeholder-based village-level institution. It took considerable time to convince the traditional leaders that the functions of the proposed village-level institutions would focus on socio-economic and mangrove management-related issues, and would not intervene in the functions of the traditional controlling system[23]. In many of the hamlets, village-level institutions had representatives from the leaders of the traditional controlling system.

The socio-economic concerns of the community were many, and balancing focus on solving these issues and integrating them with restoration and sustainable management of the mangroves posed a great challenge. However, the participation of government agencies as a member in the village-level institution provided an opportunity for the government and the community to work together, which helped in improved understanding of the concerns of the community, identifying interventions to solve these concerns, and planning, implementation and monitoring of the results of interventions[24].

The understanding of the Forest Department that the primary cause of degradation of mangroves was the past unscientific management practices rather than utilization of mangrove resources by the communities played an important role in reducing the animosity between the Forest Department and the local community. Secondly, the learning of the Forest Department from joint forest management (JFM) experiences that community participation is the key for long-term sustainability of both restored and healthy mangroves, drew them close to the community and made them accept the local community as a partner in JMM.

Policy support for large-scale replication

The Ministry of Environment and Forests (now Ministry of Environment, Forest and Climate Change), GoI formed a four-member Sub-Committee (Office Memorandum vide letter no. J-22012/19/92-CSC(M) dated 20.03.2000) to take stock of mangrove restoration, afforestation, conservation and different aspects of mangrove management. The Sub-Committee visited mangrove sites in Tamil Nadu, Andhra Pradesh and Odisha, where a science-based and community-centred mangrove restoration and conservation approach was being pilot-tested. The Sub-Committee recommended the inclusion of this approach in the guidelines for National Mangrove Conservation and Management[25] and replication of the same in restoring saline blanks that exist in the mangroves of Tamil Nadu and Andhra Pradesh. Later, the same approach was applied to the restoration of mangrove wetlands of Odisha[26] and Maharashtra. According to the Forest Survey of India[27], mangrove forest cover in India has been increasing since 1993, and the present approach developed and demonstrated by MSSRF on a pilot scale in all the major mangroves along the east coast of India played a catalytic role for such positive changes in the mangrove cover of the country.

Conclusion

The results of this study clearly show that in the participatory research and management of natural resources, including mangroves, local and traditional knowledge, observations and perspectives of local people form the basis for designing sound, applied research and development and demonstration of practically feasible and sustainable management practices. A major factor for the success of this JMM initiative was that in the tripartite arrangement among the facilitating agency (MSSRF), government agency (State Forest Department) and local people (mangrove user communities), each partner recognized and respected, and contributed and complemented to the strength of the others, which needs to be extended to restore the remaining degraded mangroves and sustain healthy mangrove areas. However, a recent review indicates that the village-level institutions established (variously named as Village Development and Mangrove Council, Eco-Development Committee and Village Forest Council) for JMM are being increasingly marginalized in decision-making and planning. The leaders and members of these village-level institutions have a feeling that they are being used by the NGOs and Forest Departments to implement projects[28]. This study also shows that there was no major change in the conviction and attitude of the communities to JMM, but the Forest Departments in almost all the states are distancing themselves from genuine participatory management. One of the reasons could be the quality of human resources available at the disposal of the State Forest departments. When the present JMM was initiated in the late 1990s, JFM was at its peak, and there was huge political and administrative support to it. Both managerial and field staff of the Forest Departments were constantly exposed to the concept and thoroughly trained on the process to be followed to achieve true participation of the community. The present younger generation of both managerial and field-level staff has limited exposure to the participatory approach and practical training in JFM. Hence, they are not much convinced that people's participation is necessary for the long-term sustainability of the mangroves. Moreover, declaring all the mangroves as Wildlife Sanctuaries has also complicated the participatory process further. To improve the situation, the State Forest departments have to enhance the understanding and capacity of the younger generation of officials to participatory management, which can be achieved through more formal and informal training. There is a need to revisit the curriculum of the Indian Forest Service and Range Officers and other field staff training, which reflects the colonial legacy aimed at exploiting the forest rather than the present need for participatory sustainable management.

