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Mangrove Area Assessment in India: Implications of Loss of Mangroves

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Abstract

Mangroves are extremely important bio-resources which are crucial to coastal environment. Mangroves are declining rapidly as they are getting degraded for agriculture, aquaculture, tourism, urban development and over-exploitation. India lost 40% of its mangrove area during the last century. Hence, it is highly necessary to assess the status and trends of mangroves in India. We have assessed the trends of mangrove area in India during 1987-2013 and found that the mean annual change during the period is 24.25 ± 82.57 km^2. Most of the states are experiencing an increase in area except Andhra Pradesh (-5.95 ± 15.70 km^2) and Andaman and Nicobar (-3.41 ± 52.32 km^2). The present review is focused on assessing the status and trends of mangrove area in India including the causes of loss and its restoration and traditional conservation. Implications of loss of mangroves have been discussed with respect to exposure to cyclones, hurricanes and sea water intrusion, tsunami and climate change. Effective governance structures, better planning for rehabilitation of degraded mangroves, education and awareness building in local communities are needed to conserve, protect and restore the valuable mangrove wetland ecosystems. Further, mitigation and adaptation to climate change aspects are considered.

Keywords: Mangrove area assessment; Threats; Loss of mangroves; Implications; India

Introduction

Evolutionarily adapted to coastal environment, an ecologically distinct group of halophytic plant communities found in tropical and subtropical shores may be defined as mangroves. Some workers viewed that plants growing in between the highest and the lowest tidal limits may be considered as 'mangrove' [1-9]. Mangrove forests are among the most productive and biologically important ecosystems of the world [10,11]. It provides several important ecosystem services including the maintenance of coastal water quality, reduction in severity of storm, wave and flood damage, bio resources as well as breeding ground for commercial fishery species [12,13].

Mangroves in India are unique in terms of their extent, variability and biodiversity. However, there has been an overall continuous decline in mangrove forests caused by conversion to agriculture, aquaculture, tourism and urban development [14,15]. Reduced mangrove area and health will increase the threat to human safety and shoreline development from coastal hazards such as erosion, flooding, storm waves, cyclones and tsunami, as recently observed during 1999 super cyclone in Odisha and 2004 Indian Ocean tsunami [16-20]. Mangrove loss will also reduce coastal water quality, reduce biodiversity, eliminate fish and crustacean nursery habitat, adversely affect adjacent coastal habitats and eliminate a major resource for human communities that rely on mangroves for numerous products and services [21-23]. Further, decline in mangrove vegetation will release large quantities of stored carbon exacerbating global warming and climate change. According to the recent IPCC fifth assessment report [24], climate change will contribute to the range of sea grasses, mangroves and kelp in the northern hemisphere will expand pole ward. As a consequence, important ecosystem goods and services (e.g. natural barrier, carbon sequestration, biodiversity) provided by mangrove forests will be diminished or lost.

According to the Government of India report [25], India lost 40% of its mangrove area during the last century [26]. Given the importance of mangroves, it is highly necessary to assess the status and trends of mangroves in India. Further, assessment of mangrove areas at country level is a prerequisite for its restoration, management and conservation. Although, Forest Survey of India reports are available to get the information on mangrove area, it is urgent to analyze the reports and draw conclusions on trends in area loss/gain including annualized change during the last 25 years and the spatial variation.

Literatures are available on mangroves saving coastal areas from cyclones, storms and tsunami [16-20]. However, potential of mangrove biomass in India to offset carbon emission in the process of carbon sequestration process is neglected. Therefore, review of mangrove biomass carbon stocks is highly significant. We review implications of loss of mangroves with respect to exposure to cyclones, hurricanes and sea water intrusion, tsunami and climate change. Importance of various threats is addressed specific to various regions.

Keeping view of the above perspectives on mangroves, the present review is done mainly with two objectives-

1) An assessment of mangrove area in India
2) Threats to mangroves, its loss and implications of its decline including restoration and traditional conservation.

