Chapter 11
A Holistic Study on Impact of Anthropogenic Activities over the Mangrove Ecosystem and Their Conservation Strategies

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Abstract Despite their importance, the mangrove ecosystem is one of the highly vulnerable ecosystems in the Anthropocene era. Mangrove ecosystems lie in an intertidal zone of subtropics and tropics regions. They provide ecological and economic services to the coastal communities. Mangrove provides multifaceted advantages to the local ecosystem such as it reduces the severity of the hurricane, storm surge, cyclone, and tsunami, prepares a perfect bed for spawning marine fishes, and also plays a major role in carbon sequestration. Deterioration in global estimates of mangrove covers ~150,000 km^2 is the consequence of exponentially increasing urbanization and industrialization. These two major anthropogenic activities induce numerous problems such as an increment in the intensity of natural calamities, local inhabitant losing their livelihood, and many marine species standing on the verge of extinction. An integrated approach is required for the preservation and management of mangrove biotopes with an amalgamation of local inhabitants, researchers, and government. Conservation techniques include afforestation, legislation, policies, application of remote sensing and geoinformation system (GIS), and development of parks and reserves for protection. This chapter is a consolidated approach to study the sources and impact of anthropogenic threats on mangrove forests from a global and Indian perspective with holistic conservation strategies.

Keywords Mangrove ecosystem · Anthropogenic · Impacts · Conservation

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1 Introduction

1.1 A Brief Outlay of Mangrove Ecosystem (ME)

Mangrove ecosystems are one of the most fragile coastal forests. It is commonly found near the cliff of lagoons, shores, estuaries, and riverside in the subtropics and tropics zones. Maiti and Chowdhury (2013) explained the term "mangrove"; according to them mangrove trees or shrubs have specialized capabilities to adapt in tidal regions. Mangroves are salt-tolerant plant species. Which uptake water through high osmotic potential but after absorption of saline water, its excreted salt through their salt glands which are located in leaves (Parida and Jha 2010). Mangroves are tough, hard, and woody halophytic plants, and their salt-tolerant characteristics angrove ecosystems salt-tolerant characteristics help them to exist in highly saline, extreme tidal, strong windy, high temperature, and muddy-anaerobic soil conditions (Guo et al. 2017). Mangrove is indigenous in halophytic condition with the help of supportive root system, pneumatophores, stilt root, and leathery and evergreen sclerophyllous foliage with salt excretion glands and recessed stomata. Out of the total percentage of mangrove in India, more than half are existing on the east coastline of the Bay of Bengal, only 20% on the west shore of the Arabian Sea, and a major chunk of 13% on the Andaman and Nicobar Islands (Kathiresan et al. 2018). According to the India State of Forest Report (2009), mangrove ecosystem range in India is categorized as highly dense (more than 70% plant cover, 140,500 ha), moderately dense (40–70%, 165,900 ha), and open type (10–40%, 157,500 ha) forest types. It is explained in previous studies; Sundarbans is a very diverse mangrove forest and enriched with more than 62 species. The Indian-Malaysian region is considered to be the center for the progression of the mangrove ecosystem (Maiti and Chowdhury 2013).

Mangroves are considered as a linkage between freshwater and marine ecosystems. Mangroves plays multiple roles in maintaining ecological services such as (1) pollution sink; (2) source of nutrient exchange in coastal environment; (3) increasing sediment accretion and stabilizing shorelines; (4) binding nutrient and heavy metals to improve quality; (5) serving as a reservoir of food, fuel, fodder, and medicine for coastal inhabitants; (6) providing a breeding bed for aquatic species like amphibians, fishes, and crustaceans; (7) providing shelters for reptiles, birds, and mammals; and (8) reducing the risk of some natural calamities, e.g., cyclones, typhoons, or tsunamis (Valiela et al. 1974; Banus et al. 1975; Mitchell 1978; Giblin et al. 1980; Chu et al. 2000). Because of human activity's overextension, the mangrove environment continues to be in grave danger despite these ecological, social, and economic benefits. As a result, in many parts of the world, the species diversity index of mangroves is decreasing steadily (1–2 percent each year), in many regions of the globe. Gradual loss of mangroves in the entire globe will project to 60% by the year 2030 (Chaudhuri et al. 2015).

According to a study by Di Nitto et al.'s (2014) global warming may raise sea levels, causing mangroves to migrate closer to the land report illustrated global warming could increase the sea level and, as a repercussion of that, mangroves can

move toward land. However, across the world, mangroves are unlikely to shift land-ward because of human intervention at the terrestrial boundary, and the major patch of the forest cover is likely to diminish (Ward et al. 2016). A drastic paradigm shift can be observed in mangrove habitat; it alters because of neighboring circumstances such as the condition of wetland and its type, geomorphic setting, as well as most important substantial activities in the wetland. It is predicted that the sea rise may range from ~450 to 650 mm per century (Mimura 2013). However, mangroves can only survive in ~80–90 mm rise in sea level, and hence the predicted threat moves faster toward the mangrove to disintegrate the ecosystems (Sasmito et al. 2016).

