Degradation of Indus Delta Mangroves in Pakistan

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***Abstract*—** A largely arid/semi-arid country, Pakistan has a diverse landscape, with high mountain ranges, fragile watersheds, alluvial plains, sandy deserts and coastal mangroves. Indus, the major river of Pakistan, falls into the Arabian Sea in the Sindh coast forming a fan-shaped delta interspersed with 17 major and numerous minor creeks and mudflats. Indus delta mangroves are unique in being the largest area of arid climate mangroves and the 7th largest block in the world. They are dominated by *Avicennia marina* (locally known as Timmer), which occupies about 90% of total mangroves in the delta. Reduction in inflow of freshwater from Indus on account of diversion of water for other purposes, inflow of pollutants from industries, navigational activities and intermix of industrial effluent, and human and livestock population pressure for fuelwood and fodder collection have exposed this complex ecosystem to severe environmental and social stresses in the form of loss of habitat and biodiversity, decline in fish productivity and social problems for coastal communities. The paper provides an overview of Pakistan's Indus delta mangroves, lists the manifold causes threatening their existence, and suggests corrective measures for preserving/developing this important ecosystem of the world.

***Keywords*—** Arid climate, Environmental and social stresses, Mudflats, Mangroves.

I. Introduction

Mangroves are ever green forests between land and sea, found essentially in the intertidal zone and occupying large tracts along the shallow coasts, estuaries and in the deltas where they are influenced by tides, widely differing conditions of saline and rainfall regimes. The coastline of Pakistan is 1,050 km long and 40-50 km wide shared by the provinces of Sindh (350 km) and Balochistan (700 km). In the Sindh province, mangroves are found in the Indus Delta which occupies approximately 600,000 ha extending from Korangi Creek in the north to Sir Creek in the South [3]. Indus Delta comprises 17 major creeks, numerous minor creeks and extensive mudflats and constitutes 97% of total mangrove forests found in Pakistan.

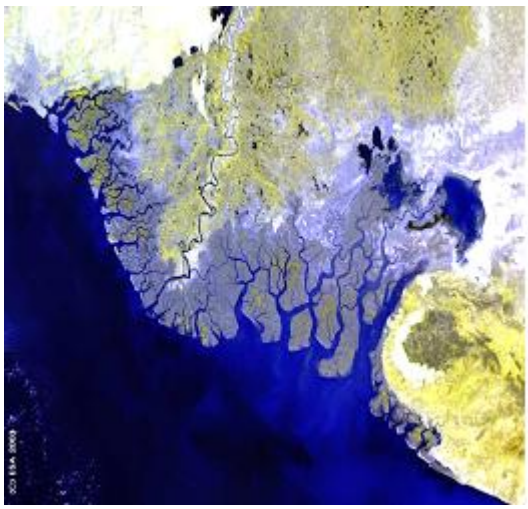

Fig.1 A satellite view of the Indus Delta Mangroves

Mangroves of Indus delta are unique in being the largest arid climate mangroves in the world (Fig. 1). The survival of these forests is largely associated with perennial freshwater supplies from the River Indus, which flows through the delta before reaching the Arabian Sea. An area of 344,845 ha of the Indus delta has been declared as protected forests and is under the control of Sindh Forest Department [6]. The Indus Delta is

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believed to have had as many as eight mangrove species in the past. However at present, only four species have been left. Nearly 95% of the mangroves located in the Indus Delta comprise the species Avicennia marina. Very small patches of Ceriops tagal and Aegiceras corniculatum are found near the mouth of the Indus at Keti Bunder. Rizophora mucronata has been introduced in the Indus delta through replanting work. In Baluchistan province, the mangroves occur at three sites, Miani Hor, Kalmat Khor and Gwatar bay. Total area under mangrove cover in all three sites has been estimated to be 7,340 ha [5]. This area is equal to 3% of total mangroves found in Pakistan. Miani Hor is the only area in Pakistan where three species of mangrove Avicennia marina, Rhizophora mucronata and Ceriops tagal occur naturally.

The mangroves are very important ecosystem both economically and ecologically. Although mangroves play protective and productive roles but their protective role is more effective than productive. Some of the roles/functions of mangroves are as under:

- As pool of diversity they support diverse forms of plants and animal life.
- Provide food, shelter and breeding ground to prawns, shrimp, several fin fish, crabs and other marine life. Annual export earning of US$4 billion.
- Reduce wave action and help stabilize coastlines.
- Assimilate sewage water wastes and heavy metals from industrial plants.
- Protect seaports from cyclones.
- Reduce the intensity of cyclones.
- Provide livelihood to local population living along the coastline.
- Source of wood for heating and cooking and fodder for live stock.
- Provide shelter to migratory birds during winter.
- Serve as scientific laboratory/material for research

