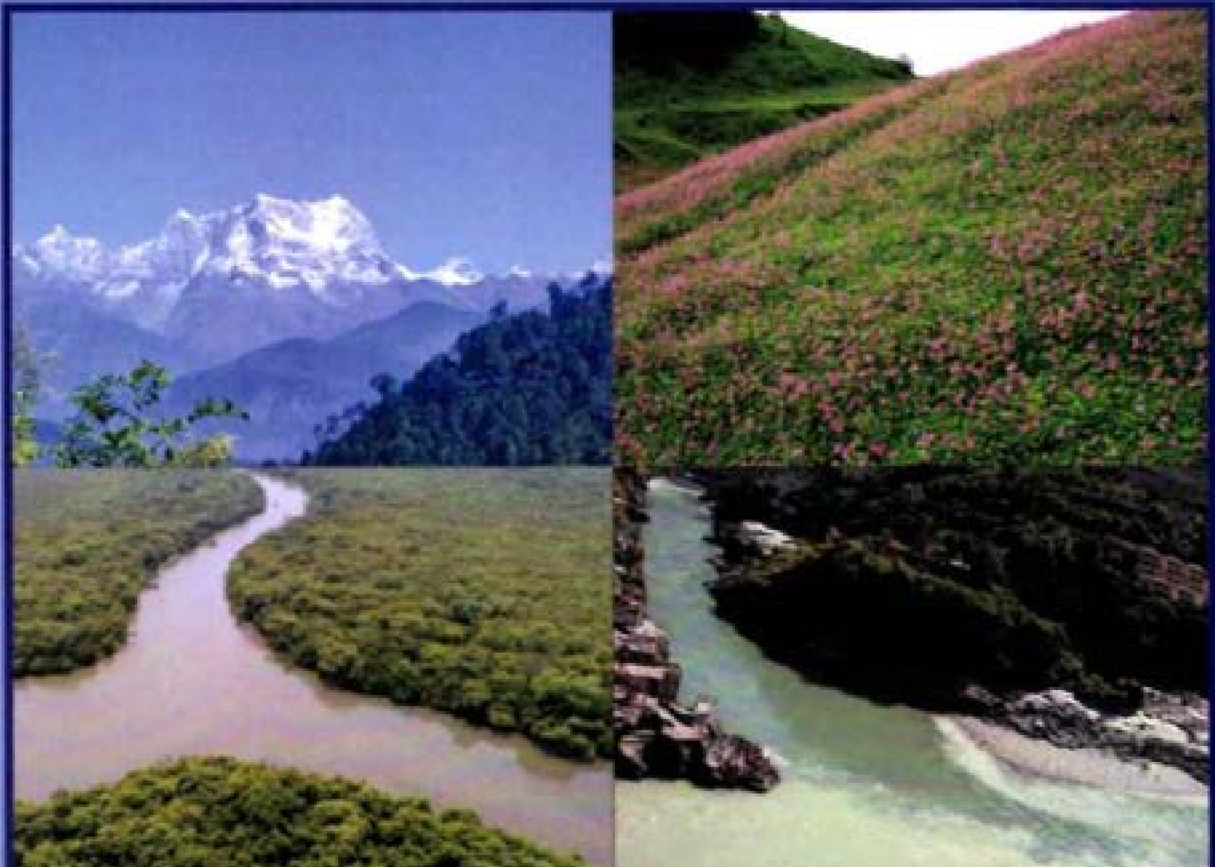
CLIMATE CHANGE BIODIVERSITY & DEVELOPMENT



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CONSERVATION AND MANAGEMENT OF MANGROVE WETLANDS OF ANDHRA PRADESH FOR COMBATING THE IMPACTS OF CLIMATE CHANGE

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Introduction

Mangroves are littoral plant communities that occur in inter-tidal marshy areas of tropical and subtropical countries. Mangroves thrive in these areas by means of adaptations such as thick and leathery leaves and salt-excreting glands, stilt roots, pneumatophores and viviparous propagules. Interestingly, mangrove forests act as barriers against cyclones and tsunamis, reducing the tidal floods entering the mainland, thus minimizing the damage to property and life (Guebas, 2006). Mangroves reduce coastal erosion and also help in land building process by trapping the sediments. Mangrove wetlands serve as spawning and nursery grounds for many economically important fin-fishes and shellfishes.

Compared with other coastal ecosystems, mangroves contribute an average of 14% to carbon sequestration in the world's oceans, although accounting for 0.5% of the total coastal ocean area (Alongi, 2012). Mangroves also sequester large amounts of carbon and store it below the ground, thus contributing to a reduction in the greenhouse gas particularly carbon-di-oxide. It also provides habitat and harbors many wildlife, resident and migratory birds. Though the mangrove ecosystem is highly productive and has multiple uses, mangroves are declining rapidly due to physical, biological, anthropogenic and social factors.