This study aims to point out how the mangrove ecology is adversely affected by pollution, population, overexploitation, habitat encroachment, invasion, land-use change, management, and conservation programs through different techniques. Mangrove nurtures the pivotal balance of the integrity of the environment, and it acts vitally in maintaining equilibrium between nutrient cycling in the estuarine and coastal ecosystem. Mangrove restoration activities have been conducted in the Tutuila Island, American Samoa. Countries involved in the rehabilitation of mangrove, and they tried to sustain the coherence of the ecosystem, for instance, substrate conditions, salinity regime, depth of inundation, wave energy, tidal velocity, soil and water pH, and sediment matrix (Maiti and Chowdhury 2013).

2 Benefits of Mangrove Ecosystem

Mangrove ecosystems provide multiple services: provisioning, regulating, cultural, and ecological services. Provisioning ecological services include the use of mangrove-grown fuel, such as Nypa leaves, lumber, and charcoal. Mangrove forests contribute significantly to carbon sequestration/storage and provide ecological benefits (Cornell et al. 2018) and deliver its ecological services. In addition, supporting services of that mangrove provide opportunities for recreation and moderation of extreme events. It reduces the intensity of floods, cyclones, coastal erosion, tsunami, etc.

2.1 Provisioning Services

Mangrove forests are the host of thousands of people. It supplies many essential products such as firewood, charcoal, timber, honey, etc. to the local villagers and flourishes the fishery businesses in this mangrove to deliver their provisioning services (Aye et al. 2019). Mangrove woods and their charcoal product have high calorific value than Indian coal. Its product producing more heat and less smoke might be because of the high content of tannin (Sathe et al. 2013). Each part of the mangrove has its importance. Its uprooted pneumatophores are used for manufacturing bottleneck stopper; their leaves are thatched as roofs; shells are used for manufacturing lime. Mangrove facilitates apiculture activities; around 2000 people are

engaged in more than a hundred tons of annual honey and wax production in Sundarbans, India (Kathiresan 2018). Some specific mangrove such as *Avicennia* produces cheap and nutritive feed for ruminants (Sathe et al. 2015).

Mangrove ecosystems are very sensitive to hydrological changes; minor variations in tidal regimes trigger remarkable variation. Therefore, it acts as a precursor of rising in sea level (Blasco et al. 1996). Mangrove ecosystem plays a pivotal role in the maintenance of nutrients by restoring them in dead modified roots varying from 36% to 88% of total viable tree biomass (Alongi et al. 2003), unlike terrestrial forests where a significant percentage of nutrient capital can restore in floor litter.

2.2 Ecological Services

Mangroves can protect the coastal communities from harmful solar UV-B radiation. *Avicennia* is a species of mangrove that grows in high sunlight endowed area and well adapted to arid zones (Moorthy and Kathiresan 1997). The mangrove foliage is a good source of flavonoids that screen the UV-B and reduce the detrimental effect of ultraviolet (Moorthy and Kathiresan 1998). IUCN report illustrates mangroves are the sink of carbon dioxide and up to some extent curtail the greenhouse gas. A sufficient amount of carbon dioxide doubles the biomass. *Rhizophora mangle* aboveground biomass (shoot) got doubled. On the contrary, the root system, above and belowground biomass not as responsive as shoot biomass, and the proportion between responsiveness is about 2.5:1. This might be because of the significant amount of organic carbon storage in sediments (Estrada and Soares 2017). Mangrove wood has thick organically rich sediments in its substrata. Except in the deltaic area, the majority of mangrove peat substrate in the tropics is derived by mangrove roots. This entire belowground coalition in forests has great productivity as well as are nutrient-rich. The whole setup of mangrove forest is good for carbon sequestration not only above- but also belowground (Alongi 2014).

Mangrove grows in swampy beds; it is a good source of nutrients for fishes. The swampy bed provides breeding grounds and nurseries for marine Pisces (Mandal et al. 2013). This ecosystem is the ecotone between terrestrial and marine systems so comparatively more productive than the agricultural fields. It is 25 times fertile than the plane paddy cultivated area (Tripathi et al. 2016).

