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# MANGROVE ECOSYSTEM WITH CHANGING CLIMATE: A REVIEW

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## ABSTRACT

This review highlights the distribution, characteristics, importance, habitat of mangrove ecosystem, possible impacts of climate change and action plan to protect this ecosystem. It is shown that global warming would increase the level of $CO_2$, temperature, salinity, sea level and storm frequency which may not only alter the mangrove habitat but would also impact on human population and environmental resources. Climate change may influence on species diversity, positively or negatively. It is mentioned that unsustainable use of marine resources and anthropogenic disturbances may enhance the impact of climate change.
Recent experiments have shown that *Avicennia marina* is highly adaptable species and if planted on ground does not produce pneumatophore, nor shows vivipary but show stilt or prop roots. In addition up to certain limits it is resistant to drought and light fire. Therefore, it may be anticipated that at least this species would cope with the increasing temperature, due to its rapid adaptability to anthropogenic disturbances. However more detailed studies are required to explore its potential.

**Key words:** Climate Change, Global warming, Mangrove ecosystem, *Avicennia marina*.

## INTRODUCTION

Mangrove is a group of large number of halophytic plants, naturally distributed in coastal intertidal zones of subtropical and tropical areas of 123 different countries of the world. Indonesia, Sri Lanka, Myanmar, India, Bangladesh, Pakistan, Saudi Arabia, Philippines, Thailand, Iran, Brazil, Papua New Guinea, Mexico, Nigeria, Columbia, Cuba, Panama, Mozambique, Cameron, Gabon, Ecuador, Tanzania, Madagascar, Belize, Australia, New Zealand, United States of America are some of them.

According to Kaimun and Mami (2013) mangrove ecosystem is a rare yet highly threatened ecological unit among the coastal environment covering with approximately 137,760 $km^2$ – 152,360 $km^2$ of the world's surface (Wilson, 2017). A total of 73 mangrove species (true and hybrids) are distributed around the globe (Spalding *et al.*, 2010). Aaron *et al.*, (1999) described that mangrove ecosystem around the Tethys Sea and modern distribution is due to vicariance events. Luther and Greenberg (2009) stated that during the Pleistocene period when dry environment spread in many areas some plants adapted a steep environmental gradient between terrestrial and marine ecosystem and provide unique environment which help local morphological, physiological and behavioral adaptations. Ramdari *et al.* (2015), concluded that mangrove appeared in upper cretaceous period and lower Miocene epoch (66 and 22 million years ago) from Indo-Malaya region, by ocean current. Same way it spread in other areas of globe up to Caribbean and New Zealand. Its complex ecosystem is spread between latitude $32^0$N and $38^0$S along the coast.

Mangrove also moved away from the equator towards temperate wetlands (salt marshes) and tropical islands of Tahiti and Hawaii as invasive species. World largest (14,000 sq. mile) mangroves population (with 23%) is reported from Indonesia (Giri *et al*, 2011) while the world largest (4,000 sq. mile) continuous forest of mangroves is distributed in Sunder bans (Rehman and Asaduzzaman, 2013). Global mangrove area by region is shown in Table 1with modification of Spalding *et al.* (2010). Saifullah, (1982) reported mangrove on 800,000 acres in which 40% covered by thick mangrove. Qureshi (2005) estimation was 86,727 ha in which 94% belong to Indus Delta. According to Sindh forest Department, Indus Delta mangrove spread in 600,000 ha areas while other report is 129,000 ha. Abbas *et al.*, (2011) reported 98,128 ha. However, Global and regional estimates of mangroves are greatly varying (Table.1).

Mangrove habitat covering 13700 sq. km miles area in the world and 42% of its area is located in Asia (Giri *et al.*, 2011) while, Spalding *et al*., (2010) estimated 150000 sq. km and account for 80% of the total global mangrove area (Table 2). According to some experts among 110 different types of mangroves plants, 20 genera, 16 families and 54 species are considered true mangroves. Large number of species (60) found in Indo-Pacific area, only 8 in western hemisphere, while beside *Avicennia* a small bush of mangrove grows in Australian Arid Desert. Due to anthropogenic activities such as urbanization, developmental projects, cutting, camel browsing, pollution, industrialization, shrimp farming, aquaculture and climate change, these forests are in threats. FAO (2007) reported that from 1980 approximately 35600 sq.km mangrove population has been lost on global basis, in Pakistan the destruction rate is 60%, in China 70% while in Indonesia the rate of destruction is 40% in last 3 decades (FAO, 2007). However, according to Gilani *et al*. (2020) Pakistan is the only country with increasing mangrove cover.

