Mangrove Restoration: An Overview of Coastal Afforestation in India

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Abstract

Mangroves, a major wetland type in the intertidal belt, are one of the most productive ecosystems in the world. With their annual disappearance at the rate ~1%, mangrove conservation through plantation has gained an unprecedented significance in the recent decades. Many South and Southeast Asian countries are regularly engaged in mangrove restoration initiatives through massive plantation initiatives. Akin to this trend, mangrove wetland restoration in terms of plantation is underway in the Indian state of Gujarat where plantation to the tune of 30,000 ha has been completed so far. The Gulf of Kachchh (GoK) coast of Gujarat in India has witnessed sustained mangrove plantation efforts in the last two decades. *Avicennia marina* is the preferred candidate species in this region due to its environmental plasticity.

In the Gulf of Kachchh, three different plantation techniques, namely, (a) transplantation of nursery-raised saplings, (b) raised bed method, and (c) direct propagule dibbling, are generally followed either singly or in combination to raise mangrove plantation. These different techniques have their own pros and cons though transplantation of nursery-raised saplings is considered as most successful. Many unresolved issues such as high incidence of mortality, poor site selection, poor technical skills, and legal bottlenecks in obtaining appropriate sites cripple mangrove plantation in the GoK. Proactively involving coastal industries in mangrove restoration activities together with participation of other stakeholder coastal communities could be more meaningful and productive. Thus, an integrated sustainable mangrove management plan encompassing different stakeholders is suggested. It is also recommended that instead of plantation

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B.A.K. Prusty et al. (eds.), *Wetland Science*,
DOI 10.1007/978-81-322-3715-0_26

as the sole measure of restoration, other restoration techniques such as biophysical amendments could be undertaken.

Keywords
Avicennia marina • Gujarat • Mangrove plantation • Stakeholders

26.1 Introduction

Wetland ecosystem covers an area of about 8.3–10.1 million km^2 in the world and constitutes about 6.4% of the global landmass (Lehner and Döll 2004). Wetlands include diverse habitats ranging from extensive peats, bogs, tropical mangrove forests, seasonal ponds and marshes, floodplains, riparian swamps, freshwater lakes, margin of reservoirs, salt lakes, brackish lagoon, estuaries, and coastal salt marshes (Gopal 1995; Gopal and Sah 1995). Wetlands are among the most productive ecosystems on earth, producing food and raw materials for many people and freely providing valuable services. Maltby (1986) aptly describes wetland as waterlogged wealth. During the last few decades, tropical wetlands have been destroyed, degraded, and considerably altered, driving many associated species to near extinction. The recent "Millennium Assessment" of ecosystem puts wetland biodiversity as the most threatened of all types of biodiversity.

As a prominent wetland in the ecotone between land and sea, ecological, economical, and social services of mangroves are numerous. They are a distinct ecosystem composed of peculiar plants, animals, and microbes. A vast coastal populace depends on this ecosystem for their traditional livelihoods. Nevertheless, indiscriminate degradation and reclamation (in fact, filling up) of this valuable ecosystem continues unabated. India reportedly lost nearly 38% of wetlands during 1990s (Khaleel 2009). In case of mangroves, which make up less than 0.4% of world forests, a worldwide loss of 1% per annum and 0.66% in India has been earlier reported (Kathiresan and Bingham 2001; FAO 2007). In some areas, the rate of reclamation and degradation is as high as 2–8% per year (Miththapala 2008). It is estimated that within 100 years from now, mangrove wetlands may become so degraded that they would be considered as "functionally disappeared" (Duke et al. 2007). It is apparent that the present rate of mangrove disappearance could be controlled only through effective and refined mangrove plantation, restoration, and rehabilitation measures. The three different terms, namely, rehabilitation, restoration, and plantation, are interchangeably used to denote mangrove plantation. Field (1999) defines rehabilitation as return of degraded mangrove land to a fully functional mangrove ecosystem and restoration as returning the degraded mangrove land to something like its presumed original state. The term, plantation in this chapter in particular, relates to raising mangroves in a technically suitable coastal belt where mangroves were absent earlier.