2.3 Supporting Services

Mangrove forest reduces the intensity of cyclone and tidal storms (Krauss and Osland 2020). When the 310 km/h super cyclone struck the Odisha coast in India on October 29, 1999 and killed approximately 10,000 people and devasted the mangrove-depleted region, it was the finest example to illustrate its significance (Das and Vincent 2009). The thick mangrove gallery, on the other hand, sustained just

little damage occurred at the dense mangrove gallery. Mangroves, rather than the "cleared" zone, may be used to protect hectares of land in cyclone and tsunami-prone regions. Mangrove plantations are capable of diminishing the fury of the tsunami as well as controlling the shoreline against damage (Das and Vincent 2009) (Table 11.1). Dense mangrove growth avoids the intensity of several disasters in the Bay of Bengal, West Bengal, Bangladesh, Myanmar, Maldives, etc. There is one incidence in Thailand's coastline where mangroves breach the lethality of the tsunami in Surin Island (WHO Report 2004). A hydraulic experiment was done by Harada et al. (2002), to study the tsunami reduction effect on coastlines with five major models of mangroves. According to the result found, the coastal forest is more effective than the seawall to resist the sea wave in the disaster like tsunami, to protect the houses and livestock. To tranquilize the amplitude and energy of the wave, dense vegetation has also been effective via wave forces measurements and fluid dynamics modeling (Massel et al. 1999). For example, according to the analytical model, the agitation caused by tsunami flow pressure may be reduced by as much as 90% when 30 trees from 10sq meter are planted in a 0.1km broad strip. But this method only works when the wave height is between 0m and 5m (Tanaka 2009).

Mangroves not only protect us from tsunami and cyclones but also provide flood resistance in the coastline and reduce seawater intrusion in groundwater. It has a prominent root system and pneumatophores that spread out in the immense area which provide stability and promote sedimentation reducing flood expectancy (Srikanth et al. 2016). Mangroves act as a boon for coastal inhabitants, supporting in maintaining purity of underground water.

Mangrove ecosystem provides commendable services to minimize coastal erosion due to large waves. Its lush growth reduces the severity of large waves and coastal erosion. The restoration of mangroves in Vietnam's Red River Delta has taken many stages and cost millions of dollars (Hai et al. 2020). Around 100-m-wide belt of mangroves can be helpful in protecting the adjacent mangrove area (Albers and Schmitt 2015). However, the diminishing of immense mangrove forest causes huge sediment erosion in the coastal zone. The mangrove induces sedimentation with the help of pneumatophores and thus causes land expansion (Kathiresan 2018). In various cases, there has been evidence of yearly sedimentation rate, lying between 0.1 and 0.8 cm in mangrove zones, which causes expansion of land (Woodroffe et al. 2016) (Table 11.1).

Table 11.1 Services provided by mangrove ecosystem

Benefits of mangrove ecosystem	Provisioning services	• A good source of firewood, charcoal, timber, honey, etc. • Facilitate apiculture and aquaculture
	Ecological services	• Protect from harmful solar radiation • Act as sink for carbon dioxide • Provide swampy bed for fish spawning
	Supporting services	• Reduce intensity of tsunami and cyclone • Act as seawall • Avoid mixing of saline water and fresh water

3 Anthropogenic Threats for Mangrove Ecosystem

Human intervention plays a vital role in mangrove deforestation in past decades. Approximately 73% declined over the 16 years' (2000–2016) period. However, a large proportion of mangrove loss was reported in the first epoch around 1186 km^2, whereas a comparatively slow degradation of 314 km^2 occurred in the last epoch (Goldberg et al. 2020). Anthropogenic activities are responsible for 80% (2065 km^2) loss of the mangrove ecosystem in just six countries: Indonesia, Malaysia, Myanmar, Thailand, Philippines, and Vietnam (Goldberg et al. 2020). Other than these six nations, Southeast Asian countries are also facing the major deterioration of the ecosystem primarily due to widespread mangrove transition to aquaculture ponds and agricultural field (Richards and Friess 2016). According to Synthesis Report on Ten ASEAN Countries Disaster Risks Assessment (2010), coastal mangrove hotspot was widely spread in South Asian countries such as the Rakhine State of Myanmar, Mekong Delta in Vietnam, and the Kalimantan and Sulawesi regions of Indonesia (FAO 2007). A substantial (77%) decrease has been observed in mangrove percentage area from previous year data in last decades (Goldberg et al. 2020). There are many incidences available of nonproductive conversion (NPC), such as petroleum extraction in the Niger Delta causing 20 km^2 area loss and mining activities in Grasberg mine tailing in Papua, Indonesia, inducing 5 km^2 loss (Alonzo et al. 2016). NPC-stimulated losses somehow declined by 46% from 268 km^2 in 2005 to 129 km^2 in 2016 (Toumbourou et al. 2020). Nonproductive conversions (NPC) approximately cause 12% (398 ± 29 km^2) of global loss but reclaimed land for human colonies only representing 3% (96 ± 15 km^2) of global loss extent (Goldberg et al. 2020).

The remarkable amount of mangrove density decreases; many drivers justify this change such as leading aquaculture industries, agriculture practices, forestry, oil palm plantation, rice cultivation, urban sprawling, and irrational industrial establishment (Webb et al. 2014; Lai et al. 2015). These factors are basically responsible for land cover change along with mangrove exhaustion.

