



# Climate Change Impact on Mangrove Forests in Pakistan

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## Abstract

Mangroves are shrubs and trees mostly found in tropical and sub-tropical regions along the coastlines. Mangroves being halophytes could survive in soil with high salinity and low oxygen. There are significant number of mangroves species and genera usually found in dense and thickets. In Pakistan mangrove forests are in Sindh and Balochistan provinces in coastal areas along Arabian sea. Mangrove ecosystem provides breeding space, habitat and niches to several flora and fauna. This ecosystem makes available number of goods (timber and timber products, food and livelihoods, recreation and sports, employment and business) and services (clean water and healthy environment, prevention of shoreline erosion and protection from storms, carbon sequestration and carbon sinks). Additionally, that very ecosystem does contribute to local and national economy. All this demand sustainability of mangrove ecosystem which has been threatened by anthropogenic activities (cutting of trees, clearing of forest areas for agriculture, housing, urbanization, industrialization) and climate change (global warming, rising sea level, high salinity, storm surges). Things if not controlled timely may cause biodiversity loss, unemployment, unproductive local community exposed to the risk of extreme weather conditions. This situation warrants to adopt holistic but inclusive approach while taking all stakeholders on board and framing

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‘Disaster Risk Reduction Policy’ and undertaking best conservation practices to save mangrove forests of Pakistan.

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**Keywords**

Sustainable ecosystem · Halophytes · Ecotourism · Habitat and niche · Carbon sequestration and carbon sinks · Biodiversity · Food web · Economic gains · Community participation · Holistic approach

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**1 Introduction**

Mangroves are mostly found in tropical and subtropical coastal areas. These are primarily shrubs and trees of varying height depending on climatic conditions, soil type, water salinity, tidal inundation time. Such coastal forests can be found in 118 countries and territories, though nearly 75% of their area occurs in just 15 countries. They are most often found straddling the equator between 25° North and South latitude. About 42% of the world’s mangroves are found in Asia, with 21% in Africa, 15% in North and Central America, 12% in Australia and the islands of Oceania, and 11% in South America (NASA (2022) Earth observatory, ‘Mapping Mangroves by Satellite’).

As mangrove trees are halophytes – salt tolerant trees, therefore they could survive and thrive in soils having characteristics of high salinity and low oxygen- conditions under which it is very difficult for other plants to survive (Fig. 1). Moreover, mangroves grow in dense forests along coast lines or in intertidal zones. The coastal ecology sustainability is mainly indebted to the contributions of mangroves (Baig and Iftikhar 2005). Globally, there are 60 true mangrove species in 27 genera and 20 families (Sengupta 2010).

Socio -economic, ecological and environmental benefits derived from the mangrove forests make them an essential component of shoreline environment. They are the best shield against cyclones, tsunamis and storm surges as they break the energy of devastating waves and provide a buffer zone between coastline dwellers and the storms besides preventing coastal erosion. Present day rapid urbanization, economic growth and concerns about environmental sustainability have compelled everybody including governments, planners, developers, scientists, and coastal dwellers to realize the value of mangroves owing to their remarkably diverse but very important advantages to the sustainable development.

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**2 Salient Services Provided by Mangrove Forests**

Major contributory services of mangroves including economic goods and services are listed below:



**Fig. 1** Pictorial view of Mangrove forests in Pakistan

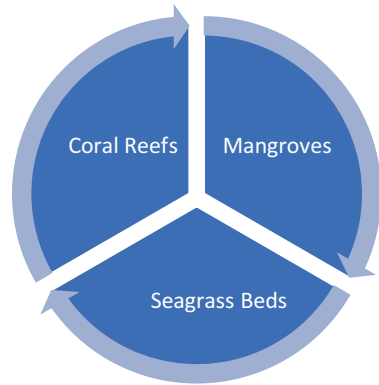
## **2.1 Mangroves Ecosystem's Contributions**

