

## Chapter 2

# Fragile Mangroves and Increasing Susceptibility to Coastal Hazards in Pakistan

Atta-ur Rahman, Samiullah, and Rajib Shaw

**Abstract** This chapter deals with the spatiotemporal distribution and trends of mangroves along the Pakistan coastline, with a special emphasis on the actors and drivers of changes. In the country, mangrove along the coastal belt of Sindh province is comparatively dense and more productive than the Balochistan coastal zone. In Pakistan, the chronological analysis of the extent of mangrove forest reveals the grave scenario. Sparse distribution of mangrove forest cover and gradual diminishing of this natural asset have posed a challenge for Pakistan to prompt respond and devise sustainable strategies for its conservation. It was found that area under mangrove cover decreased from 122,000 ha in 1992 to 73,000 ha in the year 2000, indicating a 50,000 ha decline in mere 8 years. The analysis reveals that mangrove forest cover has been degraded due to rapid human intervention, overexploitation, and lack of attention toward regeneration and expansion. However, with the government and private sector intervention, increase in regeneration and rehabilitation of mangrove cover has been registered. The chapter further identifies several persistent stressors such as rapid human intervention, overexploitation, lack of freshwater flow, and discharge of untreated industrial effluent as key factors endangering mangrove sustainability in the future. In conclusion, the chapter recommends some key strategies for mangrove sustainability, of which, effective implementation of existing environmental legislations and ensuring freshwater supply for the coastal ecosystems remain imperative.

**Keywords** Mangrove • Coastal hazard • Marine environment • Climate change

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## 2.1 Introduction

Mangrove is evergreen forest in the tropical environment (Nguyen et al. 2013). It is largely found between latitude 25°N and 30°S in a relatively narrow fringe of tropical and subtropical coastline (Leopold et al. 2013). These forests are the most common ecosystem in the coastal belt of subtropical regions. Worldwide, more than 60 % of the global population is living in coastal areas where mangrove forest plays a significant role in livelihood and protecting the coastal community from the impacts of tsunamis, tropical cyclone, and storm surges (Nguyen 2014). These forests support densely populated coastal communities. Mangrove forests constitute an important component of marine environment and a major component of salt-tolerant ecosystem (Valiela et al. 2001).

Globally, it is estimated that mangrove forests are degrading gradually (Iftekhara and Islam 2004). The rate of mangrove degradation is rapid in developing countries, and the degradation rate is estimated over 1 % per annum (Alongia et al. 1998). In South Asia, mangrove cover mainly lies in the tidal coastal zones of India, Bangladesh, Pakistan, and Sri Lanka (Fig. 2.1). There are numerous physical and anthropogenic factors determining the degradation of mangroves (Day et al. 2008) including ruthless cutting of mangroves, overgrazing, industrialization, coastal pollution, and urban and agricultural expansion (Hoppe-Speer and Adams 2015).

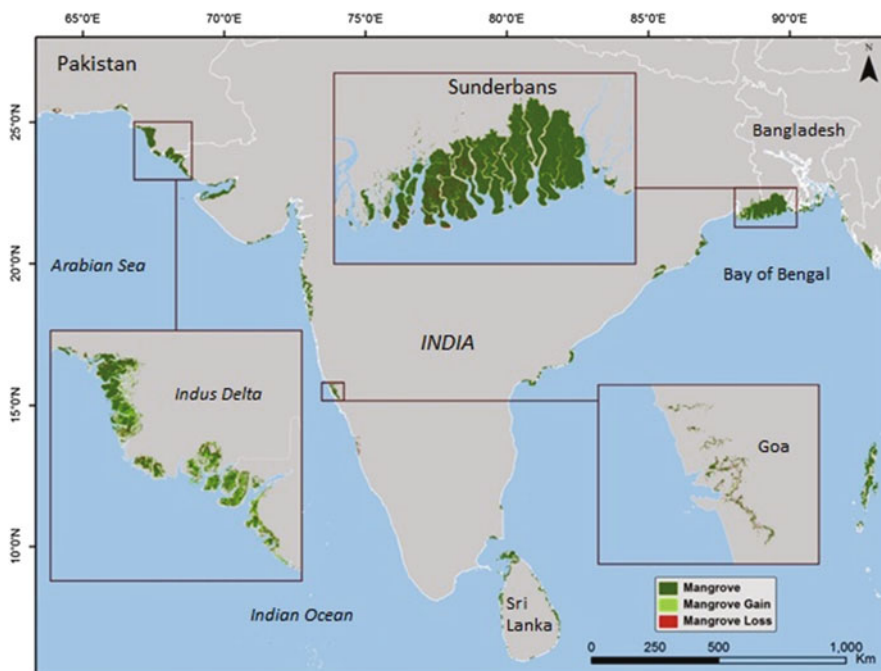


Fig. 2.1 Spatial distribution of mangroves in South Asia (Modified after Giri et al. 2015)