Table 1. Global Mangrove area by regions.

| Regions | Sq. Km | Global % |
|---|---|---|
| South East Asia | 51049 | 33.5 |
| South America | 23882 | 15.7 |
| North and Central America | 22402 | 14.7 |
| Central and West Africa | 20040 | 13.2 |
| South Asia | 10344 | 6.8 |
| Australia | 10171 | 6.71 |
| East and South Africa | 7917 | 5.2 |
| Pacific Ocean | 5717 | 3.7 |
| Middle East | 624 | 0.4 |
| East Asia | 215 | 0.1 |

(Modified from Spalding *et al*, 2010)

Table 2. Global Mangrove cover, biomass and area ($km^2$) in different countries.

| Nos. | Countries | World Bank, 7596, (2016) | Mangrove Cover | Mangrove Biomass | Giri *et al* (2011) | Spalding *et al* (2010) |
|---|---|---|---|---|---|---|
| 1 | Indonesia | (27865) | 23143 | 42478 | 31139 | 31894 |
| 2 | Brazil | - | 7663 | 17287 | 9627 | 13000 |
| 3 | Malaysia | - | 4691 | 7616 | 5054 | 7097 |
| 4 | Papa New Guinea | (4763) | 4169 | 6236 | 4801 | 4265 |
| 5 | Australia | - | 3315 | 3314 | 9780 | 9910 |
| 6 | Mexico | (6478) | 2985 | 6036 | 7419 | 7701 |
| 7 | Nigeria | - | 2653 | 6908 | 6537 | 7356 |
| 8 | Myanmar | (5612) | 2508 | 3783 | 4946 | 5029 |
| 9 | Venezuela | (3398) | 2401 | 7516 | - | - |
| 10 | Philippine | (2849) | 2060 | 2084 | 2631 | - |
| 11 | Thailand | - | 1876 | 3936 | - | - |
| 12 | Bangladesh | (4365) | 1773 | 2314 | 4366 | 4951 |
| 13 | Columbia | - | 1672 | 6236 | - | 4079 |
| 14 | Cuba | (4463) | 1624 | 2407 | 4215 | 4944 |
| 15 | United State | - | 1553 | 1554 | - | - |
| 16 | Panama | - | 1323 | 2673 | - | - |
| 17 | Mozambique | (3071) | 1223 | 2658 | 3189 | - |
| 18 | Cameroon | - | 1113 | 1323 | - | - |
| 19 | Gabon | - | 1081 | 3864 | - | - |
| 20 | Ecuador | - | 935 | 1906 | - | - |

Note: Pakistan, Madagascar and India are missing in these studies.

Mangroves form most productive, biologically diverse, unique and complex ecosystems and playing vital roles between aquatic and terrestrial ecosystems. They receive resources from land and transfer to marine ecosystem, and reduced vulnerability and risk from waves and storm surge, providing natural protection (Saifullah *et al.*, 1994). It is stated that, Florida mangrove forest prevented 1.5 billion damage and half million people from 2017 Hurricane Lama.

According to a report of FAO (2005) mangroves are distributed in small pockets in many bays and inlets of tidal areas of Red Sea and Persian Gulf, covering an area of about 2000 ha. One of the best mangrove forests, after

North America forests, are also spread in coastal areas of Pakistan (Nazim, 2011) covering 250,000 ha area (Mirza *et al*., 1983). However recent Satellite images show 160,000 sq. ha area (Ahmed and Shaukat, 2015).

The coastline of Pakistan is extending 1,050 km along the Arabian Sea, the mangroves exist only at five locations: Indus Delta and Sand spit in Sindh province while Sonmiani Khor (Miani Hor), Kalmat Khor (Kalmat Hor), and Jiwani (Gwadar Bay) in Baluchistan province (Fig. 1) covering total area 9,538 $km^2$ (Gillani *et al*., 2020). Three out of five sites i.e. Indus Delta, Sonmiani Khor, and Jiwani are Ramsar sites. The human population in and around mangroves forests of Pakistan is approximately 1.2 million, and almost 90% of the population derive their primary income from fishing and its associated activities. During winter abundance migratory water birds including pelicans, flamingoes waders, gulls and terns make Pakistan's mangroves their temporary home.