3.1 Contribution of Aquaculture in Mangrove Loss

The involvement of aquaculture in the drivers for mangrove deterioration is very high in the last decades. The huge area is converted into fish or shrimp ponds (Valiela et al. 2001; Hamilton 2013). The government of various coastal nations, such as Thailand, Vietnam, Indonesia, and the Philippines, is encouraging the conversion of forest to fish and shrimp ponds in order to increase food security and livelihood. Conversion of mangrove areas into aquaculture is now in trend especially at Kalimantan and Sulawesi, Indonesia. Deforestation accounts for 54% of mangrove for aquaculture since 1980 to the 1990s (Hamilton 2013), and the

percentage is going to rise during 2010–2011 (Richards and Friess 2016). Local people got involved in aquacultural development at the site of mangroves in 2010–2011 (Richards and Friess 2016). The current Indonesian government has backed aquaculture it is important to mention that, not only aquaculture is a factor, but production of rice also contributes to mangrove loss.

3.2   Enhancement of Rice Cultivation

In recent years, Myanmar has promoted rice cultivation, but at the cost of Southeast Asia's mangrove forests. Numerous studies reported about natives of the Ayeyarwady Delta affecting the mangrove ecosystem for paddy cultivation (Webb 2014), but the present situation deepens in whole Myanmar for expansion of rice agriculture. Such examples act as a driving force for the fastest rate of mangrove deforestation of any country in Southeast Asia. After this incidence Myanmar government realizes their fault and trim all the activities affecting mangroves. They have taken various steps for the conservation of assets of Myanmar in the form of mangrove wood (Aung 2007) (Fig. 11.1). The government of various countries is enhancing rice production through technical assistance and conventional village level expansion targets to improve their food security (Okamoto 2007; Matsuda 2009). The nation benefited financially from rice cultivation, aquaculture, and oil palm culture (Webb 2014; Richards and Friess 2016).
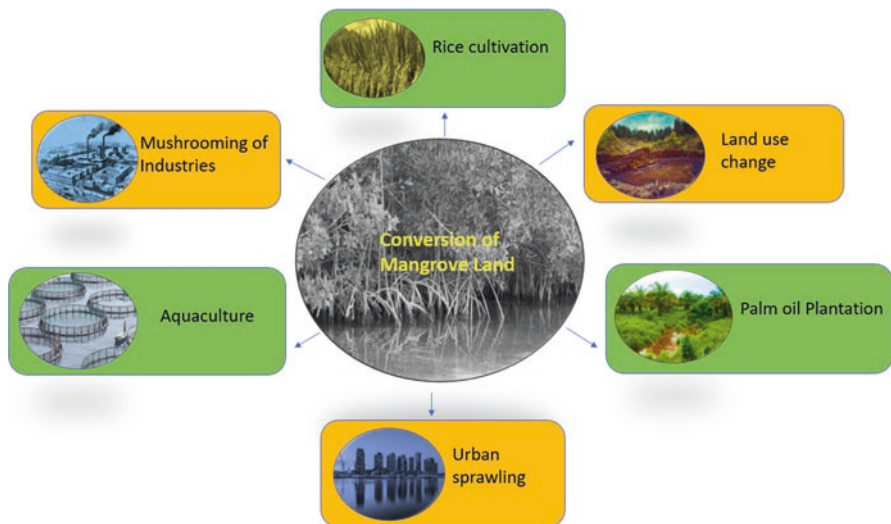

Fig. 11.1 Anthropogenic threat over mangrove land

3.3 Increase of Oil Palm Plantation

The increasing trend of oil palm plantations in Indonesia and Malaysia in the coastal region is also responsible for mangrove replacement and their loss (Koh and Wilcove 2008; Koh et al. 2011). According to Lee et al.'s (2014) study, most of the areas of Malaysia, Sumatra, and Indonesia contribute to oil palm production on the replacement of mangrove forest. Numerous governments of Southeast Asian countries support palm oil production companies for energy independence and economic benefits (Wicke et al. 2011) (Fig. 11.1). Now is the time for intertidal inhabitants and government agencies to initiate monitoring and supervising mangrove density and rehabilitation.