In Asia, the mangrove cover has been decreasing at an annual rate of 1.5 % (Valiela et al. 2001), and Pakistan is no exception to it. Nevertheless, the role of human intervention has played a devastating role in mangrove destruction, where mariculture, urbanization, and agriculture have been blamed for the loss of mangrove cover.

Pakistan has a long coastline of 1046 km in the south along Arabian Sea (Khan 2003). It is spread over two provinces: approximately 250 km is in Sindh province and remaining almost 800 km in Balochistan province (MoCC 2014). In Pakistan, the mangrove forest cover largely falls in the arid climatic region and mostly dependent on freshwater of Indus and Hub rivers (Barkati and Rahman 2005). However, the relative humidity remains high throughout the year; however, summer is more humid than winter. The average annual rainfall is ~221 mm, which is erratic in nature. In the coastal belt of Pakistan, the soil texture is predominantly fine alluvium. Balochistan part of the coastline is poor in mangrove forest cover where most of the mangroves are concentrated along the Hub river delta. Against this, Sindh province has rich and dense mangrove in the Indus deltaic region (Khan 2003).

Pakistan's coastal and marine environment has a great potential for fisheries and other aquaculture. It plays a significant role in national economy through export of various products (Ewel et al. 1998). Nevertheless, in Pakistan the marine and coastal ecosystem is under constant stress due to frequent human intervention in the form of pollution and degradation of ecosystem. The cursory example of resource depletion is the mangrove ecosystem along the deltaic part of Indus River. Seawater intrusion is another example of coastal hazard resulting from excessive withdrawal of Indus River water in the upstream areas.

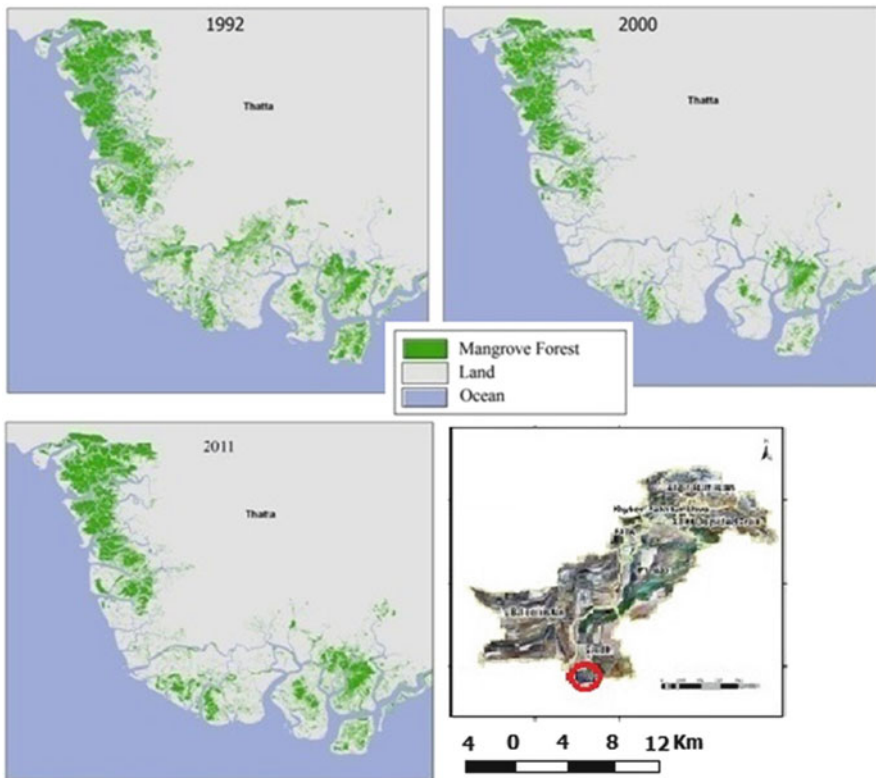
## 2.2 Spatial Distribution of Mangroves in Pakistan