Status, Extent and Trends in Area under Mangroves in India

India with a long coastline of about 7516.6 km, including the island territories [27], had a mangrove cover of about 6,749 km^2, the fourth largest mangrove area in the world [28]. However, a recent assessment shows that India has a total mangrove cover of only 4,628 km^2 [29], or 0.14% of the country's land area, 3% of the global mangrove area,

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and 8% of Asia's mangroves., of which about 60% is along the east coast (Bay of Bengal), 27% is along the west coast (Arabian Sea) and the remaining 13% is in the Andaman and Nicobar Islands. These mangrove habitats (69°-89.5°E longitude and 7°-23°N latitude) comprise three distinct zones: east coast habitats having a coast line of about 2700 km, facing Bay of Bengal, west coast habitats with a coast line of about 3000 km, facing Arabian sea, and Island Territories with about 1816.6 km coastline. The state of West Bengal has the maximum cover (2,097 km^2), followed by Gujarat (1103 km^2) and the Andaman and Nicobar Islands (604 km^2) [29].

India's mangroves can be broadly categorized into deltaic, backwater-estuarine and insular types according to Thom's classification of estuary habitats. Deltaic mangroves are found along the east coast within the deltas of the Ganges, Brahmaputra, Mahanadi, Krishna, Godavari and Cauvery rivers. Estuarine mangroves are found on the west coast in the estuaries of the Indus, Narmada and Tapti Rivers. They are also growing in the backwaters, creeks and neritic inlets of these areas. Insular type of mangroves is found in the Andaman and Nicobar Islands [30].

Assessment of Mangrove Area since 1987

The National Remote Sensing Agency (NRSA), Hyderabad, India recorded a decline of 59.18 sq. km of mangrove between 1972-75 and 1980-82 [31]. According to the Government of India report [25], India lost 40% of its mangrove area during the last century [26]. Of this, east coast has lost about 26%; west coast area about 44%; and Andaman and Nicobar Islands about 32% [32,33]. At present, we have assessed the state wise mangrove area since 1987 to 2013 (Data adapted from Forest Survey of India). There was a net increase of 582 km^2 area during this period with a maximum area increment in Gujarat (676 km^2) followed by Maharashtra (46 km^2), Goa (22 km^2), West Bengal (21 km^2) and Odisha (14 km^2). On the other hand, there was also decline in the areas of mangroves. There was a decline of 143 km^2 in Andhra Pradesh followed by Andaman and Nicobar (82 km^2). It has been found that the mean annual change in mangrove area during the period 1987-2013 is 24.25 ± 82.57 km^2. Most states showed mean annual increment in area except Andhra Pradesh (-5.95 ± 15.70 km^2) and Andaman and Nicobar (-3.41 ± 52.32 km^2) (Figure 1). This change can be attributed to tsunami that swept the Andaman and Nicobar coast during 2004 and agriculture and other developmental activities in Andhra Pradesh. Mean annual increase in area was maximum in Gujarat (28.16 ± 50.58 km^2) followed by Maharashtra (1.91 ± 11.14) and Goa (0.91 ± 1.57 km^2). Overall, the mangroves in India are well protected. This is largely because of the efforts of state Forest Departments and Ministry Of Environment and Forests, Government of India for initiating plantation as well as restoration and conservation of mangroves.

Data from SFR published biennially from 1987 to 2013,

Annual change=$(A_2-A_1)/t_2-t_1$

Where, A_1, A_2 mangrove areas at two different time periods t_1 and t_2 respectively

Biodiversity

Mangrove ecosystems are one of the most biodiversity rich areas inhabited by diverse groups of aquatic and terrestrial organisms. It occupies a diversified habitat like core forests, litter-forest floors, mud flats, water bodies (rivers, bays, creeks, etc.), coral reefs and sea grass ecosystems. A total of 4,011 species including 920 plants (23%) and 3,091 animals (77%) species (Table 1) have been recorded from Indian mangrove ecosystems, which is highest in the world. Among flora, marine algae had highest number of species (557 species) i.e. 60.1% followed by fungi 11.2%, mangrove associates 9.3%, bacteria 7.5% and mangroves 4.2% etc. *Heritiera fomes* and *Sonneratia griffth* are two globally threatened mangroves found in India. Among fauna, other invertebrates had highest number of species (745) i.e. 24.1% followed by insects 22.3%, finfish 17.6%, birds 13.8%, molluscs 9.9% etc. Olive ridley turtle, one of the most threatened and endemic fauna is found in Odisha coast.