Ecological as well as economic importance of Mangroves Ecosystem cannot be undermined as mangroves help maintaining coastal environment on sustainable basis. Benefits accrued from this special ecosystem are discussed herein:

## **2.2 Mangrove-Seagrass-Coral Reef Continuum**

Mangroves are also known as mainstay of any coastal ecosystem. The classical phenomenal functional correlation between mangroves, seagrass beds, and coral reefs is highly remarkable (Fig. 2). This marvel prodigy poses itself as an essential integrant for the sustainability of that ecosystem. When mangroves stop the eroded soil particles from flowing to sea then Seagrass beds work as filters to contain mud and silt from destroying the coral reefs whereas coral reefs in turn provide shield to the seagrass beds and mangroves from strong waves while diluting waves energy. So, without mangrove forests, this incredibly productive ecosystem might have been unproductive rather would likely collapse.

**Fig. 2** Functional correlation



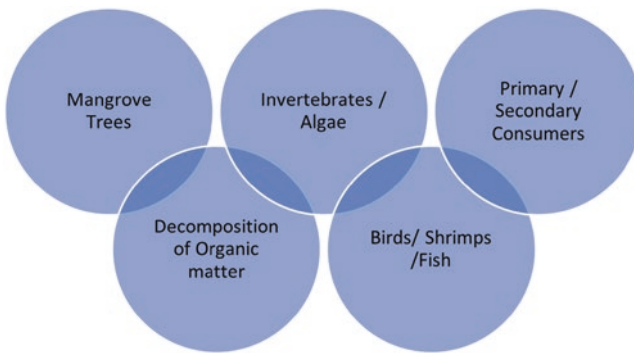
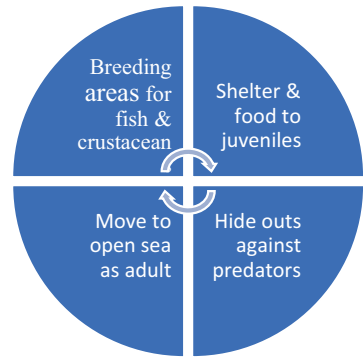
### 2.3 Breeding and Nursery Places

Mangroves swamps do provide a congenial breeding place for a lot many fish and crustaceans etc. Nearly 100 species of fish have so far been recorded from mangroves in Pakistan, of which 46 species were in fingerling or young stages while 52 in sub-adult or adult stages. In fact, more than 75% of commercially caught fish may inhabit mangroves at some point of their life (Dey 2020; Sadilyan et al. 2010; Sahu et al. 2016; World Economic Forum 2019; The Editors of Encyclopaedia Britannica 2018). Because intertidal zones are quite nutrients-rich areas therefore, many fish and crustacean's species select these places as their breeding grounds. Again, marine life such as barracuda, tarpon, and snook also find shelter in the roots of Mangroves forests and spend their juvenile period of their life. This is the area wherein these juveniles can easily find ample food for their growth and development while hiding themselves from predators. In this way mangroves and seagrasses provide foraging opportunities to young ones as well, in addition to food and shelter. Afterwards these juveniles move into open sea as adults after completing their 'nursey and kindergarten' age. This interesting phenomenon can easily be understood in the given illustration (Fig. 3).

### 2.4 Habitat and Niches

Variations in biotic and abiotic characteristics promote various types of niches and habitats for macrofauna within the intertidal zone. Mangrove forests are important habitats that support a unique assemblage of organisms. Mangrove forests not only provide habitat for thousands of species of flora and fauna at all levels but also serve as forest food webs ranging from bacteria to Bengal tigers. On the other hand, mangrove forests do serve as niches- a subset of habitat, for many species with their own exclusive functioning role in the energy chain and remarkable impact on the environment.