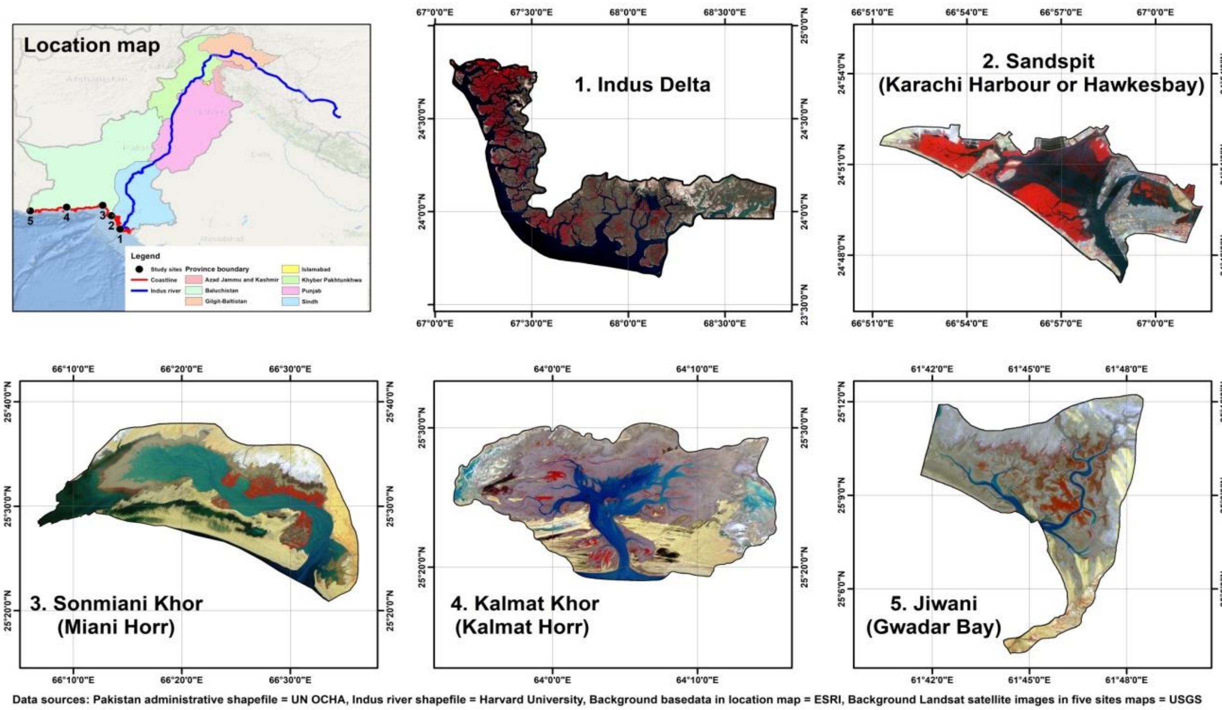


Fig. 1. Five mangroves study sites of Pakistan: 1. Indus Delta, 2. Sand spit 3. Sonmiani Khor (Miani Hor), 4, Kalmat Khor (Kalmat Hor) and 5. Jiwani (Gwadar Bay) (Gillani *et al*., 2020).

In Saudi Arabia, *Avicennia marina* is a widely distributed species, while *Rhizophora* sp. is located only at one site (Saifullah, 1994). The Saudi Kingdom protecting mangroves since 1970 and pledged to plant over one million plants. In Pakistan coastal area 98% are either gray or black mangrove. The experimental plantation of mangroves was initiated as early as 1986 by Sindh Forest Dept. in Indus delta (Qureshi and Khan, 1988). *R. mucronata* was highly successful species as compared to *A. marina*, the abundant species of the delta. Therefore. Massive plantation of *R. mucronata* was undertaken by planting 847.275 saplings in Kharro Chan, Thatta (The Express Tribune, 2013).The community-participation endeavour broke the earlier Guinness Book of World Record by planting 1,129,294 mangrove saplings on an island near Keti Bunder in Thatta district of Sindh on April 19, 2018 (The Express Tribune, April 19, 2018). The results of early plantation in Indus delta were presented by Qureshi and Khan (1988) and later discussed by Qureshi (2012). The sapling growth of *R. mucronata* has been evaluated by Khan *et al*. (2021) for Gwadar and Indus delta nurseries.

**Definitions of mangroves**

Mangroves are defined in various following ways.

- Mangroves are a group of halophytic shrubs and trees which grow both in salt and fresh water regimes, unlike other plants. They are known to be well-adapted in the highly saline, coastal, intertidal, estuaries, salt marshes environment with hypoxic fine muddy sentiments. They belong to different families, size and shapes.

- Plants grow in swamp, producing tangled roots above the ground surface is also known as mangroves.
- According to the Hege Dictionary (2010), trees with roots, which are above the ground, growing along the coast or on banks of large rivers in hot areas are called mangroves.
- American described, any coastal tropical tree or shrub as mangrove, that form large colonies is swamps or shallow water, providing habitat for young fish and shrimp.
- Designating a family (order Rhizophoraceae) of dicotyledonous tree and shrub that inhabit tidal marshes and river mouths in the tropics.