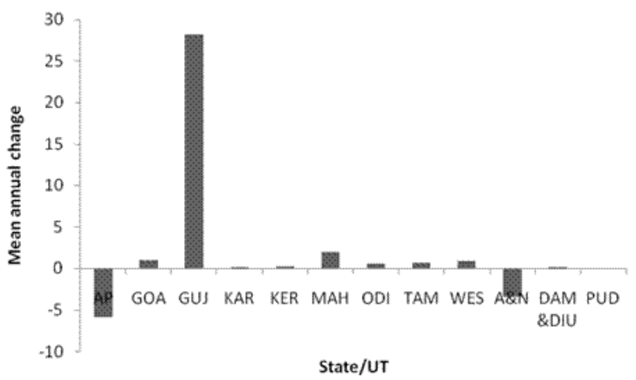

Figure 1: Mean annual change in mangrove area (km^2) in different states/ Union Territories.

Category	Type group	No. of species	% of total species
Flora	Mangroves	39	4.2
	Mangrove associates	86	9.3
	Sea grass vegetation	11	1.2
	Marine algae (Phytoplankton+sea weeds)	557	60.1
	Bacteria	69	7.5
	Fungi	103	11.2
	Actinomycetes	23	2.5
	Lichens	32	3.4
Fauna	Prawns and lobsters	55	1.8
	Crabs	138	4.4
	Insects	707	22.3
	Molluscs	305	9.9
	Other invertebrates	745	24.1
	Fish parasites	7	0.2
	Finfish	543	17.6
	Amphibians	13	0.4
	Reptiles	84	2.7
	Birds	426	13.8
	Mammals	68	2.2
Total		4,011	100

Table 1: Total number of species in mangrove ecosystems of India [34].

Major Threats to Mangroves

The main causes of mangrove forest destruction in India are given below:

Aquaculture and agriculture expansion

A large fraction of the mangroves in India was destroyed due to aquaculture and agriculture expansion. In India and Bangladesh, about 1,50,000 ha of mangroves were destroyed for agricultural purposes during the past 100 years. Mangroves are destroyed and reclaimed with rain water for reducing the salinity of the soil. Then, these areas were protected from soil water intrusion by forming embankments. After salt is leached from soil, these areas are used for raising plantation of coconut or paddy. These activities are very common in South Indian states of Goa, Karnataka and Andhra Pradesh [34-36]. Aquaculture in mangrove areas is another pressure on regeneration and survival of mangrove seedlings [37]. Sometimes for aquaculture expansion people destroyed whole patches.

Cutting of mangroves for timber, fuel and charcoal

Because of high calorific value of mangrove wood and high strength, people are destroying mangroves for firewood, charcoal and timber collection [36]. Mangrove wood is highly suitable for chipboard and paper industry. So due to its industrial value, forests were cleared annually for these purposes.

Pollution

Mangrove patches in cities such as Mumbai and Kolkata are affected by discharge of large amounts of solid wastes and effluents from various sources. Pollution has made the habitats difficult for mangrove survival and growth [38].

Natural calamities

Frequent occurrences of tropical cyclones, storms and tsunamis, have damaged the mangroves of India. To cite an example, in the east coast of Odisha during the year 1999, a major cyclone devastated a large area of mangroves [20].It has been estimated that the total mangrove area fell from 30,766 ha to 17,900 ha during the super cyclone. The tsunami that occurred in 2004 caused extensive damage of mangroves in the south coast of India and Andaman and Nicobar Islands [18,39-41].

Reduction of fresh water and tidal water flows

Mangroves are well established in areas where there is good amount of fresh water inflow. Dam and barricade construction on upper portion of rivers reduces fresh water flow into mangrove swamps. Embankment construction and siltation at the river mouth obstruct tidal water flow in to mangrove swamps. Reduction in fresh water and tidal water inflow increases the salinity of these areas, resulting in poor germination, growth and regeneration of mangroves. For example, at Pichavaram, South India, mangroves are largely dying due to hyper salinity and other associated factors such as increasing temperature, poor precipitation and poor flushing of mangrove soil by tidal waters [42,43]. In Sundarbans, due to reduction in fresh water inputs, species such as *Heritiera fomes* and *Nypa fruticans* are reducing in their population [34]. According to Duke [44], this may lead to the population at greater risk of local extinction.