1. Hutchison, J., Spalding, S. and zuErmgassen, P., *The Role of Mangroves in Fisheries Management*, University of Cambridge, The Nature Conservancy and Wetlands International, UK, 2014, p. 54.
2. Hunter, W. W., *Statistical Account of the Districts of the 24 Parganas and the Sundarbans*, Trubner and Co, London, UK, 1875, p. 389.
3. Anon., Proceedings of the Mangrove Symposium, Ministry of Food and Agriculture, Government of India, 1957, p. 136.
4. Swaminathan, M. S. and Kesavan, P. C., Agriculture in an era of climate change. *Agric. Res*., 2012, **1**, 3–11.
5. Venkatesan, K. R., The mangroves of Madras state. *Indian For.*, 1966, **92**, 27–34.
6. Emery, K. O., A simple method of measuring beach profile. *Limnol. Oceanogr*., 1961, **6**, 90–93.
7. Gordon, D. M., Disturbance to mangroves in tropical-arid Australia: hyper salinity and restricted tidal exchange as factors leading to mortality. *J. Arid Environ*., 1988, **15**, 117–145.
8. Richards, L. A., *Diagnosis and Improvement of Saline and Alkali Soils*: *Agriculture Handbook No. 60*, United States Department of Agriculture, Washington DC, USA, 1954, p. 166.
9. M. S. Swaminathan Research Foundation, Integrating conservation with development in the mangroves of Tamil Nadu. Project report (File No. 38-7-122-5) submitted to the Canadian International Development Agency, New Delhi, 1995, p. 65.
10. Blasco, F., Kerrest, R. and Marius, C., Considerations on some ecological factors influencing the biology of Indian mangroves. In Proceedings of the National Symposium on Biology, Utilization and Conservation of Mangroves, Shivaji University, Kolhapur, 1986.
11. Venkataramany, P., Working plan for the Chingleput Forest Division (1949–50 to 1963–64), Forest Department, Government of Madras, Madras, 1954, p. 57.
12. Venkatesan, K. R., Working Plan for the Cuddalore Forest Division (1966–67 to 1975–1976), Forest Department, Government of Tamil Nadu, Chennai, 1972, p. 132.
13. Stephens, J. C. and Speir, W. H., Subsidence of organic soils in the USA. In *Land Subsidence* (ed. Tison, L. J.), International Association for Hydrological Sciences Publication No. 89, USA, 1969, pp. 523–534.
14. USDA, *Soil Survey Manual*, United States Department of Agriculture Handbook No. 18, United States Department of Agriculture, Washington DC, USA, 1995, p. 305.

15. Selvam, V., An assessment of mangrove management during the colonial and post colonial periods. *Curr. Sci.*, 2021, **120**, 766–771.
16. MSSRF, Annual Report 1994–95. M.S. Swaminathan Research Foundation, Chennai, 1995, pp. 11–12; http://59.160.153.188/library/sites/default/files/AR1994-1995.pdf
17. Selvam, V., Ravichandaran, K. K., Gnanappazham, L. and Navamunnyamal, N., Assessment of community-based restoration of Pichavaram mangrove wetland using remote sensing data. *Curr. Sci.*, 2003, **86**, 794–798.
18. Selvam, V., Karunagaran, V. M., Ravichandaran, K. K. and Beula, E. J., Joint mangrove management in Tamil Nadu part 2: Participatory rural appraisal in mangrove user villages. MSSRF, Chennai, 2004, p. 134; http://59.160.153.188/library/sites/default/files/Joint%20mangrove%20mgt%20in%20TN%20part%203.pdf
19. Anon., Annual Administration Report of the Forest Department, Madras Presidency for the Year 1894–95, Government Press, 1896, p. 340.
20. Ravishankar, T., Gnanappazham, L., Ramasubramanian, R., Sridhar, R., Navamuniyammal, N. and Selvam, V., *Atlas of Mangrove Wetlands of India: Part II. Andhra Pradesh*, MSSRF, Chennai, 2002, p. 68; http://59.160.153.188/library/sites/default/files/Mangrovewetlands%20Andhra.pdf
21. MSSRF, The mangrove decade and beyond: activities, lessons and challenges in mangrove conservation and management, 1990–2001, M.S. Swaminathan Research Foundation, Chennai, 2002, p. 40; http://59.160.153.188/library/sites/default/files/Mangrove%20decade%20and%20beyond.pdf
22. Selvam, V., Ravishankar, T., Karunagaran, V. M., Ramasubramanian, R., Eganathan, P. and Parida, A. K., Tool kit for establishing coastal Bioshield, MSSRF, Chennai, 2005, p. 117; http://59.160.153.188/library/sites/default/files/Toolkit%20for%20establishing%20coastal%20biosheid_0.pdf
23. Selvam, V., Mani, K. G., Karunagaran, V. M., Ravichandaran, K. K. and Beula, E. J., Joint mangrove management in Tamil Nadu part 3: Village Mangrove Council, MSSRF, Chennai, 2004, p. 56; http://59.160.153.188/library/sites/default/files/Joint%20mangrove%20mgt%20in%20TN%20part%203.pdf
24. MSSRF, Annual Report 1998–99, M.S. Swaminathan Research Foundation, Chennai, 2000; http://59.160.153.188/library/sites/default/files/AR1998-1999.pdf
25. MoEF&CC, National mangrove conservation and management: guidelines for implementation, Ministry of Environment, Forest and Climate Change, Government of India, 2006, p. 45.
26. OFSD, *Technical Manual for Restoration of Mangroves*, Orissa Forest Sector Development Project, Forest and Environment Department, 2010, p. 81; http://ofsds.in/Publication/TechnicalManual-Mangrove.pdf
27. FSI, *State of Forest Report 2017*, Forest Survey of India, MoEF&CC, GoI, 2018, pp. 55–61; https://fsi.nic.in/isfr2017/isfr-mangrove-cover-2017.pdf
28. MSSRF and IUCN, Mangrove restoration and afforestation: participatory assessment of current practices, M.S. Swaminathan Research Foundation, Chennai, 2011, p. 102; https://www.mangrovesforthefuture.org/assets/Repository/Documents/003-SG-IN-01-02-05.pdf

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