Globally, mangrove conservation through restoration, rehabilitation, and plantation has a long history and it is discussed in detail by several authors (Watson 1928; Chapman 1976; Lewis 1982; Hamilton and Snedaker 1984; Lewis 1990; Crewz and Lewis 1991; Saenger and Siddiqi 1993; Field 1996; Lewis 1999; Lewis and Streever 2000; Macintosh et al. 2012). Since early 1990s, many South Asian and Southeast Asian countries, which harbor nearly 80% of mangrove cover of the world, are engaged in mangrove restoration and plantation initiatives. Efforts to conserve, protect, and restore them can be seen in many South and Southeast Asian countries such as Bangladesh, India, Indonesia, Myanmar, Seychelles, Sri Lanka, Pakistan, Thailand, and Vietnam (Macintosh et al. 2012). Since 1985, in Pakistan 800 km^2 of mangroves is planted in the Sindh and Balochistan coast (Memon 2012). Among South Asian countries, Bangladesh is pioneering in mangrove plantation as massive mangrove afforestation program is in operation since 1960s, resulting in restoring/planting about 1773 km^2 of mangroves in four coastal provinces (Ahmad 2012). This probably is the highest extent of mangrove plantation undertaken by any country. Mangrove restoration through plantation gained further impetus post-Indian Ocean tsunami in 2004, which unambiguously proved mangroves' shoreline protective role. In Indian Sunderban alone, 17,288 ha of mangrove plantation has been carried out by 2011. Among Indian states, Gujarat so far has carried out plantation to an extent of 25,000 ha since last two decades that, probably, is the highest extent of mangrove plantation among Indian maritime states.

In South and Southeast Asian countries, restoration is mostly through plantation. In countries like Pakistan, Sri Lanka, Bangladesh, Indonesia, and Myanmar, plantation is mostly carried out through transplanting nursery-raised seedlings (Memon 2012) with some minor variations. For example, in Pakistan, along with transplantation of nursery-raised saplings, plantation of seedlings collected from wild and broadcasting seeds are followed as a supplementary to seedling transplantation. In India, though nursery method is common, planting techniques vary regionally, e.g., planting seedlings in coconut shells is practiced in Karnataka, using cut bamboos to raise seedlings is practiced in Kerala, and raising seedlings in earthen pots and planting seedlings along artificially constructed canals is practiced in Tamil Nadu. One method specific to Gujarat is "raised beds" wherein seeds are dibbled on raised circular or square earthen beds in order to counter tidal currents.

26.2 Mangrove Plantation in Gujarat, India

Implementation of mangrove plantation with stakeholder communities like fishermen, livestock tenders, and other resource users is increasingly becoming a norm for mangrove plantation in the Gulf of Kachchh (GoK), Gujarat, India. It stems from the belief that community-raised mangroves will be taken care by the stakeholders since their livelihood is directly related to mangrove well-being. Conservation efforts without envisioning the local needs and values have failed in many instances (Ostrom 1990). However, mangrove plantation in participatory mode is generally opted by government and non-government agencies. While according sanction to new coastal industries, Ministry of Environment, Forest and Climate Change (MoEF & CC), New Delhi, mandates mangrove plantation as a condition specifying the extent of plantation to be raised by the industry. This legal directive has prompted many industries to take up mangrove plantation in the coastal stretches of Gujarat. From 1996 to 2015, government agencies and coastal industrial houses have completed around 25,000 ha of mangrove plantation in several stretches of Kachchh coast alone which forms northern coastal belt of GoK.

26.3 Techniques Followed in Mangrove Plantation

Identifying suitable intertidal stretch for mangrove plantation is the first step in the mangrove plantation activity. A list of biophysical parameters such as gradient of the intertidal belt, soil nature, number of days of tidal flushing, presence/absence of natural mangroves in the vicinity, and availability of adequate intertidal extent are considered while choosing an intertidal belt for plantation. One major parameter that is paid special attention is the number of days of tidal flushing which in turn is influenced by the gradient of the intertidal area; intertidal stretches with gentle gradient receiving good tidal flushing for >15 days in a month are chosen for plantation.

26.3.1 Method of Plantation

A sound knowledge of the site is prerequisite to choose which method/s are to be followed. In GoK, three different methods as given below are generally adopted either singly or in combination to raise mangrove plantation based on the site conditions and potential for obtaining higher survival percentage.