Pakistan's coast extends from the Iranian border (Gawatar Bay) in the west to Indian border (Rann of Kutch) on the east. The exclusive economic zone (EEZ) of Pakistan is about 240,000 km<sup>2</sup> with an additional area of continental shelf of about 50,000 km<sup>2</sup> (SACEP 2007). As such, the total maritime zone of Pakistan is over 30 % of the land area. In Pakistan, initially mangrove forests were neglected section of coastal economy. In the coastal belt of Pakistan, mangroves are found in patches of sparse to dense cover. In Pakistan, out of total mangrove forest cover, 97 % lies in Sindh province, whereas mere 3 % is reported from Baluchistan province. These mangroves are under constant stress of various human factors including shortage of nutrients down the Indus, decrease in annual flow of freshwater, cutting of mangroves for fuel wood, intense browsing by camels, fodder, urban expansion on mangrove land, and coastal water pollution by domestic and industrial establishments (Barkati and Rahman 2005). Due to frequent influence of coastal hazards, depletion of fisheries, and marine ecology, the government of Pakistan has realized

its importance, and due attention was given to rejuvenate the mangrove forest along the coastal belt.

In Pakistan, mangroves are reported from the muddy coast of Arabian Sea in Sindh and Balochistan provinces (Fig. 2.2). This coastal belt is especially important as habitat for fish and other marine lives. The ecosystem of this region has been severely degraded due to consistent intrusion of seawater, pollution, and deforestation. It has been analyzed using 30 m LANDSAT satellite data that in 1992 mangrove forest cover in the Indus deltaic region has shrunk from 122,028 ha to less than 73,000 ha in the year 2000 making a colossal loss of over 50,000 ha in just 8 years (Figs. 2.2, 2.3, and 2.4). However, since then an increasing trend has been observed. For example, from 2000 to 2011, a rapid increase has been noted and the area under mangroves enhanced from 73,000 ha in 2000 to 106,000 ha in 2011 indicating an expansion of 33,000 ha in 8 years (Fig. 2.2). This positive change is attributed to the contribution of the Sindh Forest Department, IUCN, and other international organizations.

In Pakistan, during 2002 a total of about 250,000 ha was under mangrove forest cover, which was ranked as the sixth largest in the world (Saifullah and



**Fig. 2.2** Mangrove forest cover along Indus delta in 1992, 2000, and 2011 (Modified after MoCC 2014)

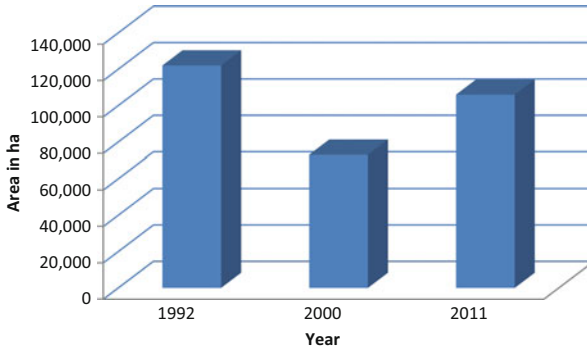


Fig. 2.3 Area under mangrove forest in Indus deltaic region after MoCC (2014)