3.4 Elevated Trends of Urban Sprawling and Industrialization

Urban settlement and mushrooming of industries are migrating towards the coastal regions because mangroves are associated with job creation, land reclamation and recreation activities. Despite these many people dependent on the coastal ecosystem for their livelihood (Thuo 2013). There are few reasons which triggered the change in land-use pattern in the coastal zone such as overexploitation of mangrove for wood, timber (Rahman et al. 2010; Sahu et al. 2015) (Fig. 11.1). These factors are listed in the major drivers of non-replenish mangrove loss. The rate of rising urbanization and industrial development on the sea coast might result in the disposal of wastewater, irrational solid waste disposal, sewage generation, as well as invasion in mangrove zone and converting them into metropolitan space (Ibharim et al. 2015; Hasnat et al. 2018). This will lead to rapid devastation, deforestation, and forest degradation, even in countries such as Brazil, where mangroves are subject to permanent environmental protection. There is some prominent example of 5000 ha mangrove reduction in Guanabara Bay, Brazil, due to urban settlement and expansion of landfill sites (7000 t/day) (Godoy and Lacerda 2015; de Lacerda et al. 2019). Extension of metropolitan cities in seaside always attracts tourists and always provides peace and socioeconomic benefits, but it tremendously reduces forest cover (de Lacerda et al. 2019). Caribbean forest faces considerable loss up to 1.7% per year and 0.2% per year in islands, 2.2% (10,702 ha/year) per year in Central and South America in Panama, 1.48% per year (5358 ha/year) in Ecuador, and 1.23% per year (794 ha/year) in Costa Rica (Ellison and Farnsworth 1996; López-Angarita et al. 2016). To pacify the destruction rate of mangroves, some regulatory frameworks are implemented in various countries.

Oil spill is a common problem in the proximity of unregulated industries which forms a layer over the sea and causes eutrophication. An oil spill incident happened in Panama on April 27, 1986, where approximately 5,962,024 L of medium-weight crude oil percolated into coastal lines and expressed deleterious effects on mangrove forest (Cubit et al. 1987). This event triggered an extensive regulation that

involved oil spill preparedness on offshore and onshore support activities (Arbo and Thủy 2016). About 54% of vessel incidents, 21% of pipelines, and 14% of shore tanks have already happened, but now the number of oil spill cases is decreasing, and their ill impact on mangrove ecosystem has also reduced in three decades of the twentieth century (Duke 2016). However, when past and current centenaries are compared, it must be seen that the frequency of occurrences (oil spills) has increased significantly, and the total mangrove area has been significantly reduced by these incidents (de Lacerda et al. 2019).

3.5 Extensive Agriculture

Extensive agriculture contributes to nutrient enhancement, but its consequences deprive the water quality and ultimately cause mangrove degradation (Maryantika and Lin 2017). Extensive agriculture includes intensive use of pesticides, damming of rivers, and diversion of waterways shifting the sedimentation erosion equilibrium ratio of coastal land and augmenting the salinity of groundwater (Kusmana 2014) (Fig. 11.1). Agriculture-induced mangrove loss is observed in Colombia, due to sudden alteration in water quality and its chemistry because of agrochemicals. This mangrove disappearance stimulated the most successful restoration experiment of mangroves in the USA (de Lacerda et al. 2019). Regionwide lessening of sediment transport to the coast is the repercussion of damming over the river. Damming causes topsoil erosion in coastal forests in arid and semiarid littoral zone. The salt intrusion has prolonged the saline impact upriver triggering mangrove migration inland (Godoy and de Lacerda 2014). Unbridled use of mangrove resources such as timber, wood, bark, medicinal use, fisheries use, and salt adversely affects the percentage of mangrove. Mangrove wood product has high economic and cultural values all over the world, and this specialty increases its utility as well as deforestation in Northern and Southern America (Venezuela). Approximately 3/4 of the area of Venezuelan mangroves was lost during the twentieth century (Villate Daza et al. 2020).

4 Current Global Status of Mangrove

Currently, a paradigm shift is observed in the density of mangrove forests throughout the world due to anthropogenic actions such as urban sprawling, population burst, the establishment of several industries, sewage discharge, and irregular disposal of municipal solid waste. These mentioned activities cause considerable change in the mangrove population everywhere. Chen et al. (2009) reported a drop of mangrove cover by more than 40% to approximately 22,000 ha in 2001 from more than 50,000 ha in 1950. Numerous threats and possibilities in the environment such as human-induced oil spill, aquaculture, agriculture, surface runoff, excessive