1. Transplantation of nursery-raised saplings (polybag method)
2. Raised bed method (locally called *Otla* method)
3. Direct propagule dibbling (locally called *Sing* plantation)

26.3.1.1 Transplantation of Nursery-Raised Saplings (Polybag Method)

Nursery method is considered as the most reliable and best method yielding high success rate in mangrove plantation. Another major advantage of establishing a mangrove nursery is that it extends the period of plantation activity and a ready-made stock of saplings are available which could be utilized for plantation at appropriate timing of the year. Transplanting nursery-raised saplings shows higher survival rate than other methods since saplings have a well-established root system and they are maintained under simulated conditions for longer duration. Further, incidence of crabs eating the seeds and seedlings are minimal in nurseries. However, this method is cost and labor intensive and takes more time than other plantation methods. In spite of its higher cost and longer time, nursery method is the most preferred method in GoK coast.

Nurseries are developed in beds of 1000 or less polythene bags placed parallel to the tidal water sources such as creek systems and minor channels, which daily flush the nursery beds. In GoK, though three species, namely, *Avicennia marina*, *Ceriops tagal*, and *Rhizophora mucronata*, are used in the plantation, *A. marina* is the preferred species for nursery raising. Generally, polythene bags of 5×8 inches are filled with clayey sediment collected from nearby mudflats during low tide to raise the seedlings. The filled polybags are kept in shade for few days before they are arranged on the nursery bed. In many coastal stretches of India, mangrove nurseries are developed indoor with care and regular watering, yielding 100% survival of saplings (Selvam et al. 2005). However, this indoor nursery practices are seldom attempted in GoK, and it is always a practice that nurseries are developed in an extensive manner in outdoor conditions along minor creek banks where they are fed by tidal flows. In this extensive nursery preparation method, many factors like natural tidal watering and water logging are beyond the control resulting in lesser survival rates. Transplantation of nursery-raised saplings is undertaken when saplings attain a particular height. Different densities and gaps are followed to produce a final sapling density of 5,000–10,000/ha after an anticipated 10% mortality of planted saplings.

26.3.1.2 Raised Bed Method (*Otla* Method)

This method of plantation is unique to Gujarat and is not practiced in any other coastal stretches of India. In GoK, this method is preferably followed in majority of the plantation ventures since it is perceived to give better results while countering strong tidal currents. In this method, earthen mounts of 10–15 cm height are raised, and propagules numbering 15–20 are sown on the surface of the raised bed. Generally, the number of raised beds per hectare is more than 400 and may go up to 1500 beds by adopting different spacing. Mounts in each row are raised in alternate fashion in order to reduce tidal velocity in ebb and flow tidal currents. In the coastal stretches with moderate tidal currents, raised earthen mounts counter the ebb and flow of tidal currents and prevent uprooting of the planted saplings/propagules.

26.3.1.3 Direct Propagule Dibbling

Direct propagule dibbling is less cost and labor-intensive. This method is frequently used to restore potential mudflats and is often used to supplement other methods of plantation in order to raise survival percentage. This method is simple and even untrained laborers can follow it. In this method, mangrove propagules are dibbled in mudflats at specific intervals. Propagules are dibbled in such a way that nearly two-thirds of it is above the sediment surface while one-third is buried into the sediment. Different spacing is maintained between each dibbled propagule based on the type of mangrove forest to be developed. Generally, a spacing of $1 \times 1\ m^2$ is preferred, and propagules are soaked in freshwater for nearly 24 h in order to fasten the germination and achieve higher survival rate.

26.4 Issues in Mangrove Plantation

By virtue of possessing the largest extent of mudflats suitable for mangrove plantation, GoK of late is witnessing extensive mangrove plantation both by government agencies and by industrial houses. Nevertheless, many unresolved issues cripple mangrove plantation efforts in the area. The foremost problem faced in many plantation activities is poor survival. Often, plantation activities are undertaken in technically unsuitable sites resulting in high mortality of planted mangroves. Site selection, the most important criterion that determines the extent of plantation success and requires scientific input, is often ignored resulting in poor survival in the plantation. In addition, poor technical skill and failure to understand the governing scientific principles of plantation lead to costly failures. Engaging trained and skilled workforce with good knowledge of site-specific conditions will ward off failure in many plantation efforts.

Increasing the technical capacity of different organizations engaged in mangrove plantation is essential. This could be done through (a) awareness programs; (b) conducting scientific studies and developing technical packages for plantation in a participatory manner by expert consultants, implementing agencies, and community organization involved; and (c) through training programs on ecological and economic value of the mangroves and other aspects of restoration and regeneration. Similarly, awareness programs and exposure visits to other project sites with the participation of local community and various other agencies will enable exchange of ideas and learning new techniques.