**Habitats of Mangroves**

Mangroves are distributed in different zones adapting particular niche *i.e.* close to shore, fringes sheltered bays, estuaries and transitional zones in tidal areas. Lugo and Snedaker, (1974) reported following five types of mangroves on the basis of habitat.

- Fringes Mangroves: Which grow in open bays and lagoons.
- Over washed Mangroves: similar to fringe species, isolated from land, becomes flooded during high tide.
- Riverine Mangroves: River delta, during summer faced drought, high salinity, inundated with fresh water.
- Basin Mangroves: Grow in deep bays, cover, extended for inland.
- Dwarf Mangroves: Bush type, lack of nutrients, high salinity, and rocky soils.

**Types of Mangroves:**

Following species are famous with their non-scientific names (Lugo and Snedaker, 1974).

1. Red mangroves (*Rhizophora, Ceriops, Kandelia, Bruguiera).*
2. Gray mangroves (*Avicennia marina*)
3. Black mangrove (*Avicennia germinans*)
4. White mangrove (*Laguncularia recemosa*)
5. Buttonwoods, White Mangroves (*Conocarpus erectus*)
6. Mangrove apple (*Sonneratia* sp.)
7. Mangrove Palm (*Nypa fruticans)*

**Unique abilities of mangrove plants**

Plants have unique following adaptive abilities to survive in harsh environment.

- Plants have filtration system to remove large amounts of salts from the absorbed water (salt hair and salt glands) by osmotic adjustment.
- Leaves are coated with wax to minimize transpiration like desert plants.
- In addition to the main root system, cable roots protrude Pneumatophores (above ground porous roots) for salt exclusion (Sobrado, 2005); Munns and Tester (2008) gas exchange due to hypoxic or anoxic environments in muddy soil, such as in *Avicennia marina* and *Sonneratia alba*.
- Some species possess extensive root system for support in muddy soil (up to 50 m away from main trunk (Nazim, 2011).
- Some species have prop roots (*Rhizophora*) to support and exchange gases)
- Seeds are buoyant hence suitable for water dispersal.
- In some species seeds start to grow in seeding (propagates or propagules) while attached to the plant (vivipary). After discharge these propagules are able to grow in one year time and able to float up to one month to find suitable place to grow. However different species adopted different strategies to handle harsh conditions.
- Able to re-sprout from epicormic shoots (Alongi, 2008).
- Mangroves are highly potential to adapt sea level rise, however it depends on availability of suitable land or expansion with fresh water supply, sediments and nutrients (Lange *et al*., 2010); Ward *et al*. (2016) also stated that mangrove can migrate to higher level due to sea rise if topographic barrier does not exist.

**Characteristics of a typical mangrove species**

- Inflorescence an axillary or terminal head like cyme. Bisexual, white to golden yellow, tiny, sessile, regular, 0.5cm wide in a group of 3-5 flowers, 3 bracts up to 4mm long at base, 5 sepals (3.5-4mm long), 4 yellow green petals (4.5-7.0mm long). Pollination by bees and small insects, Cross and self-pollination. Fruit takes 2-3 or up to 5 months to mature after pollination.
- Fruit oval shaped, capsule, leathery, scaly hairs, 1-3 cm long and light yellow in color. It contains large cotyledon and produces one fleshy seed, which normally grow while attached to mother plant (viviparous). Dispersed by water during high tides.
- Plant produces a thick network of underground shallow root system, spreading up to 50 m around a single tree with hundreds of aerial roots above ground (pneumatophores) normally up to 40 cm tall in Pakistan, which go up to one meter high elsewhere. These roots not only support during high tide but help to respire directly from the air through small pores on it.

**An example of a typical mangrove species is presented here:**
***Avicennia marina* (Forssk.) Vierh:**

*Avicennia marina* is a widely distributed plant in Pakistan, Saudi Arabia, UAE, Oman, Qatar, Iran, Egypt, Eritrea, Somalia, South Africa, Australia, and New Zealand. This species belongs to flowering plants (angiosperm) family Acanthaceae Grows in the intertidal zone of estuarine, swamp along the coastal belt. In Pakistan, once they were widely distributed along the banks of River Indus, now more than 70% have vanished. Regional phinological differences may exist, however for description, Flora of Pakistan and Ahmed *et al*. (2021) may be followed.

This species is also dominated in Arabian Gulf providing shelter for marine life and birds. Every year these forests provide breeding ground to different types of migratory birds (over 500 species) and protect sea coast/harbors from erosion, floods, hurricane, cyclone and pollution. These plants also improve and protect our marine resources on which millions of people depend for living. In Pakistan, these forests are threatened due to loss of habitat, overgrazing by camels, crab collectors, cutting, pollution and coastal development.