use of mangrove products, etc. disturb the mangrove ecosystem (Liu et al. 2008; Chaudhuri et al. 2015). In Myanmar, around 168,500 ha of mangrove were reduced in previous decades (Giri et al. 2011; Webb et al. 2014). Indonesian mangrove forest is one of the largest coastlines belonging to 257 cities. According to the Ministry of Forestry (2007) report estimation, 7.8 million ha (30.7% in good condition, 27.4% moderately disturbed, 41.9% heavily disturbed) potential areas are covered with mangroves. The Agency of Survey Coordination and National Mapping, Republic of Indonesia (2009), estimated at 3.2 million ha the mangrove area. Maximum exploitation of mangroves in Indonesia has occurred due to extensive fishery culture, shrimp farming, salt ponds, mining, and expansion of urban activities (Kusmana 2014). More than 50% of mangrove areas are ruined by human activities in Segara Anakan Lagoon, Indonesia (Ardli and Wolff 2009; Hinrichs et al. 2009). Major destruction of the mangrove ecosystem in the Philippines happened because of the invasion of human activities. Land-use change is responsible for 4500 km^2 in 1920 to 1200 km^2 in 1994 ecosystem cover (Primavera 2000; Chaudhuri et al. 2015). Mangrove forests are spread on the southern and eastern coasts of the Gulf of Thailand mostly concentrated in the Andaman Sea. Coastline mangrove ecosystem forms two-story forest cover: the upper layer has around 20 m height and is dominated by *Xylocarpus mekongensis* (syn. *X. moluccensis*), *Rhizophora apiculata*, *Heritiera littoralis (ngon kai)*, and *Rhizophora mucronata*, *and the lower layer consists of Bruguiera parviflora*, *Bruguiera sexangula*, *Ceriops decandra*, and *Ceriops tagal.* Mangrove covered around 2 million Rai (1 Rai = 0.16 ha), till 1975, but the land cover changed since 1996, so the mangrove number decreased by 50% (Pumijumnong 2014). Following the strict implementation of conservation and rehabilitation strategies in 2004, the mangrove area increased to 1.5 million Rai, with the remaining mangrove area encroaching for shrimp cultivation. Mangrove land was also used for human settlement expansion, industrial expansion, and road construction in mangrove areas following the increase. In 2007, through remote sensing technology and interpretation of Landsat 5 satellite images, mangrove cover was estimated at 18.55% out of the total area in Thailand, and the largest mangrove cover is in Phang Nga, Thailand (Pumijumnong 2014).

In Brazil, nearly 0.5 thousand km^2 area of shoreside mangrove was deforested in the last 25 years mainly for aquaculture and farming (Giesen et al. 2007). Mangrove cover was dramatically decreased by 18% within 25 years at a mean rate of 0.7% per year due to improper legislation and habitat moderations (Kirui et al. 2013) During the last decade, mangrove forest was diminished by ~15 km^2 in Tanzania due to land reclamation (Wang et al. 2002). In Bangladesh problems have deepened more; Sundarbans' mangroves have lost 45% of their total coverage due to uninterrupted encroachment due to logging, shrimp farming, and natural disasters (Islam and Gnauck 2008; Roy 2014). Despite urbanization and industrialisation, certain nations, such as Australia and New Zealand, continue to invest heavily in the management and restoration of mangroves. These efforts continuously increase the restoration area and lead to the expansion of mangrove boundaries at a constant rate over the last few decades. The pace of extension doubled, from 240 ha in 1943 to 545 ha in 1999, in Tauranga Harbour, New Zealand (Ghosh et al. 2015). Mangrove

land cover was improved by approximately 3.8%, 32.8%, and 55% in Gosford (New South Wales), Botany Bay (Sydney), and Phillip Island (Victoria) from 1954 to 1995, 1956 to 1996, and 1939 to 1999, respectively (Harty and Cheng 2003; Harty 2009).

5   Indian Status

The coasts of nine maritime and four Indian union territories are well flourished at 4740 km^2 of mangroves along the bank of estuaries. Indian mangroves are broadly classified into three main categories: (1) deltaic, (2) estuarine and backwater, and (3) insular (Andaman and Nicobar Islands). 58% of total Indian mangrove (which is 4740 km^2) can be found along the eastern coast (Bay of Bengal), 29% along the west coast, and 13% along the Andaman and Nicobar Islands. In mangroves, spatio-temporal changes had started 200 years ago at the degradation rate of 4% per year, which in the recent decades got intensified to an enhanced rate of degradation. Mangrove forests in transboundary Sundarbans reserve forests are drastically degrading for the last 20 years. Unfortunately, before 1870, no reliable data for mangroves is available. So, from the available records, it can be stated that the previous 200 years were more crucial for mangrove degradation. In addition to this, from 1873 to 1933, total forest cover was reduced to an extent of 1500 km^2. The last 2 years were more crucial for using remote sensing techniques in mangroves for mapping and understanding the spatiotemporal extent of mangrove forest especially in the perspective of natural disasters and anthropogenic forces. Such, site-specific or short-duration (2 years) investigation is extremely uncommon for the Indian Sundarbans world heritage site, particularly in the southwestern region. Among numerous studies, the majority were related to change in coastal geomorphic patterns, ocean level elevation (Jayappa et al. 2006). Change in vegetation dynamics is one of the least discussed issues in micro-/meso-level studies. Thus, using conventional NDVI methods, an attempt has been made to monitor and assess net changes in the vegetation of the entire integrated Sundarbans.