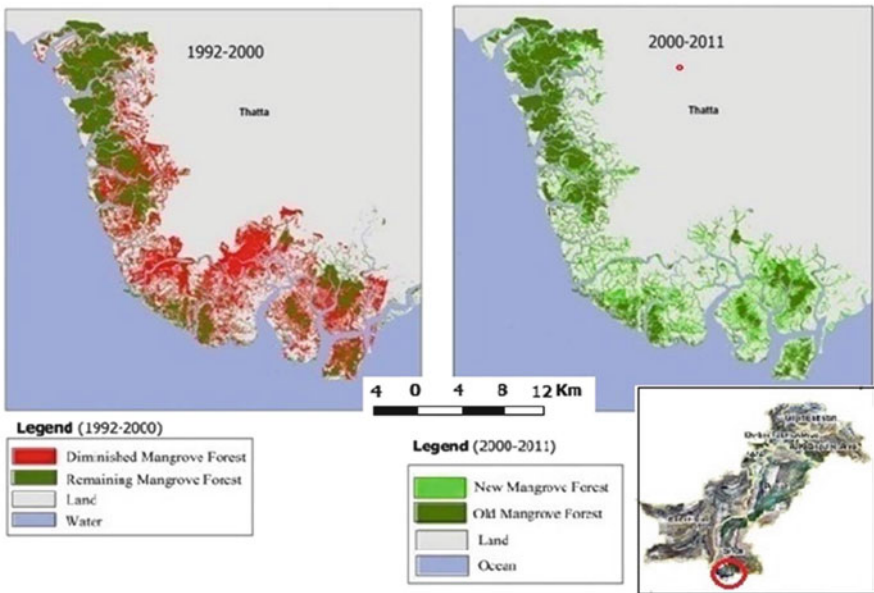


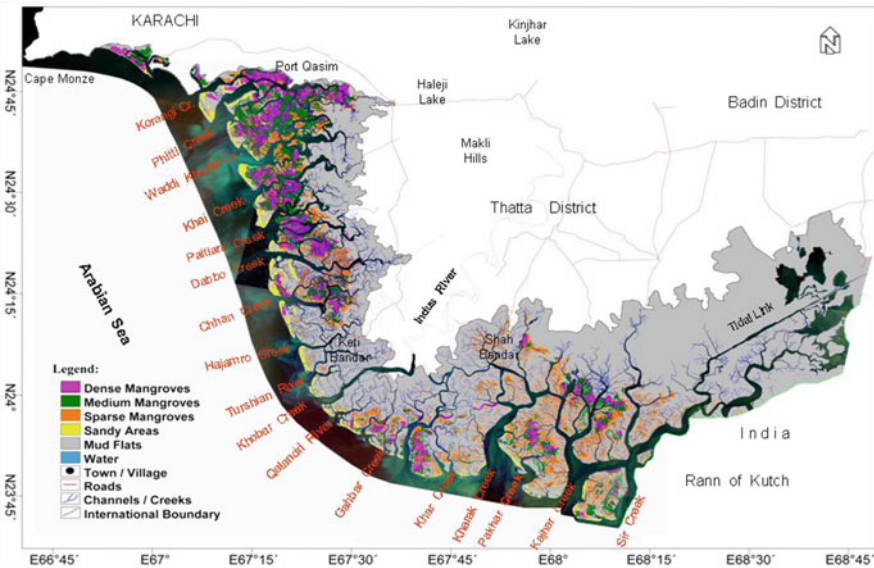
Fig. 2.4 Mangrove forest cover along Indus delta, 1992–2011 (Modified after MoCC 2014)

Rasool 2002). Mangroves are the nurseries for shrimp and fish culture and contribute to the livelihoods of coastal communities. Similarly, the mangrove forest cover minimizes coastal erosion, stabilizes the shorelines, acts as a carbon sinking point, reduces the impacts of coastal floods, and mitigates the cyclone and storm surges. IUCN (2005) estimated that in a year, one hectare mangroves can yield 100 kg fish, 25 kg shrimp, and 15 kg crab. In 1932, area under mangrove forest cover was 604,870 ha, which gradually reduced to 440,000 ha in 1986 (Table 2.1). The area under mangrove was further shrunk to 160,000 ha in 1992 and 86,000 ha in 2005. This gradual decreasing trend is attributed to numerous physical and anthropogenic factors.

**Table 2.1** Pakistan, mangrove distribution

Year	Type of mangrove cover	Area in ha
1932	Dense to sparse mangroves	604,870
1986	Dense to sparse mangroves	440,000
1992	Dense to sparse mangroves	160,000
2005	Dense to sparse mangroves	86,000 (appr.)