Coastal industries and corporate houses that are mandated to carry out mangrove plantation are often constrained by legal bottlenecks like non-availability of suitable plantation sites in revenue land. Though Kachchh coast has several potential mudflats for plantation activities, they fall under the legal jurisdiction of forest department, which, as per law, cannot be leased out to corporate houses. This legal constraint prevents many coastal industries from taking up plantation, which needs to be addressed before involving industries in mangrove plantation.

Coastal industries in Gujarat are in a position to contribute better for mangrove conservation through plantation. A series of activities by forest department could be initiated to involve industries in mangrove plantation, which will go a long way to conserve mangroves. Some of the measures that could be initiated are:

- Forming a forum of industries in coastal regions with the mandate to regenerate and restore mangroves
- Working out mechanisms to enable availability of forest land in the coastal belt to aspiring industries for plantation
- Organizing workshops and meetings with industrial association/industries to motivate them to take mangrove regeneration
- Exposure visits for key personnel from the industries
- Linkages and networking with NGOs and community organizations for lobbying against industries that are not complying with environmental protection laws

It is often claimed that impact of industries on mangroves by way of direct reclamation and chronic degradation is the primary cause for areal shrinkage of mangroves in GoK. However, there is dearth of studies that tangibly point out this impact. In fact, involving industries in mangrove restoration works by the earlier India-Canada Environment Facility (ICEF) funded project, which was implemented in different parts of Gujarat, has yielded very limited results. One of the serious constraints identified in involving the industries in mangrove plantation is related to availability of lands. A mechanism has to be developed by industries and government agencies by which industries can undertake mangrove restoration and conservation activities without bureaucratic delays.

Invariably, most of the mangrove plantations in Kachchh are single species in nature with *A. marina* as the only candidate species. Few multispecies plantation attempts with *Rhizophora mucronata* and *Ceriops tagal* by some coastal industries and forest department achieved very limited success. Inherent hypersaline coastal waters and aridity of the zone are major hindrances to multispecies plantation efforts. Ease of plantation due to proven and standardized technique, high adaptation to prevailing coastal *milieu*, increased survival due to its hardy nature, and high seed resources are reasons rendering *A. marina* as the only candidate species in all plantation activities in Kachchh.

In many coastal stretches of Gujarat and particularly in Kachchh, macrolevel environmental factors such as climate, rainfall, freshwater runoff, and supply of sediments are not favorable to support high species diversity and luxurious growth of mangroves as in Sundarbans or Bhitarkanika of Odisha. However, it is possible to grow mangroves in the mid-tidal areas of the vast mudflats by manipulating microlevel environmental factors such as soil conditions and tidal flow. In many plantations of Kachchh, survival and growth of mangrove seedlings are poor, and there is constant exposure or uprooting of seedlings due to high tidal currents. Coastal geomorphology of Kachchh, except in some locations, has hard rocky formation just below the surface that prevents establishment of the saplings. This is one of the main causes for exposure of the roots of the seedlings. This problem can be addressed and growth may be enhanced by suitable technical means like deep pits. This highlights the underlying need for experimentation and innovations, which will improve the plantation success. In the readjustment of project design, considerable scope is to be given to conduct experiments, assess the results, and document the process.

Most of the mangrove plantation efforts by coastal industries are not in participatory mode. Coastal communities are involved only as laborers without any other stakes. The post-plantation care, which is essential to raise the planted mangrove into a full-fledged ecosystem, is taken care by the community in participatory mode. By negating community participation, many of the plantation activities tend to fail. Mangrove plantation in Gujarat in general faces the menace of grazing by livestock, mostly owned by nearby coastal villages. Grazing and browsing by cattle largely could be controlled in participatory mode as villagers take an active interest to prevent their livestock from grazing in the raised plantation and that does not happen in single institutional plantation activities.