In India, mangroves are distributed in 5,000 sq. km. and in Andhra Pradesh, the mangroves account for 582 sq. km., representing 12% of the total mangrove forest area

(Fig. 1). The State of Andhra Pradesh has a geographical area of 162,307 km^2 out of which an area of 22,862 km^2 is under forests, which accounts for 14% of the geographical area. The mangrove forests of 582 sq km, accounts for 2.5% of the total forest area of the state. The recent report of Forest Survey of India, 2017 indicated that the state has 404 sq. km. of mangrove cover. The majority of the mangroves in the state are found in the Krishna and Godavari estuaries. Mangroves are also found in small patches along the coast in Srikakulam, Visakhapatnam, West Godavari, Guntur, Nellore and Prakasam districts (Fig. 2).

The Intergovernmental Panel on Climate Change (IPCC), National and state action plans for climate change suggested conservation of mangroves as one of the climate change adaptation strategies. Globally, mangrove wetlands are some of the highly exploited ecosystems and are declining at an alarming rate. However, in India, the recent estimates proved that the extent of mangroves is gradually increasing due to mangrove conservation efforts by respective state governments in collaboration with NGOs and local communities. This increase in mangrove area or status quo in some states enhances the resilience against the coastal disasters including the impact of climate change induced sea level rise. The status of mangroves of Andhra Pradesh and the efforts on conservation and management of the wetland to reduce the impact of climate change are discussed in this chapter.