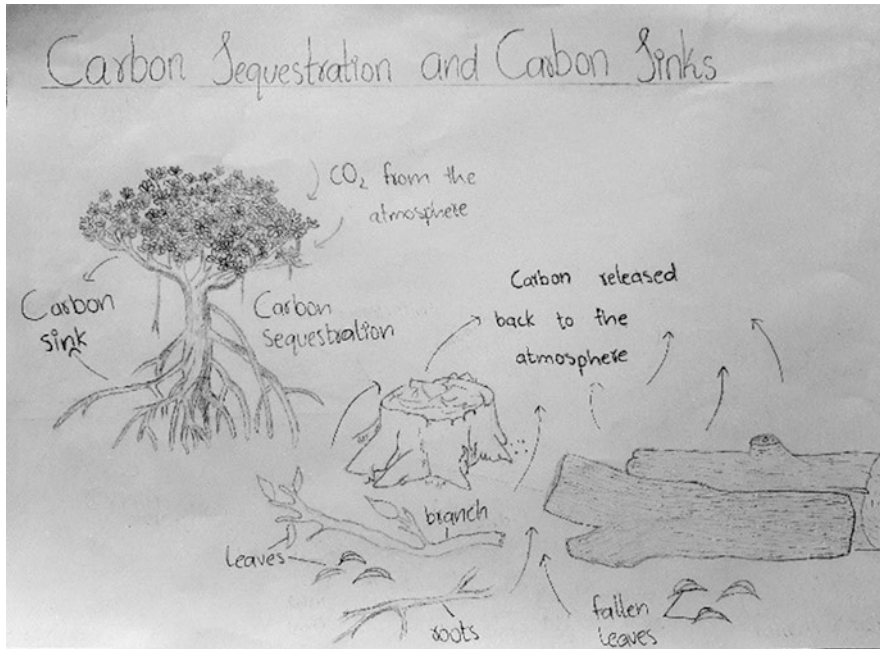
**Fig. 3** Breeding area, nursery and kindergarten



**Fig. 4** Mangroves food web

## 2.5 Mangrove Food Web

Food web in Mangrove ecosystem not only supports the species concerned in their survival but also makes the very system sustainable (Fig. 4). Mangroves, being autotrophs, produce their own food as primary producers through the process of photosynthesis. There are many herbivore species in marine ecosystem which consume mangrove leaves, bark or fruits in the ecosystem. Whereas, on the other hand, fallen leaves of mangrove forest become the very basis for this incredible and productive mangroves food web. Essential nutrients become available on decomposition of these organic materials which are consumed by invertebrates and algae. These in turn feed many organisms like birds, sponges, worms, anemones, jellyfish, shrimp, and young fishes. Water tides also help shifting nutrients to different mudflats, coral reefs and estuaries providing food to oysters etc. These primary consumers then feed secondary and tertiary consumers in turn at multiple levels.



**Fig. 5** Carbon sequestration and carbon sinks. (Source: Illustration by Rahma Rafique Rana)

## 2.6 Carbon Sequestration and Carbon Sinks

Mangrove forests do help fighting against global warming by reducing atmospheric carbon dioxide ( $\text{CO}_2$ ). They consume a lot of atmospheric  $\text{CO}_2$  in photosynthesis and thereby sequestering carbon in the process. Likewise, mangroves store that carbon dioxide in the trees and soil, so they serve as carbon sinks also. However, cutting of forests cause release of carbon but regrowth of forest trees again starts carbon sequestration (Fig. 5). Whereas wood logs and fallen leaves, branches, or dead roots on decomposition release carbon very slowly and may take years. In this way, mangroves provide necessary support to combat climate change impacts while helping in reducing the overall “carbon footprint” prerequisite for environmental and developmental sustainability.