In order to ensure greater sustainability and reduce the communities' degree of dependence on mangrove resources, formation of village *samithis* and creation of grass plots near villages was attempted in some instances. The best example is the ICEF funded project on community-based mangrove plantation. In this attempt, along with mangrove plantation, promotion of grassland was undertaken to reduce dependency on mangrove resources through raising alternate fodder sources. A robust benefit sharing mechanism was worked out to ensure equated distribution of gross production in tune with the cattle holding of each household. Though the annual grass yield from these plots met only a small portion of the fodder requirement, it amply demonstrated how an alternative fodder resource could be raised to wean the villagers from relying on a single resource. However, this attempt yielded only limited success since villagers often complain about lack of funds to maintain the raised grassland and mangrove plantation.

Post-plantation maintenance has emerged as a major issue in plantations raised in Gujarat. It is realized that participatory mode of plantation with local community involvement is the best means to enable raised plantation to become a functional ecological entity. An essential requirement in post-plantation maintenance is the creation of adequate funds for villagers for post-plantation activities.

An integrated sustainable mangrove management plan encompassing different sectors and players is to be aimed in all plantation activities to ensure that goods and services derived from mangrove forests meet the present-day fodder and ecological needs while securing their continued availability and contribution to long-term development. Sustainable mangrove management encompasses administrative, legal, technical, economic, social, and environmental aspects of conservation and use of mangroves. It also strives to integrate conservation and restoration of mangroves with the development in that coastal belt. Once in place, it is to be ensured that the plantation activities result in such a sustainable situation by continuous midcourse correction in all the activities. Instead of treating mangrove plantation as a mere physical activity, more attention and actions are to be taken to make the impact felt at social, ecological, and economic realm of the coastal mass. Mangrove villages as an ecosystem with its components of agriculture, animal husbandry, fisheries, rural development, and a host of other factors interacting with forestry in the form of fodder, fuel, manure, medicines, and aesthetics need to be kept as the basis while designing the strategies in a mangrove restoration program.

26.5 Discussion

It is apparent that the present rate of mangrove disappearance of 0.66% in India could be controlled only through effective and improved mangrove plantation, restoration, and rehabilitation. The current scenario in GoK clearly underlines the need for further refinement of the whole process by way of imparting technical skills to planters, more participatory mode of plantation, enhanced involvement of stakeholders like coastal communities, awareness creation, and involvement of industries. Inter-sectoral interest, which often hinders plantation activities, needs to be addressed by appropriate integrating mechanisms. The limitations inherent in the sectoral approach are in fact now recognized as major constraint for conserving mangrove resources (Olsen and Arriaga 1989; Nuruzzaman 1993). Though a sound ecological understanding is stressed while undertaking mangrove plantation (Ellison 2000), documented knowledge on mangrove ecology in Southeast Asia including India is poor (Biswas et al. 2009). Often researches leading to detailed understanding of ecological processes that govern success or failure in plantation activities are lacking (Biswas et al. 2009). Similarly, traditional knowledge on mangrove conservation and promotion is often neglected. Rist and Dahdouh-Guebas (2006) emphasize the use of science and traditional knowledge in management of natural resources. This kind of approach in participatory mode will yield better results in terms of successful plantations than programs purely based on scientific expertise.

In GoK, mangrove plantation sites are mostly chosen based on availability of suitable coastal stretches. In the absence of suitable sites, gaps among mangrove stands and even dense mangrove stands are chosen for plantation. Foremost criterion considered in defining a suitable site for mangrove plantation is tidal flushing. Though the field staffs are aware that site selection is the foremost criterion for successful mangrove plantation, they are often constrained by unavailability of good sites forcing them to choose sites of lesser suitability among scrubby or even dense vegetation. Analysis of factors that lead to low survival revealed that high natural erosion and the resultant tidal currents are the major reasons rendering the survival poor. Nevertheless, the practical experience possessed by the field staff coordinating plantation activities contributed positively. Implementers of plantation are generally aware that different sites have their own biophysical uniqueness and understanding the site properly and choosing the appropriate plantation technique is the key to success. In spite of this inherent knowledge, it would be further beneficial to impart them with basic practical methods of mangrove restoration/plantation in order to hone their practical skills.

Of all the plantation techniques adopted in GoK, raised bed (*Otla*) method is predominant one. Usually raised beds are made to counter the impact of tidal currents to prevent uprooting of the saplings. Arrangement of *Otla* beds in relation to the direction of incoming current is another factor to be considered. In majority of sites where raised bed method is followed, an alternate arrangement of *Otla* rows with adjacent rows could be observed that lessens the velocity of receding tidal currents and prevents sapling uproot. In order to reduce tidal impact and to enhance survival, this method could be followed uniformly in all future plantations.