In the coastal region there is a general scarcity of sweet water. All the creeks are full of sea water and are subjected to tidal action. The main source of sweet water is the River Indus which has been changing its course frequently within historical times. The Indus and its main distributaries, flow about 120 miles southeast of Karachi to join the sea. Before the construction of dams higher up in the Indus, sweet water used to reach the tail ends of these streams during low tides almost all the year round. At present, sweet water reaches the tail ends only during the flood season when the local people store it in shallow pools for human and cattle consumption. After the flood season is over, sea water comes up in these streams and main distribution of Indus and for the rest of the year; these streams are full of sea water. The existing mangrove vegetation depends for its water supply from sea. It has adopted itself to the high salt contents of sea water so much so that every part of tree is saltish in taste [7]

II. MAJOR THREATS TO MANGROVE FORESTS

There has been considerable qualitative and quantitative loss of mangrove forest in Pakistan over the last 50 years. Fig. 2[1] shows that comparison of 2000 Landsat image of the delta with the mapped shoreline (red lines) and tidal sand bars (yellow lines) in 1950, showing moderate coastal retreat in the NW of the delta, proggradation in the region of the Indus Mouth. Note the tidal inlets that characterize the Rann of Kutch area in the SE are much wider and deeper now than in 1950.

Previous various authors and agencies in their published and unpublished literature have identified external and internal factors, responsible for mangrove degradation. A significant reduction in the river water supply and increased marine water pollution in the Indus Delta from industries as well as over harvesting of mangroves by the local communities, sedimentation, and coastal erosion are generally considered to be the proximate causes of this loss. Another threat is emerging in the form of over harvesting of fish resources, largely provoked by increased pressure for exports with little or no consideration for the existing environmental laws and regulations. These threats have exposed this complex ecosystem to severe environmental and social stresses in the form of loss of habitat and biodiversity, decline in fish productivity and social problems for coastal communities.

Fig.2 Comparison of 2000 Landsat image of the delta with the mapped shoreline (red lines) and tidal sand bars (yellow lines) in 1950, showing moderate coastal retreat in the NW of the delta, progradation in the region of the Indus Mouth. Note the tidal inlets that characterize the Rann of Kutch area in the SE are much wider and deeper now than in 1950

A. External Factors

Mangrove ecosystem is under serious stress/threat due to a variety of external factors which are beyond the control/influence of people and authorities using the mangrove ecosystem. The five main external change factors are:

a. Inadequate and Irregular Inflows of Fresh Water and Silt Load from Indus

The Indus delta mangrove ecosystem is primarily dependent upon silt-laden, fresh water discharges from the River Indus which is the only source for the above supplies [4]. Most important cause of degradation of Indus delta mangrove ecosystem is reduction in the quantum of fresh water discharge from Indus due to diversion of water for agriculture, hydro-electricity, and other uses in the upper reaches. Estimated total water available from the Indus catchments is 150 MAF (181 billion m3) [4]. Over the period of past sixty years the quantity of sweet water flow has been reduce to about 35 MAF (43 billion m3) which mainly occur during 3 months. The total silt load is estimated as 400 million tons/year and the actual quantities discharged are estimated at 100 m/tons/year [4].

The data of discharges below Kotri barrage over the years from 1940-41 to 2000-01 shows that the total annual discharge below Kotri has been very variable but, indicates a gradually decreasing trend. The average flows released below Kotri has been reduced to 34.8 MAF of which 20 MAF actually reach the mangroves. Bulk of these flows is released below Kotri in July-September period. Any flow during other times of the year does not reach the mangroves but is lost due to evaporation and infiltration etc. This reduction in quantity of fresh water flows into the delta has been due to changes in landuse, expansion of agriculture, intensive cropping, power generation, industrial growth and increase in population. The situation has been further aggravated by low/no rainfall particularly in Indus catchments during the recent years which has created extreme water shortage in the River Indus. Indus River experienced extreme shortage ever in the history during the year 2000-01 as the flow down stream Kotri was recorded almost nil (0.75 MAF only). This state of reduction in inflow of freshwater have exposed this complex ecosystem to several environmental and social stresses in the form of loss of habitat and biodiversity, decline in fish productivity and social problems for coastal communities.

Annual average net water availability during the period 1922-2003 on 4 out of 5 years is estimated to be 116 MAF. Present annual water commitments add up to 146.9 MAF. That leaves a deficit of 30.9 MAF.

This has created a huge water shortage problem in the lower Indus basin, resulting in significant impacts. Fig.3 below depicted yearly flow in Indus below Kotri to the Delta.