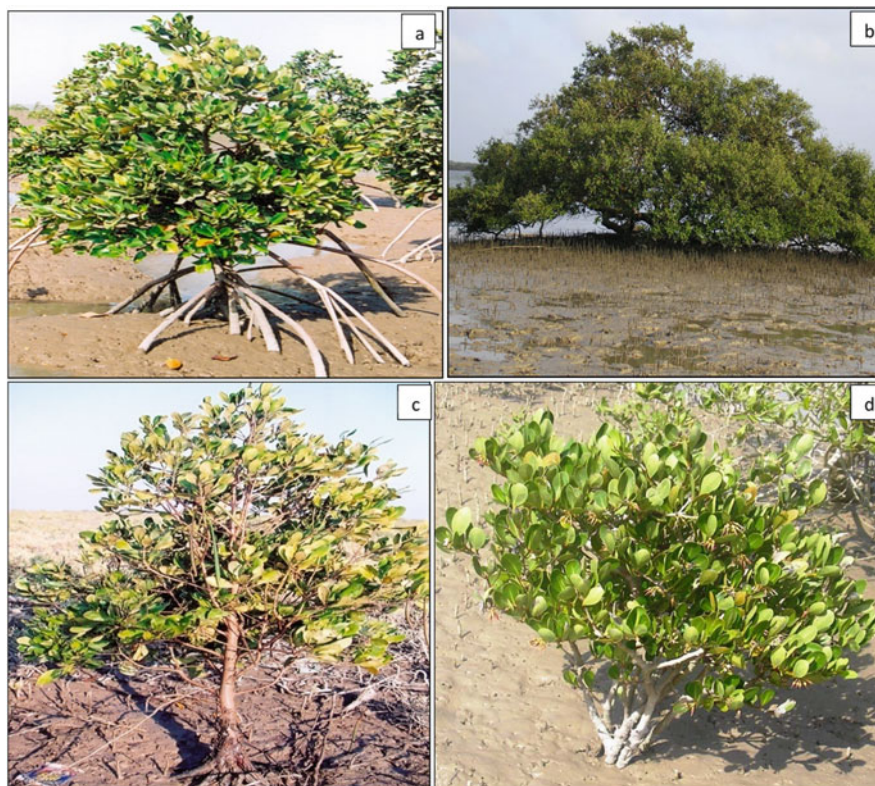
Source: UNESCAP and GOP (1996), IUCN (2005)



**Fig. 2.5** Mangrove forest along the Sindh coast after the Sindh Forest Department and Wagan (2015)

### 2.3 The Indus Delta Mangroves

Coastal region of Sindh province is rich in mangrove forest. In the province, mangroves are mainly concentrated in the Indus deltaic region and spread over districts of Thatta and Karachi. However, in the deltaic area, district Badin is sparsely covered with mangroves, whereas some patches are completely devoid of mangroves (Fig. 2.5). In the coastal belt of Pakistan, the historical records indicate that there were eight species of mangroves particularly in the Indus deltaic part. But currently, only four species are reported, namely, *Avicennia marina*, *Rhizophora mucronata*, *Aegiceras corniculatum*, and *Ceriops tagal* (Fig. 2.6). Similarly, the Indus deltaic networks of creeks (see Fig. 2.3) are a dominant breeding area for coastal fisheries including crabs, shrimps, fish, etc. that are commercially important with average export value of US \$110 million a year (2015).



**Fig. 2.6** (a) *Rhizophora mucronata*, (b) *Avicennia marina*, (c) *Ceriops tagal*, and (d) *Aegiceras corniculatum* (Modified after Wagan 2015)

**Table 2.2** Indus Delta: Ownership status of the mangroves

Organization/department	Area (ha)	Legal status
Sindh Board of Revenue	260,000	Protected forests (Nov. 2010)
Sindh Forest Department	280,470	Protected forests (1958)
Karachi Port Trust	2000	Protected forests (Nov. 2010)
Port Qasim Authority	64,400	Protected forests (1958)
<b>Total</b>	<b>606,870</b>	

Source: Sindh Forest Department modified after Wagan (2015)

The Sindh Forest Department and Wagan (2015) estimated that in the Indus delta 606,870 ha mangrove is managed by different departments/organizations (Table 2.2). Out of total coverage, 280,470 ha is a protected forest and managed by the Sindh Forest Department. Similarly, 260,000 ha is supervised by Sindh Board of Revenue, 64,400 ha is managed by the Port Qasim Authority, and the rest 2000 ha is under the jurisdiction of Karachi Port Trust. In July 2009, the Sindh

Forest Department and IUCN planted 541,176 mangrove plants in 1 month, which is recorded in Guinness World Record (Wagan 2015).