Invasive species

Most mangrove regions in India are suffering from invasive species which disrupt the ecological balance and dynamics of the mangrove ecosystem. For example, in Tamil Nadu and Andhra Pradesh, the rapid invasion of *Prosopis* species [45] can be considered for Invasive species. In Sundarbans, colonization of the twiner *Derris trifoliate* and other aquatic weeds *Eichhornia crassipes* and *Salvinia* in mangrove water negatively affecting the natural flora of mangrove ecosystems [34].

Climate change

Climate change is one of the most important environmental issues impacting mangroves in India. It results in increase in temperatures, rising sea level, increasing the frequency of tropical storms and tsunamis. Due to sea level rise mangroves tend to move landward, but human encroachment prevents this and consequently, the width of the mangroves decreases. A recent observation reveals that as a consequence of sea level rise two islands in Indian Sundarbans-Suparibhanga and Lohacharra have submerged and a dozen of other islands are also facing the same problem (http://www.thedailystar.net/2006/12/22/d61222011611.htm). Further research is recommended to record plant species with details of their flowering, germination, propagation, growth as well as the behaviour of animals as related to changing climatic conditions [46] to determine climate change induced effects on plant and animal species (Table 2).

Implications of Loss of Mangroves

Exposure to cyclones, hurricanes and sea water intrusion

The ability of mangroves to provide protection against tropical storm surges has been debated since 1970 [47-49]. Theoretical models indicate that mangroves attenuate shorter waves more than longer waves [50], and field experiments confirm that relatively narrow strips of mangrove can substantially reduce the energy of wind-driven waves [51,52]. Extensive tracts of mangroves can protect adjacent land and human populations from storm surges of water caused by high intensity coastal storms and hurricanes [53,54]. A healthy mangrove forest can also prevent salt water intrusion preventing damage of freshwater ecosystems and agricultural areas. Mangrove forests reduce the fury of cyclonic storms and gales and minimize the effect of the rising of sea level due to global warming [20]. The physical stability of mangroves helps to prevent shoreline erosion, shielding inland areas from severe damage during hurricanes and tidal waves. Mangroves can be damaged by storms or freezes but usually recover. The roots of mangrove trees are physically very strongly attached to the substratum and supports against the ocean's wave and tide.

Case of Bhitarkanika, East Coast of India

Badola and Hussain [21] evaluated the protective function of mangroves in Bhitarkanika in the eastern state of Odisha, India. This mangrove forest and the associated coast house the highest diversity of Indian mangrove flora and fauna. The mangrove forests of Bhitarkanika differ considerably from other mangroves because of the dominant

Mangrove area	Major Threats	References
West Bengal	Agriculture, prawn seed collection, reduction in fresh water flow and pollution	[34,38]
Odisha	Natural calamities, prawn farming, encroachment and rehabilitation	[15,20]
Tamil Nadu	Reduction in fresh water flow, invasion of alien species and over-exploitation of mangroves	[45,42,43]
Andhra Pradesh	Agriculture, grazing, developmental activities, invasion of alien species and aquaculture	[35,36,37,45]
Gujarat	Over-exploitation of mangroves, developmental activities, natural calamities and coral reef degradation	[14,47]
Maharashtra	Urbanization and pollution	[38]
Karnataka	Agriculture, tree felling and pollution	[35]
Kerala	Unsustainable mode of aquaculture practices, mangrove wood for fuel, industrialization and urbanization, bio-pollution	[14,48]
Andaman and Nicobar Islands	Agriculture, exploitations for wood and wood products, tourism development-encroachment and natural calamities such as cyclone, storm and tsunami	[18,39,40,41]

Table 2: Mangrove area and major threats (Compilation study).

tree species — *Sonneratia apetala, Heritiera fomes, H. Littoralis* and several *Avicennia* species. They have measured the economic losses attributed to the 1999 super cyclone relative to the prevailing socio-economic conditions of the study villages. It evaluated the extent of damage caused in areas that were under the umbrella of mangrove forests and areas that were not, in the wake of this super cyclone. In the mangrove-protected village, variables had either the lowest values for adverse factors (such as damage to houses), or the highest values for positive factors (such as crop yield). The loss incurred per household was greatest (US $153.74) in the village that was not sheltered by mangroves but had an embankment, followed by the village that was neither in the shadow of mangroves or the embankment (US $44.02) and the village that was protected by mangrove forests (US $33.31). The local people were aware of and appreciated the functions performed by the mangrove forests in protecting their lives and property from cyclones and were willing to cooperate with the forest department with regard to mangrove restoration. The case study revealed the important role of mangroves in protecting the coastal areas from furious effects of cyclones and hurricanes.