Under mangrove, soil, anaerobic bacteria, produce nitrogen gas and soluble iron, inorganic methane, sulfides and phosphate, and make soil less fertile besides shortage of light. This may be the reason mangrove seedling never grow under their own mother plants, however a recent study (Nazim *et al*., 2014), shows that beside shade it is due to the allelopathic property of decaying leaves and branches of mangrove.

Shrubs or trees, 8-10 m (Pakistan) may up to 15 m with 20-40 cm Dbh while in Australia up to 25 m tall. Mangrove in Indonesia can grow up to 50m tall with densely packed branches and intertwined roots system (FAO, 2007). Crown dense and rounded, twigs fine hairy, bark greyish brown, smooth, thin, stiff brittle flaken, inner dark green. Main trunk produces many branches just above the water surface during the high tide.

Leaves on small twig, thick, fine hairy, angular, leathery, opposite, simple entire, 5-8 cm long, acute apex, without stipule, petiole 1.5 cm long, blade elliptical to ovate or lanceolate, 3-13 cm long, 1.5-5cm wide with salt pores.

**Economic Importance**

Mangrove ecosystem may be divided in to three economic groups.

1) Plant group with direct use obtain cash, benefits from marine resources.
2) Plants with Indirect use: Ecological, biodiversity, flood control, erosion control, storm protection, nutrients retention, pollution sink and climate change values.
3) Non-used ground Existence and bequest value of mangrove.

Grayish yellow wood is durable, heavy and fine textured, used in house, boats, furniture, beehives, while branches are used in fences. Used to make charcoal and as firewood.

Tannins is used for dying, leather productions and repellent for mosquitos. Mangrove provide food and different type of traditional products and artifacts. It extracts are used by local people (as folklore medicines). Plants are rich source of steroids, saponins, alkaloids and triterpenes.

Resin from bark is used to treat snake bites. Leaves and bark used to anodyne. Ash of wood is used to cure skin problems. In Madagascar, fish poisoning is treated by leaves extracts. Chemical obtained from the plant are used as antioxidant, antifungal, antibacterial, insecticides, and pesticides by bush people.

Mangrove leaves contain several trace elements which are essential for human health.

Different species have different medicinal importance. Vinoth *et al*., (2019) reported following use of 5 mangrove species.

- *Rhizophora mangle* reported to cure malaria, fever, tuberculosis, leprosy, plaster for fractured bone, antiseptic, fungal infection, angina, dysentery, diarrhoea, elephantiasis.
- *R. mucronata* is used to cure ulcer, hepatitis and elephantiasis. It is febrifuge.
- *Ceriops decandra* used in cure of ulcer and hepatitis.
- *Avicennia marina* - cure for skin disease
- *Aegiceras corniculatum* used for diabetes, fish poison, asthma and rheumatism (Vinoth *et al.*, 2019)

**Socio-economic Importance**

World Resource Institute (WRI) reported that mangrove ecosystem contributes US$ 174-249 million/year to Brazil's national economy (Copper *et al*., 2009). Mangroves are associated with 3.5 million human populations, about 400 million dollars domestic products, infrastructure and storm surge areas especially in Myanmar, Philippines and Indonesia (Blankespoor *et al*. 2016).