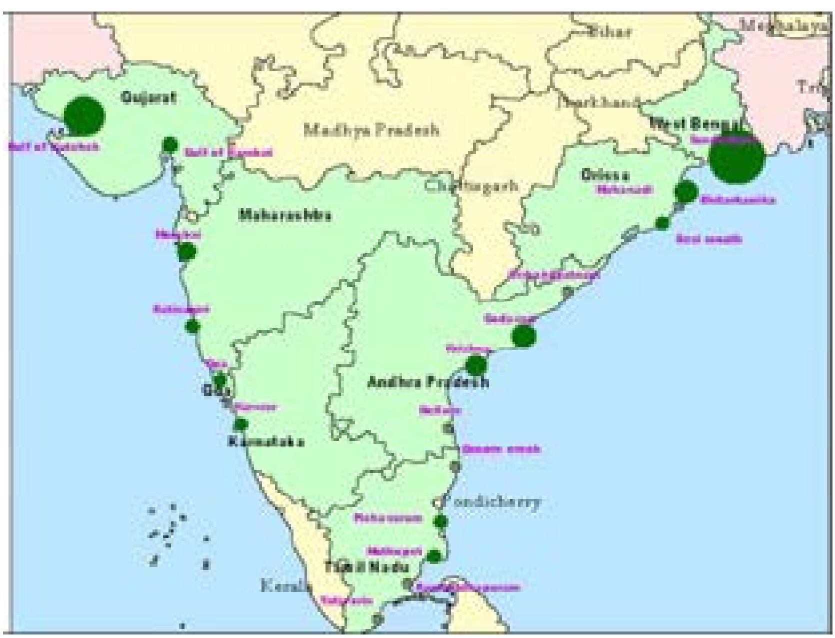

Fig. 1. Mangrove distribution on the east and west coasts of India

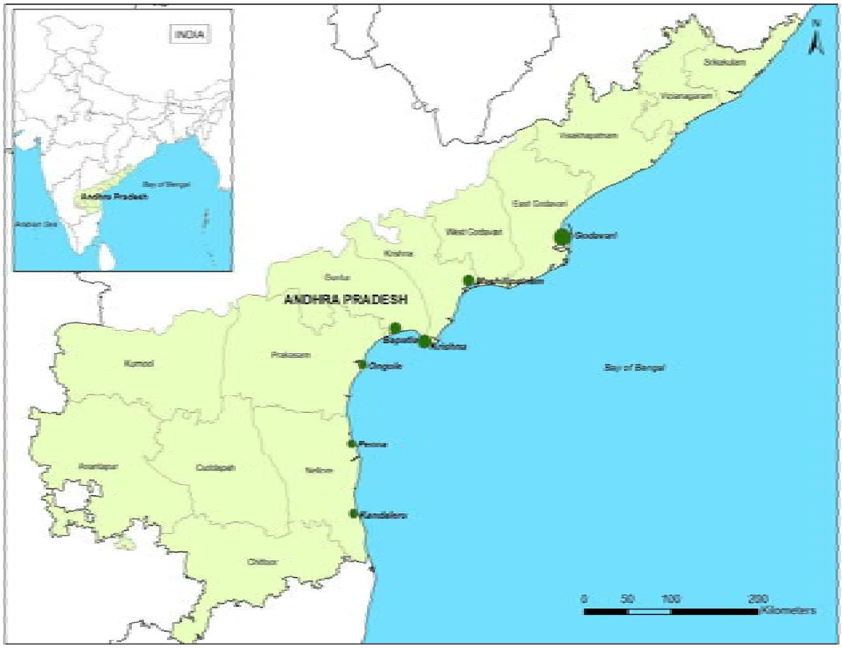

Fig. 2. Distribution of mangroves in Andhra Pradesh

Mangrove wetlands of Andhra Pradesh

Godavari Mangroves The Godavari wetlands are located in the Godavari river delta between 16° 30’ - 17° N and 82° 23’ E in East Godavari district, Andhra Pradesh (Fig. 3). The River Godavari is the second largest river in India, with a total catchment area of 314,685 sq. km. with a total length of 1,465 km. The Godavari originates at Triambakam near Nasik in the state of Maharashtra in the Western Ghats.

The extent of Godavari mangrove wetlands are 33,263 ha (Rajesh Mittal, 1993). The Coringa wildlife sanctuary with an extent of 23,570 ha occupies the northern side of the delta. This sanctuary has three Reserve Forests namely Corangi R.F, Corangi Extn. R.F. and Bhairavapalem R.F. Mangroves are also distributed in other six Reserve Forests in the southern part of the Godavari River (Fig .4). In Coringa Wildlife sanctuary, the mangroves are not directly connected to the Bay of Bengal, but through the Kakinada Bay. This bay is very shallow, about 2 m in depth in the southern side. A sand spit of about 18 km long, is located along the eastern side of the Kakinada Bay. The sand spit protects the mangroves from erosion by higher energy waves. Mangroves in Coringa Wildlife sanctuary receive water from two major creeks namely Corangi and Gaderu. Apart from these two, many small creeks and canals are interconnected to form a network of canals to supply tidal water into the mangroves. The mangrove wetland receives fresh water during the southwest monsoon as the catchment area of the river Godavari receives maximum rainfall during this period. The salinity starts increasing from October and

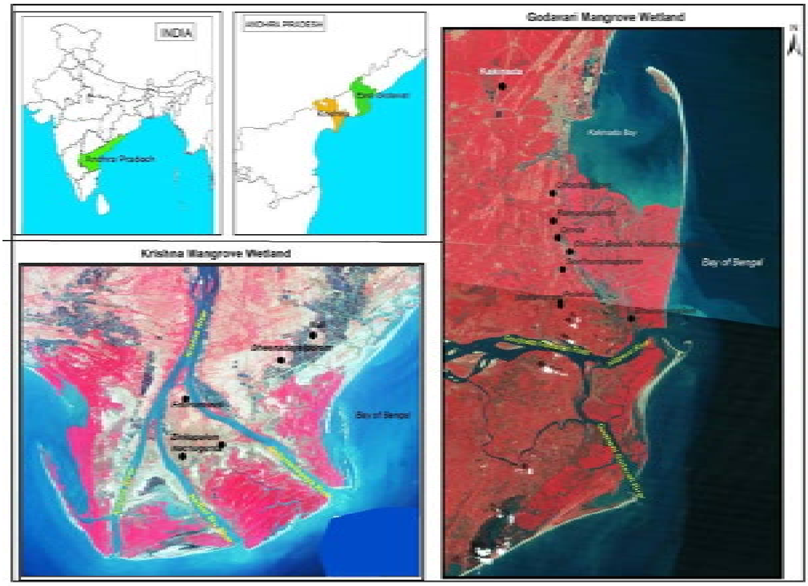

Fig. 3. Location of Krishna and Godavari mangrove wetlands

reaches its maximum during summer when there is no freshwater discharge into the mangrove wetlands.

Krishna Mangroves: The Krishna mangrove wetland is located between 15° 42' - 15° 55' N and 80° 42' - 81° 01'E spread across Krishna and Guntur Districts (Fig. 3). The extent of mangrove wetland is 24,999.47 ha. The River Krishna starts from Mahabaleshwar in the Western Ghats and runs in the southern direction to a length of about 1,401 km. The catchment area of the river is 2,58,818 sq. km. The most important tributary is the Tungabhadra, which is formed by the Tunga and Bhadra rivers both originating in the Western Ghats. Other tributaries include the Koyna, Bhima, Mallaprabha,

Fig. 4. Mangroves of Godavari Estuary

Ghataprabha, Verla, Warna, Dindi, Musi and Dudhganga. Three major distributaries apart from a large number of small creeks supply tidal water into the mangroves. The mangroves are distributed along the creeks and mudflats in between the creeks.