A similar study was carried out by Das and Vincent [20] on mangrove protection against 1991 super cyclone that struck badly on east coast of Odisha. They have found that villages with wider mangroves between them and the coast experienced significantly fewer deaths than ones with narrower or no mangroves. Their findings were robust to the inclusion of a wide range of other variables to the statistical model following regression analysis (Table 3). They have also revealed that beneficial effect is mainly due to mangrove vegetation, not physical characteristics of mangrove habitat.

Koteswaram [55] had reported about 346 cyclones in the Bay of Bengal including 133 severe ones, whereas the Arabian Sea had only 98 cyclones including 55 severe ones between the years 1891 and 1970. Tropical cyclones and storms are more common in the Bay of Bengal thus severely affecting the east and south Indian coast as compared to the Arabian Sea. However, mangroves reduce the fury of cyclones and act as protective barrier towards this natural calamity [56]. Observations revealed that the role of *Rhizophora* and *Avicennia* spp. are more significant than other species.

Tsunami

Mangrove forest protects the coastal zone against the influences of ocean as it is located in the edge of sea and land. Mangroves act as

Regressors in model, in addition to village population	Coefficient estimate: 1999 mangrove width
Only 1999 mangrove width	-0.631***
Add to above: 1944 mangrove width	-0.515***
Add to above: Height of storm surge at coast	-0.524***
Add to above: Topography (three 0-1 dummy variables: low elevation, casuarinas buffer, seawater dike)	-0.519***
Add to above: Distances to: coast, minor rivers, major rivers, nearest road	-0.507***
Add to above: Socioeconomic characteristics: literacy rate,-population share in scheduled castes, population shares in 5 occupations	-0.505***
Add to above: Government administration (0-1 dummy variable for each *tahasil*)	-0.485***

Estimates are from zero-inflated negative binomial models of number of deaths in villages in Kendrapada District, Orissa, India, during October 1999 cyclone. Variables were progressively added to those in preceding rows. ***$P<0.01$ (two-tailed z tests). Source: Das and Vincent (2009)

Table 3: Estimates of regression coefficient on 1999 mangrove width: Full sample (409 villages).

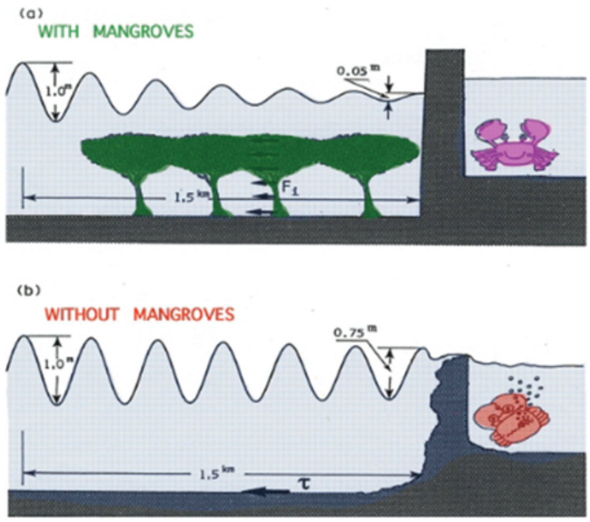

Figure 2: Differences in the effect of wave reduction (a) with and (b) without mangroves. Source: [51].