- A large number (more than 100 million within 10 km of Mangrove forest) of world population live closed to coastal areas and these forests provide shelter, marine, resources, food, jobs and playing an important role in their daily life (Nanjo, 2020). Nanjo *et al*., (2014) reported that, abundance and richness of many fishes (including offshore fishes and coral fishes) are significantly related to mangrove density. In addition, mangrove resident fish show different genetic structure than other fishes. Therefore, for the survival of their population mangrove density is important.
- There extensive root system and dense plants allow to the withstand high tides, waves, tsunamis, hurricanes, storm surges, and soil erosion. In result, coastal areas, vegetation, wildlife, harbors, coastal infrastructure and coastal human populations is protected due to creation of buffer zone between them. Storm surge is a temporary increase in the height of sea level due to low atmospheric pressure or strong winds (IPCC AR4, 2013). It is estimated that, 1000 sq. m. mangrove cover may reduce inundation (Table 3). However, many studies (Gendan *et al*., 2011 suggested it depends on the intensity of storms, density of mangrove forest, stem density, roots and shape of forest floor.
- This ecosystem produces a large population of phytoplankton and zooplankton as a primary production of food chain for uncountable marine wild life which acts as a secondary producer for larger marine populations.
- For primary consumer in mangrove forest carious other organisms like fungi, bacteria and woodborers are also involved in recycling the detritus along with air born microflora, which varies from season to season, species to species and climatic conditions (Nazim *et al*., 2013).
- This ecosystem supports millions of worms, Balanus species (Barnacles), oysters, shrimps and invertebrates, which are feed by different fishes. Besides these ants, spiders, moths, termites, scorpions, crabs, bees, butterflies, flashing fire flies, bats, lizards, frogs, snakes, birds, and monkeys live on mangrove branches.
- Barnacles, anemones, sponge, sea stars, mudskippers, lobsters, crocodiles, services close to the root systems, while tigers and deer, fox, wolfs, dogs, are found on the forest ground.
- Mangroves ecosystems protect several species of coral reefs and sea grass to keep water clean due to smooth filtering and fine sediments.
- These ecosystems are also serving as pollution sink and up to certain limits, control toxic heavy metals. However, according to Khan *et al.* (2009) high volumes of pollutants damage the sustainability of mangrove ecosystems. Fertilizers, pesticides and other toxic chemicals kill marine animals, while, oil pollution suffocates mangrove roots. These forests are world's most threatening tropical and subtropical ecosystems.
- Study shows that certain species like *Avicennia marina* is potentially high phytoremediation species (Nazim *et al.*, 2010).
- Mangrove roots reduce the intensity of floods and waves, and trap fine sediments, stabilizing coast lines. Mangrove forests can store 3 times more carbon than terrestrial forests (*Donato et al., 2011*). Waterlogged

soils (Candy, 2018) of mangrove forests also absorb and store a great amount of carbon (Blue Carbon). These ecosystems are recognized as hotspots in the impact of climate change mitigation.

- These forests provide water purification, nutrients cycling, nursery for marine fauna and help in coastal stabilization.
- Gray mangrove can be used to reclaim waterlogged and saline agriculture lands that may have lost tree cover (Nazim *et al.*, 2010).

Table 3. Wetland Migratory potential (WMP), storm surge areas, increases in GDP, human population and reduction of storm surge area due to mangrove.

| Nos. | Areas | Glob. Man. Cover. % | WMP2 % | WMP3 % | WMP4 % | A.I.S.S % * | GDP US$ | Pop. % | S.S.A % ** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | East Asia and Pacific | 57 | 77 | 19 | 3 | 19 | 225 | 108 | |
| 2 | Latin America and Caribbean | 26 | 43 | 29 | 28 | 61 | 231 | 124 | |
| 3 | South Asia | 11 | 93 | 4 | 3 | 36 | 58 | 71 | |
| 4 | Sub Saharan Africa | 7 | 100 | <1 | <1 | 3 | 11 | 10 | |
| | Ten top Countries | | | Combine 3+4 | | | | | |
| 1 | Indonesia | 33 | 83 | 17 | | 8 | 20 | 24 | 27 |
| 2 | Mexico | 8 | 00 | 100 | | 173 | 503 | 359 | 50 |
| 3 | Myanmar | 6 | 73 | 27 | | 27 | 210 | 172 | 29 |
| 4 | Papa New Guinea | 6 | 69 | 31 | | 6 | 18 | 20 | 7 |
| 5 | Bangladesh | 5 | 99 | 1.0 | | 4 | 91 | 108 | 10 |
| 6 | Cuba | 5 | 99 | 1.0 | | 2 | 6 | 6 | 22 |
| 7 | India | 5 | 91 | 9 | | 71 | 56 | 74 | 47 |
| 8 | Mozambique | 4 | 100 | 00 | | 4 | 6 | 6 | 24 |
| 9 | Venezuela | 4 | 41 | 59 | | 7 | 61 | 56 | 14 |
| 10 | Philippines | 3 | 15 | 85 | | 68 | 271 | 203 | 28 |

Source: Modified World Bank Research Policy working paper 75% (2016); Glob.man. Cover = Global Mangrove Cover area (%), WMP2= Mangrove Capable to Migrate, WMP3 and WMP4= not able to migrate, A.I.S.S= Area increase in storm surge, Pop= Pollution (Human), Wetland Migratory Potential (Hoozemans *et al.*, 1993), S.S.A= Reduction in area to storm surge due to mangroves.

Note: Above data is computed in one meter sea level rise (SLR) scenario. * = Under all climate change effects.