## 3 Status of Mangrove Forests of Pakistan

Mangrove forests constitute a significant part of green cover of Pakistan. They are located/situated in coastal areas of Sindh and Balochistan Provinces along Arabian sea. Mangroves play an important role in marine ecosystem sustainability in Pakistan. They not only provide food, shelter and security to the inhabitants of

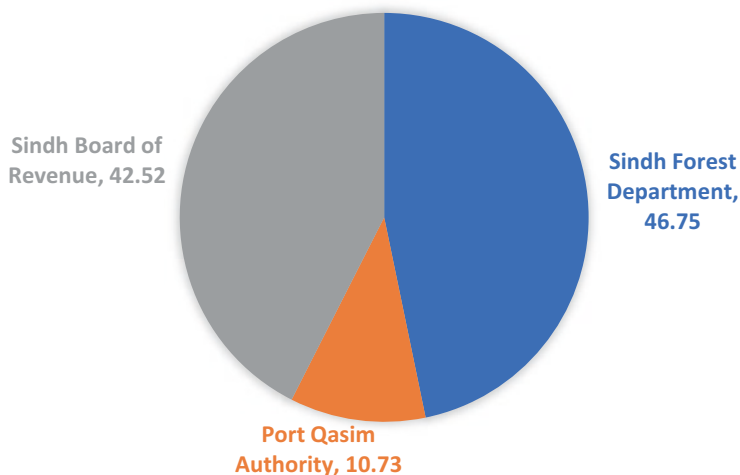
**Table 1** The key features of Mangrove forests

Sr. No.	Category	Description
1.	Sustainable environment	<ul style="list-style-type: none"> <li>• Carbon sink and carbon sequestration</li> <li>• Prevent soil and water pollution</li> </ul>
2.	Habitat and niche	<ul style="list-style-type: none"> <li>• Serve as essential habitat for flora and fauna</li> <li>• Preserve biodiversity and prevent it from extinction</li> </ul>
3.	Coastline defenders	<ul style="list-style-type: none"> <li>• Preventing erosion and stabilizing coast lines</li> <li>• Protecting the local community from storms surges, cyclones, tsunami</li> </ul>
4.	Economic services	<ul style="list-style-type: none"> <li>• Provision of wood and wood products for energy, construction and household use</li> <li>• Commercial fish and other sea food</li> </ul>
5.	Clean water	<ul style="list-style-type: none"> <li>• Improving water quality by filtering pollutants and trapping dirt</li> <li>• Water management</li> </ul>
6.	Breeding zone	<ul style="list-style-type: none"> <li>• Breeding place for fish and crustaceans</li> <li>• Shelter to juvenile marine life</li> </ul>
7.	Ecotourism	<ul style="list-style-type: none"> <li>• Recreation like bird and wildlife watching</li> <li>• Boating, hiking and fishing</li> </ul>

mangrove habitat but also sources of livelihood, employment, economic prosperity, shield against cyclones and storm surges and wellbeing to the coastal dwellers. Mangroves are a rich source of ecotourism and adventure sports. Indus delta mangroves provide habitat to many fish, crustaceans, birds, mammals, reptiles, amphibians, etc. Their role in environmental sustainability cannot be undermined as they contain soil erosion, and water pollution while stopping the sedimentation load being flown over to the sea on one hand and saving agriculture and arable land while stopping the saltwater intrusion on the other hand. Moreover, mangroves provide employment to hundreds of thousands of unemployed residents of local community attached with fisheries profession and are source of billions of rupees export earning much needed foreign exchange besides local consumption leading to contributing the local economy and national growth. The key features of Mangrove forests are presented in Table 1.

## 4 Indus Delta Mangroves

In the Sindh province, mangroves are found in the Indus Delta, Karachi harbor and Sandspit. The Indus Delta extends from Korangi Creek in the west to Sir Creek in the east, whereas Sandspit is a small locality in the west of Karachi city. Indus originated from northern part. Indus delta consists of creeks. Mudflats, sand dunes, estuaries, marshes and bays spread over an area of 600,000 hectares (ha). These mangrove forests are under the management of three different organizations namely Sindh Forest Department (SFD), Port Qasim Authority (PQA) and Sindh Board of Revenue (SBR).