Other Mangrove wetlands: Mangroves are distributed along the estuarine area of Swarnamukhi River, along the Buckingham canal near Krishnapatnam Lighthouse (Eppuru RF), Penna River mouth and in Uppeteru backwaters in Nellore district. The mangroves in the revenue lands are converted into aquaculture farms. Recently, Krishnapatnam port has been established near the mangrove wetland. Some of the mangrove areas were lost due to the development of the port. Most of the mangroves are stunted because of sandy soil and also due to very less freshwater discharge. Grazing and lopping of trees for fencing by the local people are the other reasons for poor growth of mangroves. *Prosopis* has invaded most of the wetland areas near Krishnapatnam.

In Srikakulam, district, mangroves are found in small patches in Bhavanapaadu, Tekkali drain and Nuvvularevu. In Visakhapatnam district, mangroves are seen near the port and the naval base. Mangroves are also seen in Saradha river mouth near Anakapalle. In West Godavari district, small patches of mangroves are seen near the Vasishta Godavari river mouth. Similarly, in Prakasam district mangroves are present near Chinnaganjam area and along the Buckingham canal.

Status of mangrove wetlands

The report of Forest Survey of India 2017 revealed that the mangrove cover in the state is about 404 sq. km. (Table 1). The mangrove cover in the state showed an increase of about 37 sq. km. from 2015 to 2017. The report also gave the extent of mangrove cover in Krishna mangrove wetland which showed an increase of about 29 sq km while the Godavari showed an increase of about 4 sq km (India State of Forest Report, 2017). The mangrove vegetation changes in Krishna and Godavari wetlands assessed in 2004 showed that the mangrove cover has increased from 21,727 ha in 1986 to 26,712 ha in 2004 (MSSRF, 2004). An increase of about 838 ha of mangroves was observed in the Godavari wetland between 1986 and 2004 and in Krishna wetlands, the increase was about 3,823 ha during the same period. The increase in the mangrove area was attributed to both natural regeneration as well as the mangrove plantation carried out by the State Forest Department and MSSRF. In Godavari wetlands, the forest department has restored more than 3,000 ha of degraded mangroves and in Krishna, it has restored more than 5,000 ha. Similarly, MSSRF has restored more than 900 ha of degraded mangroves in these deltas.

In Andhra Pradesh, large areas of mangrove forests are observed in the revenue land. These mangrove forests outside the Reserve Forests are an important resource because it provides numerous ecosystem services. However, the mangrove wetlands outside the forest boundaries are converted to other land uses like industries, port, shrimp

Table 1. State-wise Mangrove Cover in India

No	Name of the State	Assessment Year						
		2005	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**
1	Andhra Pradesh	354	353	353	352	352	367	404
2	Goa	16	17	17	22	22	26	26
3	Gujarat	991	1046	1046	1058	1103	1107	1140
4	Karnataka	3	3	3	3	3	3	10
5	Kerala	5	5	5	6	6	9	9
6	Maharashtra	186	186	186	186	186	222	304
7	Odisha	217	221	221	222	213	231	243
8	Tamil Nadu	36	39	39	39	39	47	49
9	West Bengal	2136	2152	2152	2155	2097	2106	2114
10	Andaman and Nicobar Islands	635	615	615	617	604	617	617
11	Daman and Diu	1	1	1	2	1	3	3
12	Puducherry	1	1	1	1	1.63	2	2
	Total	**4581**	**4639**	**4639**	**4663**	**4627.6**	**4740**	**4921**

Source: http://fsi.nic.in/isfr2017/isfr-mangrove-cover-2017.pdf

farms and agriculture. Efforts should be made by the government to bring these areas under protection since mangroves are one of the important coastal ecosystems.

Goods and services of Mangroves:

Globally mangrove forests are disappearing at a rate of 1-2 percent per year, a pace that surpasses the destruction of adjacent ecosystems, coral reefs and tropical rainforests. The U.N. Food and Agriculture Organization estimates that mangroves are critically endangered or approaching extinction in 26 out of the 120 countries in which they are found. The U.N. estimates that 20 percent of the planet's mangroves were lost between 1980 and 2005. Mangroves are most threatened by harvesting for timber and charcoal, freshwater diversion, real estate development, conversion for tourism and shrimp farms, and clearing for agriculture (notably oil palm plantations and rice)

Mangroves, tidal marshes and sea-grasses are critical along the world's coasts, supporting coastal water quality, healthy fisheries, and coastal protection against floods and storms. For example, mangroves are estimated to be worth at least US$1.6 billion each year in ecosystem services that support coastal livelihoods and human populations around the world. The annual economic value of mangroves has been estimated between US$ 200,000 and $900,000 per ha (Wells, 2006).

A 2006 report by the United Nations Environment Programme (UNEP) noted that ecosystem services afforded by mangrove forests in Thailand are worth $35,000 per hectare, while a 400 sq. km. area of mangrove forest in Matang, Malaysia supports a fishery worth US$100 million a year.