**Effects of Climate Change on Mangrove Ecosystem**

Increase population, urbanizations, industries, infrastructure, forest logging, use of fossil fuel etc. created climate change. Besides anthropogenic disturbances these important ecosystems is threatening by the impact of global warming (Alongi, 2015). Donato *et al.* (2011) stated that mangroves are among the most Carbon rich forests, known as the best Carbon scrubbers". Campbell and Brown, (2015) stressed to save these treasures. Pendeleton *et al*., (2012) stated that ⅓ of Carbon is hold by Indonesian mangrove forests. Alongi, (2008) reported that 0.5% of world mangrove area hold 10-15% blue carbon. Murdiyarso *et al.*, (2015) estimated 3.14 billion metric tons of carbon from Indonesian mangrove forests. These forests have great potential for global and regional climate change mitigation. Destruction of mangroves will release huge amount of carbon in the atmosphere, resulting increase global warming which ultimately will reduce food resources due to reduced marine resources. Therefore, these ecosystems are disturbed or destroyed on the name of development; its consequences will be great not only on biodiversity, marine resources but human life and survival.

It is predicted that increase temperature will rise sea level like Bay of Bengal but due to the construction and development projects there will be no place for new sedimentation and propagules to grow and rise with seas level. Gilmam *et al.* (2008) stated that sea level rise will change the sediments and high water-table. Plants may die back due to inverted stress. However, mangrove population may migrate to high level. Hoozimans *et al*. (1993) described 5 stages of wetland Migratory potential (WMP) in one meter sea level rise scenario *i.e*., in WMP 1 and WMP5 no mangrove occurs; WMP2 capable to migrate while WMP3 and WMP4 stages not able to migrate. It is stated that South Asia and Sub Saharan Africa mangrove have highest potential to migrate due to sea level rise. Highest vulnerability is seen in Mexico where 100% coastal mangrove may be destroyed by sea level rise (Table 3). Rise of sea level will also destroy homes and agricultural lands of coastal populations like in some areas of Sindh Pakistan.

The coastal areas will be more affected and directly face the storms, hurricanes, floods etc. (Ward *et al.*, 2016). There will be more soil erosion in coastal area and harbor authorities will required more money to clean their channels from accumulated soil and mud. After working in 42 developing countries in present and future climate change scenario, a World Bank report (Blankespoor *et al.*, 2016) predicted 10% more increase storms and one meter rise of sea level which would be a great impact on mangrove populations. Impacts of climate change on Caribbean mangrove coasts also discussed by (Wilson, 2017).

Increased pollution will spread toxic heavy metals among marine wild life and this toxic element will be transfer is human body if consumed. In consequence human population will face unwanted diseases and acute health problems. In addition, country will lose export and foreign exchange. Due to cutting, mangrove cover is rapidly decreasing. It is estimated that loss of one square mile of mangrove trees would be a loss of 124 metric tons of fish per year.

Besides loss of other marine resources, Rising temperature may decrease photosynthesis and increase salinity which may reduce rate of decomposition, hence less or delayed food for microorganism which may break or significantly disturb chains of marine ecosystem, creating harsher situation to other dependents to survive. Increase temperature may change phonological pattern of species and species composition of the ecosystem. In addition, the rise of $CO_2$ may or may not be beneficial of these forests.

Due to climate change, rainfall patterns would be change (IPCC, 2013) and likely to influence species by species in mangrove ecosystems. Some (*Sonneratia alba*) will get benefit whiles, no response to *Bruguiera gymnorrhiza* (Gilman *et al*., 2007). Similarly increase floods may bring more sediment, nutrients and reduced salinity for the better growth of mangrove ecosystem, however it is anticipated that combine effects of climate change will most likely negatively impact on mangrove forests. This situation may result in significant loss of biodiversity which is most important for human.

Small scale experiments (Nazim *et al.*, 2010) show that if *Avicennia marina* seedlings are planned on ground, pneumatophores are not produced due to presence of oxygen around root system, vivipary is also not seen while some stilt or pop roots are produced. In addition, up to the certain limits plants were resistant to drought and light fire. Therefore, it may be anticipated that at least *Avicennia marina* would cope with the increased temperature, due to the high potential adaptability if anthropogenic disturbances are controlled in these forests. However, more detailed studies are required.

It is anticipated by the World Bank, (2016) that in future (by year, 2050), from West Bengal alone more than 12 million people might migrate due to global warming (Schwartzstein, 2019). From these area 1.5 million people already moved to near cities due to land taken by floods and solid erosion. In Pakistan also a large number of coastal populations living below poverty level migrated to nearby cities due to the same reason. Amjad *et al.*, (2007) reported 67km sea water intruding in coastal areas of Sindh damaging agricultural field and coastal towns. These forests are indispensable in combating impact of climate change, therefore should be protected, conserved and restore worldwide.