**Fig. 6** Percentage area with different bodies

**Table 2** Indus delta mangroves management

Sr.#	Name of Department	Area (in ha)	% age
1	Sindh Forest Department	2,80,470	46.75
2	Port Qasim Authority	64,400	10.73
3	Sindh Board of Revenue	2,55,130	42.52
Total		600,000	

Source: Forest Department, Government of Sindh

Mangroves under the management of SFD and PQA that constitute 57.48% of total mangroves at Indus deltaic region have been declared by Government of Sindh as “Protected Forests” under Forest Act, 1927 whereby, cutting of trees is prohibited without permission.

This graph demonstrates that major area of mangroves of Indus Delta is under the control and management of SFD followed by SBR and PQA respectively (Fig. 6). These organizations are responsible for conservation as well as afforestation of mangroves falling under their area of responsibility (Table 2).

## 5 Species Diversity

Species diversity of Mangroves of Indus delta along with their presence in percentile can be seen from the table below:

This table depicts that 90% of Indus delta mangrove forests consist of *Avicennia Marina* which is the dominant mangrove species followed by *Rhizophora Mucronata* with 8% population (Table 3).



**Table 3** Mangroves species diversity in Indus delta

Sr.#	Mangrove Species	% age cover
1	Avicennia Marina	90
2	Rhizophora Mucronata	08
3	Aegiceras Corniculatum	1.5
4	Ceriops Tagal	0.5

Source: Forest Department, Government of Sindh

**Table 4** Mangroves forest in Balochistan (hectarage)

Sr.#	Location	Area (in ha)	% age
1	Sonmiani khor	4280.040	75.27
2	Kalimat khor	933.030	16.41
3	Sahidi khor	20.000	0.35
4	Sawar khor	1.600	0.03
5	Shabi & Ankara creeks	228.000	4.01
6	Jiwani	223.290	3.93
Total		5685.960	

Source: Forest Department, Government of Balochistan

## 6 Balochistan Mangroves

Mangrove forests in Balochistan are located along the coastline at scattered locations mainly at Sonmiani Khor, Kalimat Hor, shabi & Ankra Creeks and Jiwani. Mangroves covered area also keeps on changing slightly due to variance in intertidal zones. However, mangrove cover in Balochistan is as under (Table 4):

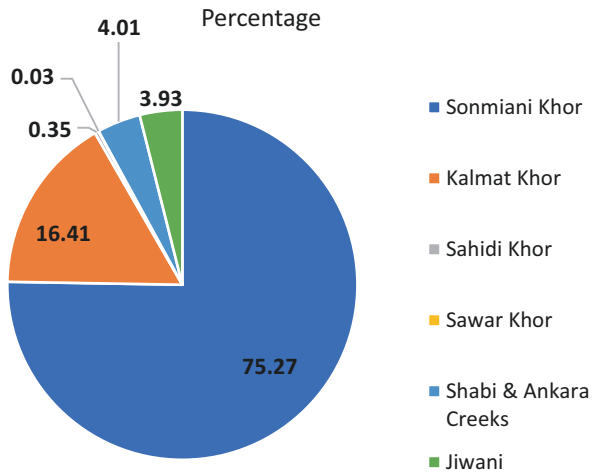
This table shows that out of total mangroves consisting of 5685.960 ha in Balochistan, major part of mangroves exists at Sonmiani Khor with an area of 4280.040 ha followed by Kalimat Khor with an area of 933.030 ha which is a second major establishment of mangroves forest in Balochistan whereas Shabi & Ankara Creeks as well as Jiwani do have significant mangroves spread over 288.000 and 223.290 ha respectively.

This chart illustrates that 75.27% of mangroves forest of Balochistan are located at Sonmiani Khor area followed by 16.41% at Kalimat Khor and 4.01% of forest is available at Shabi & Ankara Creeks (Fig. 7).