## 2.4 Nexus of Mangroves and Resilience of Coastal Communities

In Pakistan, mangrove is one of the most important resources from the coastal belt. The coastal communities directly and indirectly fulfill most of their daily requirements from mangroves (Khalil 2000). In addition to its economic value, mangroves serve as a disaster mitigation strategy for the coastal communities. It helps in protecting coastal communities from the coastal hazards and minimizing the impacts of tsunami, storm surges, cyclones, etc. It also provides nutrients for plants, fodder for livestock, and food for fisheries. For example, IUCN (2005) estimated over 15,000 camels and 5000 cattle graze over the fragile mangroves, and over 150,000 people depend on mangroves for their daily need of fuel wood. Regardless of such high dependence, mangroves remain much degraded due to variety of anthropogenic factors.

As a cursory example, an increasing population pressure and consistent human interventions in the form of urban expansion over the fragile mangroves, agricultural extension at the cost of degrading mangroves, intensification of aquaculture, industrialization, coastal pollution, disposal of solid waste in coast water, overexploitation of mangroves, the use of mangrove as fodder and fuel by the local community, and poor regeneration are some of the key determining factors in rapidly declining mangrove cover in Pakistan. However, recently, realizing the significance of these coastal forests in socioeconomic well-being and disaster risk reduction of coastal communities, the government of Pakistan in collaboration with IUCN is actively promoting mangrove regeneration (IUCN 2005; Wagan 2015; Giri et al. 2015). Nevertheless, as argued by Amjad and Jusoff (2007), effective community participation and subsequent policy implementation remain fundamental for the success of the rehabilitation efforts.

## 2.5 Mangrove Rehabilitation in Pakistan

Historically, inappropriate management and overexploitation of mangrove forest have put negative implications on ecology and composition of vegetation. As a result, Pakistan not only incurred heavy loss of mangroves, but also some species became extinct from its coast. However, since the late 1980s, IUCN started sporadic mangrove rehabilitation projects across the coastal belt of Pakistan in collaboration with the Balochistan Coastal Development Authority, Sindh and Balochistan Forest Department, Port Qasim Authority, Gwadar Development



**Table 2.3** Rehabilitation initiative by the Sindh Forest Department during the past two decades

Activity	Achievement/plantation (area in ha)
Plantation on high-lying mudflats	4000
Plantation to assist natural regeneration	15,632
Plantation on open mudflats	31,400
<b>Total</b>	<b>50, 032</b>

Source: Sindh Forest Department and after Wagan (2015)

Authority, and local government. As a result, during 1987–2008, almost 30,000 ha mangrove forest has been rehabilitated along the coastal belt of Pakistan. Similarly, the endangered mangrove species were also rehabilitated using natural and artificial regeneration process. In the rehabilitation and regeneration process, the intention was to grow mangrove plantation as protective cover against hazards of tsunami and cyclones, to reduce coastal erosion, to establish new fish and shrimp nurseries, and to minimize impacts of storm surges and saline water intrusion.

As argued by Datta et al. (2012), conservation of fragile mangrove is required to reduce the community susceptibility to various coastal hazards. The related organizations should take concrete measures for raising community awareness and enhancing local capacity for sustainable management of mangroves. The role and importance of mangrove forest need to be shared with the coastal communities, and increase sense of ownerships among the coastal inhabitants remains fundamental to participatory conservation. Especially for the resource-dependent communities, promotion of sustainable utilization of mangrove forests may help in long-term sustainability of the fragile mangrove forests. Considering the above, it is important to build local capacity for sustainable management of mangroves. Hence, the roles and responsibilities of key stakeholders, i.e., the Sindh Forest Department, Balochistan Forest Department, Karachi Port Trust, Port Qasim Authority, and Sindh Board of Revenue, are extremely important in this regard.

During the past two decades, the Sindh Forest Department has taken conservation and regeneration initiatives and plantation has been done on 50,032 ha (Table 2.3). These plantations were undertaken on open mudflats, on high-lying mudflats, and in area with a sparse mangrove cover to assist in regeneration (Wagan 2015). Similarly, the Sindh Forest Department has taken an initiative in protecting the rehabilitated mangrove forest cover through a family unit. Each family unit is responsible to take care of 60 ha mangroves, and such poor coastal communities are paid 6000 rupees (equal to \$59 in 2015) per month. The analysis revealed that this arrangement is very effective in protecting fragile mangroves and offers direct economic benefit to coastal communities (Wagan 2015).

## 2.6 Current Threats to Mangroves

In this section, we discuss the main natural and human drivers that are acting on mangroves in Pakistan and may lead to widespread concern in mangrove sustainability in the near future.