**Action Plan for Mangroves**

UNEP, (2014) stressed the need that conservation projects should be started, which cannot achieve goal without involving local communities, particularly woman. These projects should include education, training, health, alternative jobs and easy microfinance program for vegetable farming, handicrafts, and small businesses like food or bakery shops. Community should be train to protect and use these ecosystems as sustainable way. This will enable coastal mangrove community with technical skill and knowledge to take part in decisions to improve mangrove management, environment, biodiversity and livelihood. It will also provide resilience mitigation to impact of climate change.

- Beck *et al*., (2015) stated that greater awareness of the role of mangrove in coastline protection as part of a multidimensional strategy for climate change adaptation has led to large scale programs to rehabilitate and replant mangrove in countries like Vietnam and Philippines as well as small programs in many other countries. Kambaj *et al.* (2016) also stressed the need of forest conservation in changing climate.
- Lands of mangrove forests should not be reclaimed for development projects, and no project should be allowed disturbing this ecosystem.

- Cutting trees and over grazing should be banned. Considerable area of mangrove should be increased by planting more trees in suitable coastal and river areas. Width of planting belt and selection of suitable site is important. It is reported that storm surge attenuation depends on planting belt and site-specific characteristics of the area. An unpublished report of Bangladesh reported that a 600m wide mangrove belt at the Southern end of Hotia Island reduced the surge height by 0.45m from 6.2 to 5.75m while, southeast and southwest sites show no considerable effect. Therefore, for maximum benefit it should be carefully considered. In addition (i) Vigilance station to control traffic and illegal cutting. (ii) Hydrological rehabilitation, *i.e*. to prevent natural water channels and (iii) Ecological rehabilitation, *i.e*., organic matter determination, protect natural regeneration etc. is also be considered as suggested by Garcias, (2012). Different species have different range of salinity tolerance, therefore during plantation it should be considered (Aziz and Khan, 2001). Despite the opinion of Mukhtar and Hannan, (2012) that exploitation by villages for legal use do not pose a major threat to existence of these forests. Evan, (2013) stated that, with increasing human population, illegal activities, browsing up to hundreds of camel, cutting for fuel/charcoal, sale and substandard methods to obtain forest resources are great threats to ecosystem.
- Coastal forests resources (fish, crab, shrimp etc.) should not be obtained by substandard ways (unsustainable use). Shrimp forming resulted major change to ecology and destruction of mangrove fields (Alongi, 2002). Therefore, long term programs for sustainable management are required.
- No solid waste should be allowed to dump in mangrove forests.
- No industrial liquid waste should be drain in rivers and sea.
- Industrial liquid waste should be treated in water treatment plants and then taken to the deserted areas by pipe line. This water should be used to establish plants and trees cover in these dry areas for commercial purpose. This way pressure on natural forest will be reduced. These forests will store large amount of carbon and help reduce the impact of climate change. In additions our fresh water and marine ecosystem will be save from pollution.
- Only certain points should be designated in mangrove forests for tourism purpose with proper facilities and strict rules.
- National Tourism area or ecotourism would be a additional tourism project, suggested by (Kissinger *et al*., 2019). Tourists should be given garbage bag when entering and properly collected on return, so pollution could be controlled in these forests.
- Reasonable amount as fee should be charged from the visitors for proper management of these ecosystems.

To achieve these goals globally, Conservation International is a non-profit, non-governmental organization of policy makers and technical experts. Their aim is to protect re-growth and conserve this life saving unique ecosystem with the goal to increase mangrove habitat up to 20% by 2030. They are interested in issues of climate change, mitigation, biodiversity and improvement of coastal communities. It is important for each country having mangrove forest, to establish this type of organization and train volunteers to achieve this goal. To understand its important 26$^{th}$ July of each year is considered as an International Mangrove Day.

In addition, the universities and research organization conduct research on each and every aspect of Mangrove ecosystem on regional basis, since impact of climate would be regionally variable as suggested by (Ward *et al*., 2016).

**Organizations coping with Climate change**

Some organizations are working on Climate Change issues in relation to Mangroves (Wilson, 2017)

1. United Nation Environmental Programme. World Conservation Monitoring Centre
2. World Resource Institute
3. World Resource institute Mangrove Blog
4. Marine Climate Change Impact Report Card (http://www.mecip.org.uk/annual-report-card/)
5. Global Forest Watch (http://www.globalforestwatch.org)
6. Mangrove for the Future (http://mangroveforthefuture.org)
7. Planet Save (htttp://planetsave.com/2015/02/18/where-without-mangorve-)
8. Caribbean Natural Resources Institute
9. University of West Indies
10. Caribbean Community Climate Change Centre (http://www.carribeanclimate.bz/)

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