## 7 Deteriorating Factors

Forest departments of Sindh and Balochistan with the essential aid of local communities have attempted to conserve the mangroves. Although, forest departments and Pakistan Navy also been increasing the mangrove coverage by planting new saplings through different projects and campaigns yet mangrove forests in Pakistan are quite under stress and prone to deterioration due to anthropogenic activities

**Fig. 7** Mangroves area in percentile



**Fig. 8** Destruction of Mangrove forests in Pakistan

coupled with climate change impacts (Fig. 8). Some of those glaring causes are enumerated below:

- Cutting of forest trees for fuel, wood products, fodder, construction etc.
- Ill planned urbanization and construction thereof.
- Clearing of forest lands for agriculture, housing or other industrial ventures.
- Extreme weather conditions like cyclones, windstorms or storm surges etc.
- Environmental pollution caused by anthropogenic activities.

- Disposal of untreated wastes, effluences into water sources feeding these mangroves on their way to sea.
- Poor implementation of mangrove conservation Policy and Practices.
- Inefficiency and lack of capacity and resources at the part/disposal of those responsible for management of mangroves.
- Absence of political will and non-participation of civil society, community organizations and citizens in mangroves conservation.
- Lack of awareness on the part of those whom mangroves serve the most.

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## 8 Manifestations of Climate Change

In the past 20 years, the world has lost almost 50 per cent of its mangrove forests, making them one of the most endangered landscapes. It is essential to recover them and to use them as a shield against a tsunami and as a resource to secure optimal socio-economic, ecological and environmental benefits (Osti et al. 2009). Occupying a harsh margin between land and sea, most mangrove plants and associated organisms are predisposed to be either resilient or resistant to most environmental change (Alongi 2015). Like all other fields of life, climate change is also severely affecting mangrove ecosystem and things related to that marine ecological stratum. This impact can very easily be visualized in the following areas:

### 8.1 Biodiversity Loss

Change of environment caused by the destruction or change of any component of mangrove ecosystem pose a challenge to the survival of its inhabitants thereof. Therefore, foremost impact of climate change becomes visible in the form of biodiversity loss. Some of the species, owing to their inability to cope with the new environment, become endangered whereas if the situation prolongs enough some species might get extinct. Several species are listed as **vulnerable** or endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Rodrigues et al. 2006).

Destruction of mangrove forests has caused the loss of habitat for several fish, crustacean and wildlife species that live and breed in mangroves.

### 8.2 Decline in Area

The rising level of carbon dioxide and other industrial gases in the atmosphere may lead to global warming with an accompanying rise in sea-level (Field 1995). Sea-level rise, first, affects the habitat and niches provided by the mangroves. Secondly rise in sea level also influences the growth of mangroves whereas rise in temperature

is again crucial for density of the thickets. All these factors would lead to decline in mangroves area resulting into non availability of mangrove ecosystem products and services consequently.

### **8.3 Mangrove Swamp Destruction**

Climate change has reportedly various multidimensional components of varied nature and scale with different level effects on the ecosystems (Mitra 2013). Extreme weather conditions like windstorms, cyclones, tsunami and storm surges destroy mangrove swamps. Many mangrove saplings and trees got damaged or uprooted under these conditions.

### **8.4 High Salinity Impact**

Although, mangroves have the ability to survive in high saline conditions and low oxygen levels yet up to a certain threshold. A notable decrease of gastropods (snails, slugs, etc.) was reported and, similarly, migratory water birds' populations were also shown to decline, due to increases in salinity. As the change in climatic conditions affect salinity in water and soils which in turn impact the diversity of mangroves. High saline conditions also affect the marine life as well.