By adopting the same method and values, when compared the Godavari mangroves including Coringa in Andhra Pradesh, India with 316 sq.km supports fishery worth of US$ 79 million a year. Which is Rs. 545,10,00,000 at the rate of Rs. 69 per US$ and the mangroves of Andhra Pradesh including Krishna with 582 sq. km. supports fishery worth of US$ 145.5 million a year which is Rs. 997,05,00,000 (Nine hundred and ninety-seven crores and five lakh rupees).

Blue Carbon – Ecosystem Services

Blue carbon is the carbon stored in coastal and marine ecosystems – mangroves, tidal marshes and sea-grasses. Experts estimate that as much as 1.02 billion tons of carbon dioxide are being released annually from degraded coastal ecosystems, which is equivalent to 19% of emissions from tropical deforestation globally.

When protected or restored, blue carbon ecosystems sequester and store carbon. When degraded or destroyed, these ecosystems emit the carbon they have stored for centuries into the atmosphere and oceans and become sources of greenhouse gases.

Access and control over the fishery resources

The mangrove wetland area of Coringa in the Godavari is protected under Wildlife Act 1972, due to which felling of trees and hunting of wildlife is prohibited. The fishermen living nearby mangrove villages have access over the fishing in the mangrove forest. Fishermen use three types of nets namely dip net, stake net and estuarine dragnet (Salagrama, 2003). The traditional panchayat system or community-based resource management in the villages decide the rights for fishing. Traditional panchayat system helps in getting share to all the resource users. Though stake net was spread across the main creek, a small portion is left for the passage for boats as well as the fishes to migrate upstream as many other stake nets are behind. Similarly, they should not obstruct the side canals with nets so that the other fishermen in the downstream get their share. Violators of this system are punished by the traditional panchayat system (Salagrama, 2003). In a few cases, the fishermen practice rotation if the number of fishing units exceeds the space available for fishing. Crab collection in the mangroves does not have any restrictions. They can collect the crabs anywhere in the mangroves and in the creeks. In Godavari the major users of the fishery resources in the mangroves are only fishermen (Fig.5). Most of these tribal people walk inside the mangroves with less sophisticated gears to collect fishes and crabs. As the fish catch is dwindling and the level of income from the fishery is less many fishermen are opting for other works. Most of the fishermen are marginal farmers having agriculture land/ aquaculture ponds. Many, mostly young and youth are abandoning the hardest profession and take up other lucrative jobs like masonry, carpentry, auto rickshaw driving etc. and earn a decent income.

Fig.5. Fishing a livelihood activity of fishermen and fisherwomen of mangrove ecosystem

Mangrove resources utilization

Mangrove ecosystem is one of the highly productive ecosystems on the globe. The most preferred livelihood of the coastal community is fishing as 65% of the income is from fishing (Haritha *et al*., 2017). The mangrove wetlands in Andhra Pradesh provide multiple benefits to the coastal community. A decade ago, the villagers utilize mangroves for their genuine basic needs such as firewood, fodder, fencing, housing material, thatching materials and fishing poles, which has come down due to the community participated mangrove management program of APFD and NGOs. The livelihood of about 30% of the community living in the villages adjoining mangroves is dependent on fishing in the mangroves as the mangrove areas are rich in crustacean, mollusks and finfish resources. The coastal fishermen, particularly the artisanal fishermen collect these resources inside the mangrove wetland throughout the year. High-value prawns and crabs constitute a higher percentage of the catch in the mangrove wetland. The molluscan shells are collected from the creeks, near shore and in the Kakinada Bay. These shells are used for lime making.

The farming community living close to the mangroves depends on mangroves for fodder. *Porteresia* grass and *Avicennia* leaves are used as fodder. Villagers use the mangrove wetland for grazing their goats, cows and buffaloes. In Godavari mangrove wetland, the farming communities traditionally graze their semi-domesticated buffaloes (Feral Cattle) inside the mangroves. These buffaloes live inside the mangroves throughout the year. The cattle herders fetch milk from the forest. They provide drinking water for these animals during summer as the water inside the mangroves is saline.

Mangroves and climate change

Climate change induced sea level rise has become a serious threat to the coastal community. The sea level rise is predicted as one of the major factors contributing to global loss of 30% of coastal wetlands, including mangroves (Solomon *et al*., 2007). A detailed analysis based on the upper limit of IPCC sea-level rise predictions showed that 13% decline in Pacific island mangroves from the current situation by the end of the year 2100 (Gilman *et al*., 2006). Other regional analyses also predict a 10-15% decline in global mangrove area by 2100 (Snedaker, 1995). Most of the world's mangrove forests may be lost before the peak impacts felt from climate change (Alongi, 2002; Duke *et al*., 2007).