### 2.6.1 *Susceptibility to Seawater Intrusion and Associated Coastal Hazards*

In Indus River system, the government of Pakistan regularly diverts water for irrigation and other uses (Khan 2003). Consequently, reduction in Indus water encourages the seawater to intrude deep interior (MoCC 2014). The frequent intrusion of saline water into the land mass has been identified as serious ecological implications on both human and natural ecosystems in the Indus River Delta. In particular, this may lead to further loss of species diversity in an already threatened mangrove environment.

On a human dimension, consistent reduction in freshwater in Indus deltaic region has led to irrigation and water supply problems. In Sindh province, Thatta is the most seriously affected district due to saline water intrusion and its adverse impact on agricultural land. MoCC (2014) estimated that 30 % productive agricultural land of district Thatta has been severely affected due to seawater intrusion. However, such consequences are now reported from the rest of the coastal districts as well. Importantly, back in 1994, it was estimated through the Indus Water Accord among the provinces that at least 42 km<sup>3</sup> Indus water will be drained to Arabian Sea (MoCC 2014). This quantity of water was even insufficient to sustainably reinstate the degraded coastal ecological system. However, after lapse of 20 years, it has been observed that the amount of available freshwater has been further reduced. Reduction in freshwater availability, deep continental intrusion of saline water, degradation of deltaic ecosystem, and negative implication on regional economy which are some of the key adverse consequences in the Indus coastal belt.

In Pakistan, consistent seawater intrusion has generated several other associated hazards including rise in underground water aquifers and spawned problems of water logging and salinity. Salt water intrusion has also affected the rangeland and reduction in livestock due to shortage of fodder which increased indirect pressure on the mangroves. Many of the communities had no choice but to migrate. Similarly, seawater intrusion has also increased coastal erosion. The problem of saline water intrusion has been further exacerbated due to sea-level rise in the face of climate change. On the contrary, population densities in coastal areas are also increasing which put further pressure on these fragile mangrove cover. Consequently, local population exploits mangroves beyond its carrying capacity, which has led to further degradation of mangrove cover. In addition to this, growing

human settlements also encroach over the mangrove patches leading to further annihilation of these coastal forests (MoCC 2014).

### ***2.6.2 Mangrove Habitat and Increasing Coastal Pollution***

Karachi and the surrounding coastal belt generate huge quantity of waste, and there is an absence of proper collection and disposal system. As a result, waste is regularly disposed-off along the coastal belt, which increases the potentials of water pollution. The same process poses a serious threat to endangered mangrove species and marine and other aquatic ecosystems. According to Karachi Development Authority (2000), every day 104 million gallon municipal waste and 175 million gallon industrial waste are added to the seawater from power plant, harbor, ports, and steel mills. In addition to international convention to sea, in Pakistan there are various regulations, pertaining to prevention of marine pollution such as Pakistan Penal code 1861, Port Act 1905, and Factories Act 1934. Unfortunately, all these regulations are hardly implemented. It is mainly because these regulations are spread over different agencies and there is lack of horizontal coordination and integration in the policies, plan, and programs. The prominent regulatory authorities are Karachi Development Authority, Sindh Environmental Protection Agency (EPA), Balochistan Environmental Protection Agency, Maritime Security Agency (MSA), Fish Harbor Authority, and various port authorities which often lack strong collaboration.

### ***2.6.3 Space for Industrialization***

In the case of Indus delta mangroves, expanding industrial establishments need more space, and in a number of cases, they are growing at the expense of mangrove forests. The release of industrial effluents without treatment at the source also pollutes the coastal water and contributes to the fragility of marine ecosystems, including mangroves. Now-a-days, several ship-breaking industries are located in the close proximity to the mangroves. There is no proper mechanism for collection and subsequent disposal of waste products. In Pakistan, environmental and coastal legislations exist that includes Forest Act 1927 (coastal forests and mangroves), Pakistan environmental protection Act 1997 (marine pollution), and state wildlife protection ordinance 1972 (fauna, flora, wildlife, and corals), whereas climate change division is an important regulatory authority. In addition to this, a landmark decision has been passed as Sindh Coastal Development Authority Act in 1994 and the Balochistan Coastal Development Authority Act in 1998 (SACEP 2007). However, its effective implementation is a need of the hour.