5.1   Mangrove Status in Southern Parts of India

Kerala has a 590-km-long coastal line. In this state, the mangrove vegetations are spread in the form of patches or continuous form along the banks of estuaries, in nearby areas of backwater channels, and near the water bodies. In this state, the mangrove is supported by 41 perennial rivers which create a favoring ecological environment for the development of mangroves on the fringes of estuaries, bank water, and creeks. Mangroves in the Andaman and Nicobar Islands (ANI) are abundant and very contrasted with other mangrove wood in India (Dagar et al. 1991; Mandal and Naskar 2008; Goutham-Bharathi et al. 2014). However, mangrove

zones in the ANI encountered an extreme decrease in the most recent decade, potentially prompting changes in floristic organization and region termination of certain species. A region of around 54 km^2 has been degraded somewhere in the years 2003 and 2013, and especially somewhere in the range of 2011–2013, an overall zone of 13,000 m^2 of huge mangrove chunk has been disturbed (FSI 2015). It was determined that the geological and morphological changes caused by the massive seismic earthquake and subsequent tidal wave in December 2004 were the causal components of the ANI's subsequent loss of mangroves. As per the most recent measure by the Forest Survey of India (FSI 2015), the absolute mangrove zone in India is around 4740 km^2, of which 617 km^2 happens in the ANI. Of that area, 616 km^2 area in the Andaman Islands and the Nicobar Islands represents 1 km^2. There has been a net increment of 13 km^2 in the mangrove front of the ANI when contrasted with the 2013 evaluation. Even though mangroves of the ANI have seen an expanding pattern recently, the fast abatement of mangrove regions of the ANI during the most recent decade has become a significant concern regarding protection ratios of such a resource-rich island coastal environment. The mangroves of the ANI have been concentrated by numerous specialists; however, there is no agreement on the mangrove floristics of the ANI. Uncertainty exists concerning the qualification of major or genuine mangroves from minor and mangrove-related species, especially at their conventional levels. A few genera/species, viz., *Acrostichum*, *Acanthus*, *Pemphis acidula*, *Phoenix paludosa*, *Cynometra*, and *Dolichandrone spathacea*, are around the world considered as evident mangrove species (Duke 1992; Polidoro et al. 2010), though the previously mentioned species were dynamically grouped by Dagar et al. (1991), Singh (2003), Debnath (2004), and Dam Roy et al. (2009) in the ANI. Furthermore, the taxonomical character and incident of certain mangrove species in the ANI stay uncertain. Because of this, mangrove floristics of the ANI is regularly confounded and the right picture on mangrove plant variety of the ANI is under question.

6   Conservation and Management Strategies

Successful examples of mangrove conservation can be found throughout the world. Several innovative management strategies concerning the people's needs alongside the mangrove forest are reported in studies (Romañach et al. 2018). Concern over the lack of mangrove biological systems frequently centers around the disturbance or disruption in the arrangement of natural administrations by mangrove forests (Datta et al. 2012), for example, the security of coastal improvement against storms and floods that harm property and cause passing and injury, just as buffering environmental change impacts induced via ocean level rise, saltwater interruption, and coastal disintegration (Whiteley 2011). Valuation of biological services has progressively been accelerated and used in preservation and management strategy (Watson et al. 2018).

6.1   Global Approaches to Mangrove Conservation

The advancement of mangrove protection and the improvement of human affluence and occupations simultaneously have been the two essential needs of the United Nations Sustainable Development Goals plan (United Nations 2015). These two clashing desires can be met by developments in eco-cultivating inside mangrove forests to accomplish agreement between people's resources and mangrove health. Coinciding with the Millennium Ecosystem Assessment concept (MA 2005), natural system services might be characterized comprehensively as the resources given to people by specific natural environments. Natural system services should consequently relate to human well-being and social-financial values, a cycle known as Ecosystem Service Economic Valuation (ESEV). The development of ESEV methods has been driven by the growing requirement to control natural system deterioration globally, and valuation perspectives have been pushed to assist dynamic and environmental managers. ESEV gives helpful data about the social-monetary advantages and costs related to elective coastal arrangements, encouraging the evaluation of compromises and collaborations inherent in ecosystem-based management. Significant difficulties that appeared by ESEV in developing nations originate from the lack of information, absence of funding, and absence of institutional responsibility (Torres and Hanley 2017). ESEV can be utilized to recognize who gets the advantages, and who faces the expenses, especially over the social-financial gap. Assessment of nonuse values should be straightforward and performed with coordinated effort among social, characteristic, and political specialists to assemble trust and to lessen incompatible circumstances (Torres and Hanley 2017). The adjacent clients' perplexing view of the scene, their all-encompassing feeling of prosperity, and their setting explicit socio-economical valuation of mangrove ESEV past the money-related worth are essential standards to be joined into protection approaches. A decent comprehension of the overwhelming interrelationships among social and normal frameworks and of the numerous measurements and diverse time sizes of biological system administrations is crucial. Such a methodology is steady with the United Nations Sustainable Development Goals of improving human prosperity and of advancing the protection of marine biological systems (United Nations 2015).