Along the Indian coast, there has already been a sea level rise of 1cm per decade on average since 1900. The long-term tide gauge data collected from various ports along the Indian coast indicated that sea levels are rising at a rate of about 1.0 – 1.75 mm per year (Unnikrishnan and Shankar, 2007). Aggarwal and Lal (2000) predicted that the sea level along the Indian coast would rise by 15 to 35 cm by 2050 and 46 to 59 cm by 2100. Rao *et al.* (2009) predicted that an increase of about 0.6 m in sea level would result in salinization of 894 km^2 in the Krishna and Godavari delta region leading to the displacement of 1.29 million people. Most of the people living in the deltaic region are poor farming and fishing families who are highly vulnerable in socio-economic terms.

The Coastal Zone Management Subgroup of the IPCC (Dronkers *et al*., 1990) identified mangroves as one of the important ecosystems that would enhance resilience against climate change induced disasters. It also prefers soft structures like mangroves (when in considerable size, thickness, density and width) and seagrasses to protect coastal land from increasing sea level instead of hard structures such as seawalls. However, larger changes in sea level will affect the mangroves (Ellison and Stoddart, 1991). In addition, the landward movement of fringing mangrove will be affected due to lack of land for its establishment as all the lands adjoining the mangroves are used for other development activities (Parkinson *et al*., 1994). Changes in sea-level flooding through simulating experiments showed different levels of tolerance to different species, suggesting the changes in mangrove community composition in relation to sea-level rise (He *et al*., 2007). A recent study indicates that the ground level of the coastal wetlands such as mangroves and salt marshes rise more or less similar with the rate of sea level rise (McIvor *et al*., 2013). As a result, entry of seawater inland is prevented by these wetlands. This clearly indicates that these coastal wetlands with a combination of mangroves and raised mudflats act as biosheilds against sea level rise as well as cyclone and storm surges.

The predicted sea level rise of about 0.6 m by the end of this century along the coastal Andhra Pradesh will severely affect the agriculture land in about 319 sq. km.

shrimp/fish farms over 499 sq. km. and plantations over 279 sq. km. besides affecting the livelihoods of about 1.29 million people living in 282 coastal villages (Rao *et al.*, 2009).

The mangrove ecosystems may be able to move shoreward as sea levels increase provided the area is available for the mangroves to establish. However, development activities in coastal areas, such as infrastructure development, seawalls and agriculture often interrupt these transitions (Saunders *et al.*, 2014). Restoration of coastal and mangrove habitats and ecosystems can be a cost-effective way of responding to changes arising from the increasing levels of exposure from the rising sea levels, changes in storm conditions, coastal inundation and salinization (Spalding *et al.*, 2014; Elliff and Silva, 2017; Fig.6).

Tropical Cyclones

India has a coastline of about 7,516 km, of which 5,400 km is along the mainland. The Indian subcontinent is one of the worst cyclone-affected areas with varying frequency and intensity. About 5-6 cyclones are formed every year in the Bay of Bengal and the Arabian Sea, of which 2 to 3 are very severe. The coastal area, particularly the eastern coast and Gujarat coast are vulnerable to tropical cyclones. The east coast of India is more prone to cyclones than the west coast with nearly 80 percent of the cyclones generated in the Indian Ocean strike the east coast of India. Although the north Indian

Fig. 6. *Bruguiera gymnorhiza*: A healthy young tree after restoration

Ocean (the Bay of Bengal and the Arabian Sea) generates only 7% of the world's cyclones (5–6 cyclones per year) their impact is comparatively high and devastating, especially when they strike the coasts bordering the North Bay of Bengal, given the vulnerable conditions the coastal people live in. There are two definite seasons of tropical cyclones in the North Indian Ocean i.e., first from May to June and the other from mid-September to mid-December. Cyclones on the east coast originate in the Bay of Bengal, the Andaman Sea or the South China Sea, and usually reach the highly vulnerable coastline of Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Two of the deadliest cyclones of this century, with fatalities of about 10,000 people on each occasion, took place in Orissa and Andhra Pradesh during October 1971 and November 1977 respectively. The super cyclone of Orissa in 1999 caused large scale damage to life and property. Along Andhra Pradesh coast, the section between Nizampatnam and Machilipatnam is most prone to storm surges as the land elevation is very less. These storms are sometimes accompanied by tidal waves as high as five meters or even more.

In Andhra Pradesh, the coastal districts namely Nellore, Guntur, Krishna, East Godavari and Srikakulam are highly vulnerable to cyclones. The coast of Andhra Pradesh has more than 2,500 villages with a population of over six million. These people living in the belt of 20 km from the coast generally comprise of fishermen and other weaker sections of the society and mostly live in Below Poverty Line (BPL). An analysis of the frequencies of cyclones in the East and West coasts of India between 1891 and 1990 showed that nearly 262 cyclones occurred on the East Coast while only 33 cyclones occurred on the West Coast during the same period. Accordingly, the frequency of cyclones in the Bay of Bengal is about 5 to 6 times higher than the frequency of those in the Arabian Sea. The Bay of Bengal alone contributes a share of 5.5% which is one of the major centers for breeding of tropical storms. Cyclones over the Bay of Bengal usually move westward or northward and across the east coast. When this happens, it brings strong winds and high rainfall to the coastal region, causing damage to property and loss of life.