buffer against tsunami. The role of mangroves as living barriers was neglected prior to the tsunami event of December 2004, and many mangrove forests had already been destroyed or damaged. Scientists who have studied coastal vegetation have shown that coastal vegetation, both mangrove and beach forests, provide protection from "extreme" events such as tsunamis [16,17,19] as well as "during less energetic but more frequent events, such as tropical storms" [57]. The tsunami that occurred in 2004 caused extensive damage in Andaman and Nicobar Islands and coastal districts of Tamil Nadu, Kerala, Andhra Pradesh and Pondicherry. A Government of India report says that, about 10,880 people lost their lives and 1,54,000 houses were either destroyed or damaged resulting in a loss of about Rs. 994 crores. The tsunami also affected nearly 75,300 fishing crafts leading to loss of livelihood for thousands of fishing families. However, post-tsunami observations revealed that the damage in the form of lives and other property loss in villages which were behind mangrove wetlands were less [17]. This is due to the intensity of tsunami being reduced by these natural protective barriers. It has been seen that several villages of Pichavaram mangrove region of Tamil Nadu which are under direct physical coverage of the mangroves were protected from fury of the tsunami, though they are close to sea. The mangrove trees bore the furious impact of the tsunami waves and the friction created by these trees reduced the speed of the water and hence saving the villages. It clearly indicates that mangrove forests played a crucial role in mitigating the impact of tsunami. Mangrove sites in East Africa, Thailand, Indonesia, India, and Sri Lanka areas were badly affected by the tsunami tragedy. Out of the 418 villages hit by the tsunami along the Andaman coast, only 30 were severely devastated and in areas where mangroves have been degraded by the aquaculture or the tourist industries, this percentage was estimated to be 80 to 100%.

The role of mangroves in mitigating tsunami waves has been proved scientifically and it depends on the water depth, the wave period, the wave height, the species of mangrove trees, the density of mangrove forest and diameter of mangrove roots and trunks (Figure 2). For example, a six-year-old mangrove forest of 1.5 km width will reduce 1 m high waves at the open sea and 0.05 m at the coast [51]. It has been observed that *Rhizophora* species are more suitable for plantation in seaward as compared to *Avicennia* species. This is because the stilt

Location	Dominant species	AGB (t/ha)	BGB (t/ha)T/R= 2.5	Total biomass (t/ha)	C-Stocks (tC/ha)	Reference
West Bengal	*S. apetala, E. agallocha and A. alba*	54.41	21.76	76.17	38.05	[68]
Andaman Island	*Rhizophora, Bruguiera and Ceriops forests*	169.0	67.60	236.6	118.3	[69]
Gujarat	*Avicennia marina*	-	-	49.14	24.57	[47]
Tamil Nadu	*R. mucronata and A. marina*	88.8	36.82	125.62	62.81	[70]
Karnataka	*R. mucronata, A. Officinalis and S. alba*	72.00	28.8	100.80	50.40	[71]

*Note: Above Ground Biomass to Below Ground Biomass (T/R) ratio is in between 2 to 3 [72]. Here we have taken the value of 2.5

Table 4: Biomass carbon stock (t/ha) in mangrove forests of different states in India.

roots of *Rhizophora* are more tolerant than pneumatophores of the latter to long period of submergence by flood water [58].

Carbon sequestration in mangroves and climate change

Carbon sequestration is the process through which plant life removes carbon dioxide from the atmosphere and stores it as biomass. Mangrove forests play a major role in carbon cycle in removing CO_2 from the atmosphere and storing it as carbon in plant materials. They also have important roles in sustaining tropical and subtropical coastal productivity [22] and sequester large amounts of carbon below ground [59,60]. Mangroves are among the most carbon-rich forests in the tropics and their carbon sequestration potential is estimated to be up to 50 times greater than tropical terrestrial forests. A recent assessment of carbon stored in various mangrove forest domains found that Indo-Pacific are among the most carbon-rich forests in the tropics containing, on average, 1023 tC ha^{-1}, most of which is stored in soils>30 cm deep [61]. Globally, mangroves accumulate up to 25.5 million tonnes of carbon annually [62] and provide more than 10% of the organic carbon essential to the world's oceans [63]. Mangroves account for approximately 3% of carbon sequestered by the world tropical forests, although they account for <1% of the total area of tropical forests [64].

Loss of mangroves by clearing, conversion for aquaculture and other anthropogenic activities lead to changes in soil chemistry resulting in rapid emission rates of GHGs, especially CO_2. Lovelock et al. [65] have measured CO_2 emissions from cleared mangrove peat soils in Belize on the order` of 2900 tC/km^2/year; this value compares well with CO_2 emissions measured from hurricane-damaged and aquaculture-impacted mangroves (1500–1750 tC/km^2/year), rainforests drained for agriculture (3200 tC/km^2/year) and thawed Arctic tundra (150–430 tC/km^2/year). Globally, mangrove deforestation generates emissions of 0.02–0.12 pico grams of carbon per year, up to 10% of total emissions from deforestation. Thus, failing to preserve mangrove forests can cause considerable carbon emissions and lead to climate change [61,66]. Although the contribution of mangroves to global carbon sequestration is very low, their contribution to carbon burial in global coastal ocean is high. Mangrove contributes an average of 14% to the carbon sequestration in the world ocean though occupying only 0.5% of the total coastal ocean areas.