### **8.5 Reduction in Fresh Water Flow**

As the climate change affects the weather patterns and in case of drought water is hardly available. Again, climate change phenomenon coupled with extreme saline conditions have also led to a 90 per cent reduction in freshwater flow (Dasgupta and Shaw 2013). Therefore, with the decrease in freshwater availability afforestation of mangrove forest in wetlands with high salinity and low oxygen is quite challenging.

### **8.6 Environmental Pollution**

Polluted environment including water and air pollution has become a big challenge especially for the megacities. Improper and untreated disposal of wastes and effluents of all kinds into water sources discharging into sea as well as solid wastes dumped into mangroves severely affects the mangroves growth and functionality of mangrove ecosystem. Besides this, oil spills in coastal waters again badly impact

the mangrove ecosystem thereby affecting the goods and services accrued from that ecosystem.

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## 9 Implications of Loss of Mangroves

Climate change coupled with environmentally non-friendly and unsustainable human activities not only becoming challenge for afforestation of mangrove forests but severely threatening the survival of mangrove ecosystem. Loss of mangroves would expose the coastal dwellers to extreme weather events which are occurring more frequently and with more intensity. Secondly, mangrove ecosystem goods - timber and timber products, livelihoods, ecotourism, foods, fisheries, etc. as well as ecosystem services - healthy environment, coastline protection, shield against storms, clean water, etc. would either be non-available, or their quality would get compromised. Thirdly, economic gains including contributions in local and national economy whether through consumption or exports would be squeezed. Fourthly, it would cause unemployment of hundreds of thousands of people connected with fisheries and other professions relating to goods and services provided by mangrove ecosystem. Fifthly, mangrove loss may impact the economic productivity of coastal community and may lead to their food security situation. Lastly, services rendered by mangroves in carbon sequestration and carbon sinks much required for climate change mitigation would be non-available in case of no mangroves.

All situations, thus warrants the conservation of mangroves forests on sustainable basis in addition to afforestation of mangroves wherever wetlands are available to get the benefits attached with the mangrove ecosystem.

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## 10 Conservation and Restoration of Mangroves Not an Option but a Way Forward

There is dire need for preservation and restoration of mangrove forests given their role as a specialized marine ecosystem. As the optimal productivity of mangrove forests and ecosystem gets affected by a large range of anthropogenic and climate change factors therefore, an inclusive framework for understanding complexity of interactions and their management thereof needs to be evolved. With this end in view following suggestions are vital to face the challenges posed by the climate change vis-à-vis mangroves conservation:

1. First and foremost, there is need to devise a proper *Disaster Risk Reduction Policy* by the government while involving all stakeholders including local community, NGOs, leaders of civil society, scientists/environmentalists/experts on the subject and all relevant departments/organizations and agencies responsible for implementation.
2. Create awareness among the people in general and local dwellers about the pivotal role of mangroves and mangrove ecosystem.

3. Local community needs to be educated and trained as well by imparting necessary skills and knowledge to conserve and restore mangrove forests leading to mangrove ecosystems' conservation.
4. Well planned and suitable land-use plans and best farming practices for the coastal areas which complement conservation of mangroves may be developed.
5. Local community participation in the conservation of mangroves and to stop illegal cutting and encroachment on mangrove areas is critical for the success. Therefore, a robust community participatory mechanism may be devised.
6. Development policies and plans for coastal areas/cities urbanization should address the issues of coastal communities and should include the component of mangrove preservation.
7. As the survival and growth of mangrove forests are affected by salinity level therefore, factors responsible for salinity rise required to be studied and appropriate measures may be taken to cap the salinity in a range suitable for mangroves thrive.

As flourishing of mangrove forests is directly linked with sustainability of mangrove ecosystem hence, their survival and conservation are the linchpin for getting mangrove ecosystem products and services on sustainable basis. It is imperative to all stakeholders including public authorities, leaders of civil society, community organizations, citizens and coastal dwellers to play their part to achieve the objective of mangrove conservation and to relieve the mangroves from the stress being posed to them by human activities and climate change.

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