The predicted frequency and intensity of cyclones along the east coast between 2071 and 2100 will be much higher due to increased wind speed (Unnikrishnan *et al.*, 2011) compared between 1961 and 1990. Badola and Hussain (2005) conducted a study to evaluate the extent of damage caused by the super cyclone with wind speed of about 258 km per hour struck the coastal areas of Odisha on 29th October 1999. The study showed that the dense mangroves significantly reduced the loss of human lives as well as property. Similarly, the dense mangroves protected the coastal community of the southwest region of Bangladesh from the cyclone Sidr during November 2007 (Barua *et al.*, 2010). Analytical models proved that 30 trees per 100 m^2 in a 100 m wide belt may reduce the maximum tsunami flow pressure by more than 90 % (Hiraishi and Harada, 2003).

The canopy and stem of mangroves serve as physical barriers against wind action. The mangrove forest is capable of absorbing 30 to 40 percent of the total force of a tsunami or typhoon and ensuing waves before they swirl over inhabited areas by the shore (Barua *et al.*, 2010). In recent years, the accurate prediction on the wind speed, wind direction and the location of landfall helps in evacuation of the people from the vulnerable locations resulted in minimizing the human causalities. However, the property loss is very high in the recent cyclones such as Hud Hud and the recent Kaja. Table 2.

Conservation and management of mangrove wetlands to combat climate change

Causes of degradation

Mangrove wetlands in Andhra Pradesh are undergoing threat due to large scale conversion particularly of mangroves occurring in revenue lands, which has resulted in reduction in the mangrove cover. Apart from the change in the land use, mangrove resources are exploited for various purposes / uses leading to large scale degradation (Ravishankar et al., 2003; Ravishankar, 2008). The causes for degradation of mangroves are both natural as well as man-made. The mangrove trees were clear felled by the state forest department till 1972 for fuelwood requirement on a 20 – 30-year rotation similar to other highland forests. Few seed-bearing trees were left for regeneration on its own. Some of the clear-felled areas were not able to regenerate due to changes in topography. In addition, some mangrove plants do not coppice. In addition, the massive cyclone on 19th November 1977 in Krishna district also changed the mangrove topography. Some of the areas are elevated due to sand deposition preventing the tidal water flow. The creeks and canals were silted preventing the tidal water flow in both the directions.

The mangrove areas are also degraded due to changes in elevation of the river/ creek banks due to silt deposition during floods in the monsoon period. Once the land becomes elevated, the area is unable to receive free flow of tidal flushing and as a consequence of which only the fringe areas support mangroves, while the interior areas become devoid of mangrove vegetation.

Alternative uses of mangrove lands, especially conversion of mangrove forests to aquaculture have been increasing. Since 1980, large tracts of mangroves all over the world were converted to aquaculture ponds. The area of aquaculture farms in the Godavari and Krishna wetlands are 6,920 ha and 20,466 ha respectively. In Godavari mangrove wetlands about 650 ha of pristine mangrove situated outside the forest boundary was cleared for shrimp farms (MSSRF, 2004). Coastal villagers utilize mangroves for their genuine needs such as firewood, fodder, timber and twigs for fencing, poles for house construction, thatching and fishing. Mangrove wood is used for smoking of the fishes as it is one of the traditional fish-processing processes in the Godavari region. Grazing of the cattle along the fringe areas is also one of the causes of mangrove degradation.

Table 2. Mangrove properties that increase coastal protection from natural, including waves, storm surge, tsunami, erosion and sea level rise. Source: Spalding *et al.*, (2014)

	Properties	**Hazards**			
		Waves	*Storm surge*	*Tsunami*	*Erosion* *Sea level rise*
Mangrove forest properties	*Width*	Mangrove forests need to be hundreds of meters in width to significantly reduce waves. Wave height is reduced by 13-66% per 100 meters.	Mangrove forests need to be hundreds of meters in width to significantly reduce wind and storm surges. Thousands of meters of mangroves are needed to reduce flooding impact (storm surge heights is reduce 5-50 cm/km)	Mangrove forests need to be hundreds of meters to reduce flood depth by 5-30%. However mangroves do not provide a secure defense against tsunamis.	Mangrove forests need to be of significant width to maintain sediment stability and encourage soil build-up.
	Structure	A denser aerial root system and branches will help reduce wave strength.	Open channels and lagoons allow free passage, while dense aerial root systems and canopies obstruct flow.		Complex aerial roots systems will help slow water flow, allowing sediment to settle thereby reducing erosion.
	Tree size	Young and small mangroves can be effective.	Smaller trees and shrubs may be overtopped by tsunamis and very large storm surges.		Young trees can allow for soil to build up, however the more biomass in the coil the better.
	Link to other ecosystem	Sand dunes, barrier islands, saltmarshes, seagrasses and coral reefs can all play an additional role in reducing waves.			Allow room for landward retreat of the mangroves.
	Underpinning factors	Healthy mangroves are essential for all aspects of coastal protection. Healthy mangroves require: sufficient sediment and fresh water supply and connections with other ecosystems. Conversely, pollution, subsidence (due to deep groundwater/oil extraction or oxidation upon conversion) and unsustainable use negatively affects mangroves.			