6.2   Inclusion of Human Needs

The United Nations Sustainable Development Goals (UN SDG) recognize the agreeable conjunction of normal environments and people and needed the simultaneous improvement of human well-being and occupations while advancing the preservation of marine biological systems (United Nations 2015). Numerous efforts have been made around the world to achieve this harmonious relationship through ways of improvement in sustainable aquaculture practices in mangrove forests. We

quickly present three contextual investigations in Guangxi of China, in Ca Mau of the Mekong Delta, and in the Volta estuary of Ghana, to show the capability of mangrove protection and reclamation confronting expanding requests on mangrove resources because of population development in the Guangxi province of China – farmers have acquired the aquaculture system, which does not require mangrove deforestation and industrial nutrient input. This agriculture practice has succeeded in achieving the conflict between the economic return of aquaculture and mangrove conservation. This environment-friendly agriculture practice is beneficial in several other ways, i.e., this innovative practice is facilitating ecotourism, increasing the farmer's income and promoting the UN SDG program. Such agriculture practices are low in management cost and are easy to operate while providing high-quality products. Several natural events including increasing sea level, extreme weather, climatic changes, and coastal erosion had impacted mangrove habitats seriously (Sippo et al. 2018). Additionally, land-use changes caused by anthropogenic activities have arisen the extreme level of challenges before policymakers (Díaz et al. 2019). Some improper anthropogenic activities in the mangrove region are induced by population demands. For example, the modification of the mangrove ecosystem into agriculture and aquaculture for food production and industrial growth has grown in recent decades at the cost of the environmental health of mangroves.

7 The Role of Traditional Knowledge and GIS Is of Great Use in the Management of the Mangrove Ecosystem

Mangrove preservation will remain the top priority for the restoration scientist in the coming decade, and its implementation success will depend on the microscale management of the restoration sites (Doody 2008). The intensity of implementation may depend on the total valuation of the mangroves including cost-benefit analysis of restoration practices (Turner et al. 2003). Since mangroves were related to several cultural and ethnic aspects of societies, harvesting the knowledge of natural resources, i.e., specific use of plants, may be a critical challenge (Datta et al. 2012). In several nations, mangrove propagules are consistently bought from neighboring locals and village inhabitants for afforestation and protection purposes (Islam and Wahab 2005). Geographic Information System (GIS)-based complete data set methodology will be significant for fruitful micro size estimations (Shinde et al. 2010). Mangrove environments are consistently situated in a blocked-off zone because of their zone of occurrences. Mangrove natural system is frequently immersed with flowing water. The use of remote sensing will give valuable and viable constant data for identification, portrayal, planning, and observing of mangrove conditions (Moffett et al. 2015). This will give an understanding of information over a distant region. A combination of remote sensing and GIS is discovered to be profoundly advantageous in distinguishing evidence and planning of particular mangrove environments (Kuenzer et al. 2011). For example, small changes in

land use and land cover in an inaccessible district can without much of a stretch be identified by remote sensing methods. A specific redirection of the flow of water because of the development of a dam may accelerate the rate of disintegration in a specific region and the pace of sedimentation in some different territories. These data are extremely critical to plan a micro-level management for mangrove preservation.

8   Conclusion

Mangrove forests have vital importance in a coastal ecosystem. It provides multi-faceted benefits and ecological services to the coastal inhabitants and improves their livelihood. It enters in every respect in millions of people's lives and plays a significant role in protecting from solar UV-B radiation, tsunami, hurricane, cyclone, floods, and coastal erosion, and its product has medicinal use. Instead of their importance, many anthropogenic-induced threats are hovering over its density. Unrestricted growth of population, pollution, encroachment, land-use change, and overexploitation reduce the number of mangrove forests at a fast rate. Land-use changes are profoundly affected by different demographic groups of people in various circumstances. Observations in a disturbed mangrove stressed by human interferences can result in massive sedimentation and coastline receding, which further shown that the pace of flow velocities and sediment deposition rates is accompanied by a fragmented and scattered vegetation pattern. Human intervention causes sediment dryness and coastline shrinking and has evidently diminished the mangrove's resilience. Degradation of mangrove increases the intensity of disasters, creates the non-conducive condition for marine fishes and their existence, promotes coastal erosion, and negatively affects carbon cycling and groundwater purity. Excessive loss of mangroves is non-concomitant of environmental integrity. To reduce the rate of loss, ESEV studies introduce conservation and restoration. Researchers and decision-makers suggest the use of remote sensing and GIS in the management of the mangrove forest cover. This technique represents the exact situation of land-use change. These insights help the government and decision-makers in developing successful schemes and management schemes. Such global activities help to ensure the sustainability of mangrove forests.

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