Compilation of studies in India revealed that Andaman Island possessed the highest carbon stocks in biomass (118.3 tC/ha) followed by Tamil Nadu (62.81 tC/ha), Karnataka (50.40 tC/ha) and Gujarat (24.57 tC/ha) (Table 4). Covering 2,118 km², the mangroves of the Indian Sundarbans are thought to absorb over 41.5 million tonnes of carbon dioxide daily, valued at around US$79 billion in the international market [67].Therefore, mangrove restoration could be a novel mitigation option against climate change.

State	Areas in ha
Andhra Pradesh	1,978
Tamil Nadu	840
Karnataka	1,244.5
Kerala	134.78

Table 5: Detail of areas under restored mangroves in South India.

Achievement in conservation and restoration of mangroves

A total of 4195.28 ha area has been restored under mangroves in South India from 2002 to 2006 (Table 5). Mangrove conservation with the involvement of local people is highly significant in India. The best example is Soonabai Pirojsha Godrej Marine Ecology Centre (SPGMEC) of Godrej Private Sector. The centre protects the mangrove forests in Vikhroli, a suburb of Mumbai through research, education and awareness building, regular monitoring and restoration. Another example is mangrove conservation by a tea producing group AVT in Kerala. A Mangrove Interpretation Centre has been established to disseminate information regarding the importance of mangroves and their conservation through film and slide shows, seminars, nature trails, camps, poster exhibition and lectures. Around 20,000 visitors are educated every year about the importance of mangrove conservation by using various innovative methods [70-73].

Mangrove sacred groves: Traditional conservation

Traditional conservation of forests through sacred groves in India has been practised since very long. Sacred groves are the forest patches protected by a community for their religious beliefs. These forest patches are restricted for logging and hunting. Such groves are associated with the sacred deities which may be local Hindu, Islam and Buddhist origins, and some are based on smaller local religions and folk religions. There are more than 13,900 sacred groves recorded in India (*C.P.R. Environmental Education Centre* of the Government of India). However, mangrove sacred groves are very rare in India. Among the inland mangrove communities, *Avicennia marina* represents the only sacred grove species of the world's inland mangroves [74]. The inland mangrove in Shravan Kavadia, Kachchh is one of the most important sacred groves of Gujarat for the local inhabitants. Fire, harvesting, logging or collection of fire wood have been totally prohibited and considered religiously inauspicious by the local inhabitants for sustainable development of the area. Similarly, Kagekanu forest patch which is dominated by species such *as Rhizophora mucronata, Avicennia officinalis* and *Kandelia candel* off the coast of Karwar in Karnataka is one of the examples of traditional conservation through sacred groves. The reigning deity is Shiva. There is a strict regulation in exploitation of the patch except for temple purposes and only dry woods are removed and the patch is protected by the local villagers. The temple committee manages the regulation of this forest patch.

Conclusions

The present review not only provides an overview of mangroves in India but also emphasizes the importance of services both qualitatively and quantitatively. Review of case studies, comparing the loss of damage in presence of mangroves and absence of mangroves indicates importance of mangroves in coastal and marine ecosystems.

Assessment of mangrove area since 1987 to 2013 reveals that mean annual change during the period is 24.25 ± 82.57 km². Most of the states are experiencing an increase in area except Andhra Pradesh (-5.95 ± 15.70 km²) and Andaman and Nicobar (-3.41 ± 52.32 km²). Predicted mangrove loss will reduce biodiversity, eliminate fish nursery habitat, adversely affecting adjacent coastal habitats and eliminate a major resource for human communities that traditionally rely on mangroves for numerous products and services. Effective governance, adaptation and mitigation options for climate change, better planning for rehabilitation of degraded mangroves and creation of awareness to local communities are need of the hour to conserve, protect and restore the valuable mangrove wetland ecosystems.

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