Restoration of degraded mangroves

Restoration of degraded mangroves was being carried out in the tropical and subtropical estuaries throughout the world. In Andhra Pradesh, the Forest Department initiated restoration of mangroves in the Godavari by canal digging during 1991. M.S. Swaminathan Research Foundation (MSSRF) initiated mangrove regeneration from 1998. The forest department has restored more than 8,000 ha using canal method. Similarly, MSSRF also restored nearly 900 ha in Andhra Pradesh.

MSSRF and the state forest department are involving the local community in mangrove conservation and management through Joint Mangrove Management program. The approach is similar to Joint Forest Management. The mangrove restoration was carried out through the village level institutions namely Eco-Development Committees (EDCs) and Vana Samrakshana Samitis (VSSs) formed in the mangrove abutting villages (Ravishankar and Ramasubramanian, 2004; Ravishankar et al, 2017). Shallow canals were dug to facilitate tidal water flow into the degraded areas. Mangrove saplings were raised in community nurseries and planted in the canal constructed degraded areas for mangrove regeneration. The mangrove restoration not only increased healthy mangrove areas but also prevented further degradation adjoining the degraded patches as canal digging helped in establishing water regime (Ramasubramanian et al., 2006). Apart from mangrove saplings planted, large numbers of mangrove saplings were naturally established. Additionally, as a spin-off effect, the canal dug areas helped increase in crab population as the crab found the channeled areas easy to make burrows.

The mangrove plantation in the degraded area is one of the reasons for the increase in the mangrove cover (Fig. 7). In addition, the forest department stopped coupe felling. The local community also reduced the dependency on mangroves for their domestic needs as most of the households use the bottled gas. Construction of concrete houses after 1996 cyclone and 2004 tsunami has reduced felling the mangroves for timber.

Conclusion

Mangroves are one of the important ecosystems of the tropical and subtropical coastal communities. Mangrove ecosystem is one of the highly productive ecosystems providing many goods and ecosystem services to the local community for their various needs. They also act as a nursery ground to various commercially important fishes, shrimps and crabs besides habitat for various fauna. More than 30% of the coastal community directly depends on the mangroves for the livelihood. Climate change induced impacts such as sea level rise, erratic rainfall, coastal erosion, increased frequency of cyclones will affect the lives and livelihoods of the coastal community. The coastal areas along the Indian coast have already witnessed a sea level rise of 1cm per decade on average since 1900. The predicted increase in sea level will reduce the extent of mangroves globally. However, mangroves have the ability to move landward side if suitable land is

Fig. 7. Map showing fishbone type canals in the mangrove restored areas in Coringa Wildlife Sanctuary

available and provide its ecosystem services. Hence, there is an urgent need to protect the mangroves in the revenue lands adjoining the forest boundaries. Large areas of revenue lands suitable for mangrove plantations are found in the Krishna and Godavari deltas, which need to be protected to meet the challenges of sea level rise. The government should take a proactive role in protecting the mangroves in the revenue lands. The sea level rise alters the high tide level resulting in flooding of saline water in the fertile agriculture lands. It has been predicted that more than 894 sq km of land will become saline in the Krishna and Godavari delta of Andhra Pradesh which will, in turn, affect the livelihoods of the coastal community. The mangroves are one of the important coastal resources in reducing the impacts of tsunamis and tropical storms. Studies conducted after 1999 super cyclone and the 2004 Indian Ocean tsunami proved that the dense mangroves protected the villages behind them. The local community witnessed the protective role during 1996 cyclone and the 2004 tsunami. After these assessments and anecdotal evidences many national and international organizations emphasized rehabilitating ecosystems as a first line defense against the disasters. Many studies proved that the soft structures like mangroves are preferred to protect the coastal area from the disasters than the hard structures such as seawalls as the latter is cost intensive and also difficult to manage. Mangroves are very important coastal resources as they sequester large amounts of carbon. Mangrove ecosystem serves as a living platform as they trap sediments and the level will increase more or similar to the rise in sea level. The conservation and management of mangrove ecosystem is essential for not only sustain the livelihoods of the coastal community but also provide better first line defense against the increasing natural disasters.

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