As of now, plantation is the sole measure resorted for mangrove conservation. It is recommended that other restoration techniques by biophysical amendments to increase tidal flow to the stunted mangroves, rather than going for outright plantation could be attempted in future plantation activities; especially in scrubby/stunted stands facing inadequate tidal flushing, this restoration effort will yield better results. For example, desilting of natural canals will enhance tidal flushing rates and number of tidal days in natural stunted stands, rendering it healthier, viable, and a better functional ecosystem. These physical amendments in natural mangrove formations could be undertaken in sites where there is severe blockage to tidal flushing due to natural and human-induced causes. This could be done in a cost-effective manner yielding better results than direct plantation. A thorough and detailed surveillance and categorization of sites requiring different restoration approaches such as desilting, canal widening, removing blockage at canal mouth, and even constructing new canals could be more productive, rendering stunted formations into denser one.

Though GoK mangroves are known to have around eight true mangrove species, *A. marina* is the most predominant species, indicating nature's preference to this species. In view of its natural predominance, this species is most preferred in all plantation activities. Environmental plasticity of *A. marina* to tolerate extremes of salinity, temperature, and light intensity and its adaptation to different soil conditions is well proven (Downton 1982; Clough 1984; Macnae 1986; Shalom-Gordon and Dubinsky 1993; Ye et al. 2005; Jayatissa et al. 2008; Patel et al. 2010). Since GoK waters exhibit some of these environmental conditions, *A. marina*, as a candidate species, yields higher success rate in plantation ventures compared to other species whose tolerance limit is often limited. Easy seed availability, faster germination in high saline water, tolerance to prolonged drought situation, and higher growth rates enable good success rates for *A. marina*. Since species such as *R. mucronata* and *C. tagal* are less tolerant to water/soil salinity, they are planted close to waterfront in order to enhance tidal flushing. In such multiple species plantations, *R. mucronata* are planted near the waterfront followed by *C. tagal* and *A. marina* mimicking their natural zonation. Both *R. mucronata* and *C. tagal* are highly sensitive to salinity fluctuations. Their germination and sustained growth requires considerably less sediment and water salinity that is often unavailable in GoK coastline. Species-specific niche requirement like fringe areas of creeks and higher tidal flushing rates for both *R. mucronata* and *C. tagal* do not permit these species to be used in mass plantation efforts. Using other species like *Aegiceras corniculatum*, *Ceriops decandra*, and *Excoecaria agallocha* as candidate species for plantation is not feasible in GoK similar to other coastal *milieu* in proximity such as Pakistan and other Gulf countries, again due to the prevailing hypersaline environment.

26.6 Conclusion and Recommendations

It is generally believed that curbing mangrove deforestation is economically and ecologically more viable than restoration through plantation. In the context of Gujarat, deforestation has been largely arrested, and mangrove cover has registered an overall improvement due to increased conservation and restoration measures such as plantation. Long-term sustainability of mangrove restoration involves multifaceted approach such as robust management planning, capacity building at grassroot level, and awareness among all stakeholders and managers. Scope for streamlining the present restoration efforts in Gujarat is plenty that will manifold enhance the restoration outcome. Scientific input and intervention in terms of proper site selection, choosing carefully appropriate restoration method in tune with the biophysical condition of the site, and rigorous training to field staff engaged in plantation efforts are some crucial factors deserving immediate attention. Poor site selection as a single factor contributes to majority of plantation failures in Gujarat. Though many legal and technical bottlenecks cripple proper site selection, it could be overcome with an integrated approach. Another major lacuna observed is inadequate involvement of mangrove stakeholders such as coastal fishing communities, coastal industries, and cattle tenders. Promoting such public participation in mangrove plantation will ensure long-term sustainability of the raised resource ensuring that they become a fully functional ecological entity. Equally glaring is lack of restoration specific technical development and research that will render the plantation efforts more robust and technically sound. Despite these shortcomings, an overall positive approach toward mangroves is unfolding in recent years among stakeholders and policy makers, which needs to be transformed into actionable programs. Since Gujarat is pioneering among Indian states in mangrove restoration through plantation, concrete integrated management planning supported by a strong political will is most essential.

Acknowledgment The author is grateful to Gujarat Institute of Desert Ecology (GUIDE), Gujarat, India, for providing facilities and encouragement.

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