## 2.7 Key Strategies for Mangrove Restoration in Pakistan

Since long, there is gradually decrease in Indus water due to consistent building of huge structures over the Indus River and diverting water for irrigation and other uses, but the situation particularly got worse after the Sukkur Barrage in 1933, Jinnah Barrage in 1955, Kotri Barrage in 1955, Marala headworks in 1956, Taunsa Barrage in 1958, Guddu Barrage in 1962, Warsak Dam in 1965, Mangla Dam in 1967, and Tarbela Dam in 1975 (Khan 2003; IUCN 2005; MoCC 2014; Table 2.4). As a result, the flow of freshwater to coastal ecosystem largely reduced and particularly affected the mangrove forest cover and increased seawater intrusion. It is the responsibility of Indus River System Authority (IRSA), Sindh Irrigation and Drainage Authority, and other stakeholders to ensure sufficient amount of freshwater for sustainable coastal ecosystem (Wagan 2015).

On the other hand, heavy influx of industrial establishments during the past few decades has multiplied the problem of coastal pollution. In this regard, the Sindh Environmental Protection Agency (EPA) and local government should pay due attention to this menace and ensure that each industry has strictly followed the environmental regulations and water treatment plants are functional (Wagan 2015). Parallel to this, at the harbors and sea ports, oil spills and leakage are another challenge for sustainable coastal ecosystem. The Karachi port trust and Sindh EPA need to strictly monitor emergency management strategy while dealing with the oil spills and leakage (IUCN 2005).

Lastly, in order to reduce direct deforestation by the local communities, massive awareness program among the local population must be initiated to make them aware of the positive impacts of mangroves and its contribution in mitigating the

**Table 2.4** Causes of changes in mangrove habitat and scarcity of freshwater, 2005

Period	Annual discharge in Indus (million acre feet)	Percentage reduction	Structure with year	Silt load (million ton)
1940–1954	84.7	10.0	Sukkur Barrage 1933	225
1955–1965	79.9	12.9	Barrages:	220
			Kalabagh (Jinnah) 1955	
			Kotri: 1955	
			Marala: 1956	
			Taunsa: 1958	
			Guddu: 1962	
			Mangla dam: 1967	
1966–1976	46.0	45.7	Warsak Dam: 1965	133
1977–1992	35.2	58.4	Tarbela Dam: 1975	100
1992 onwards	10.0	–		30

Source: Khan (2003) and IUCN (2005)

coastal hazards. Convincing the local community in raising new plantation and provision of alternative sources of wood and energy is one of the effective strategies to minimize future mangrove degradation (Wagan 2015). The role of electronic and print media in mass awareness is required and needs to be streamlined for its effective campaign. The Sindh Forest Department, Balochistan Forest Department, Provincial EPA, NGOs, and other key partners can play their due role in monitoring and implementation of mangrove forest conservation and regeneration. Horizontal collaboration among these departments is also necessary.

## 2.8 Conclusion and Way Forward

In Pakistan, reversing mangrove forest degradation is a challenging task and needs active government interventions for the implementation of existing policies and development of community-led innovative strategies. As discussed, one of the major problems in sustainable regeneration and luxuriant growth of mangroves is consistent decrease in flow of freshwater in river Indus. It has directly affected the growth and development of mangrove forest. Hence, IRSA, the provincial irrigation departments and other key stakeholders need to ensure sufficient water downstream to sustainably regenerate the threatened mangrove. The rapid infrastructural development at the cost of degrading mangrove ecosystem is another challenging issue. Parallel to this, the industrial development along the coastline and proximity to the mangrove cover is an emerging problem. The industrial effluent without treatment at the source is directly discharged into creeks, pollutes seawater, and destroys marine ecosystem and growth of mangrove forest cover. This needs stringent action from both government and industrialist to effectively treat water/effluent before it is drained into the sea.

Presently, along the Indus delta, the livelihood of coastal communities largely depends on mangrove ecosystems. This needs government and relevant stakeholder's attention to reduce the dependency of coastal communities on mangrove and plan for the alternative sources of livelihood earnings. In order to rehabilitate and regenerate the fragile mangroves, the government of Pakistan should take an initiative for long-term sustainable development of this vulnerable ecosystem. While planning for sustainable management of mangroves, capacity building of government key organizations and community needs to be considered as top priority. Likewise, involving coastal communities in coastal resource management would be another effective strategy that may pave way for conservation of fragile mangrove ecosystem and revitalize the services of the mangrove ecosystem services.

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