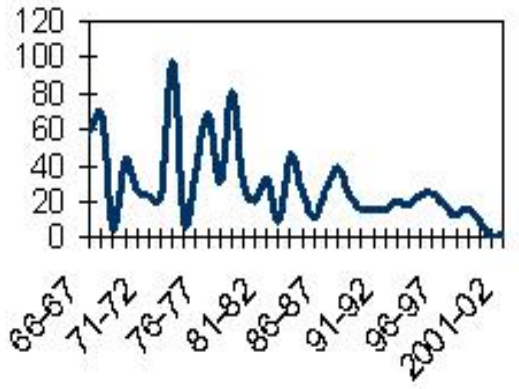


Fig.3[1] The MAF of Indus into the delta

Reduction in the flow of fresh water to the Indus Delta over the last 50 years has created two problems. First, the salinity of the sea water has increased to 50 ppt, which is detrimental to mangrove growth. Second, the flow of alluvium–the fine gained nutrient-rich soil brought by the rivers during its course through the fertile plains has declined from 400 million to 100 million tons per year thus, preventing transport and uniform dispersal of suspended sediments over mangrove areas. As a result, the surviving Indus Delta mangroves are sparse and stunted.

The above discussion clearly shows that as a result of freshwater scarcity over time, mangrove cover has been reduced both qualitatively and quantitatively. In addition, the survival of *A. marina* in the Delta, which has a higher tolerance for salinity, and the gradual extinction of other species that are less resistant to higher salinity levels indicate the increased levels of salinity in the Indus Delta. The loss of five mangrove species from the Indus Delta during the last 60 years, stunted growth of mangroves provides sufficient evidence to show that reductions in freshwater supplies in future may further reduce the genetic diversity of mangroves in the area. Such changes will have significant effects on the biodiversity of the mangrove ecosystem. Fish resources may be depleted in the process. It is quite evident that, unless appropriate policy measures are taken to increase water-use efficiency, population growth and increased demand for irrigation water will continue creating shortages in the Indus Delta. Adequate supplies of fresh water and silt to the Delta region are critical for the health of mangroves and the region's biodiversity. Any reduction will restrict the mangroves in performing their vital role as primary producers in the ecosystem.

b. Sea Water Intrusion

The continuous reduction in fresh water inflow below Kotri barrage is resulting in salt water intrusion changes in the geomorphology of the delta and nutrient balance of the ecosystem. It is estimated that the sea water intrusion has taken place up to 67 km resulting in not only damaging terrestrial ecosystem in deltaic region but also affecting adversely the agricultural fields and other habitats.

c. Gradual Increase in Sea Level

Geophysical factors affecting the mangrove ecosystem include existing problems and the threat of global warming. The general phenomenon of sea level rise is attributed to global warming. It is reported that over the last 100 years the sea level near Karachi has been rising at a rate of 1.1 mm. per year and this may increase with global warning. Pakistan has been included in the list of ten countries most vulnerable to the impacts of rising sea levels. Qureshi [7] has estimated a land loss of about 1,700 km2 in the Indus Delta due to sea encroachment over the last half century. Sea-level rise may cause stronger wave action, higher tides, and greater probability of surges, all of which may cause coastal erosion and depletion of mangroves, aggravating current patterns of physical damage. This serious threat to mangrove ecosystem is harmful if coupled with reduce silt deposition. It is estimated that mangroves with significant discharge from the land can maintain themselves by accumulating deposited silt with sea level rise as high as 2.5 mm/year.

d.Inflow of Pollutants

Pollution of the marine environment is another proximate cause of biodiversity loss in the coastal areas of Pakistan. The loss of mangrove species during the last 60 years, besides being consistent with the reduced supply of fresh water to the Delta, is also consistent with the increased volume of untreated wastewater discharges from industries and the city of Karachi and its vicinity.

More than half of the industrial units and over 70% of the country's international trade are based in Karachi. It is reported that in about 25 years the number of industries has increased from 10,000 to about 30,000. With improved infrastructure, Karachi has been rapidly transformed into one of the largest cities in the world. Rapid urbanization is accompanied by weak urban planning has resulted in generation of domestic and industrial effluents without emphasis on safe or environmentally friendly approaches to its disposal. Over time, pollution has affected the coastal areas of the Indus Delta, causing stunted growth of mangroves and biodiversity loss in the marine ecosystem. An increased supply of untreated industrial effluent has pose a constant threat to coastal biodiversity. Effluents from tanneries, including lead and mercury, are among the most harmful to marine life. It is estimated that about 37,000 tons of industrial waste is being dumped yearly in coastal environment of Karachi whereas, 20,000 tons of oil finds its way to beaches, harbours of Karachi and fishing grounds annually. Further, municipal sewers generate about 110 mil. gallons per day (MGD). In addition, land clearance for the construction of new sea ports, extension of existing sea ports, and establishment of industrial units near the coast has also contributed to the depletion of mangrove cover, particularly in the northern part of the Delta.

Based on past trends, one can easily ascertain the long-term environmental consequences of existing industrial pressures in and around Karachi and of the ineffectiveness of the environmental policy framework. A continuation of the present trend will cause more stunted growth of mangroves, and the biodiversity of mangrove areas will be eroded. Given the inelastic supply of land in Karachi, future economic growth will require reclamation of land from the sea at the cost of removal of mangroves. Unless this cost is correctly valued to capture long-term effects on the sustenance of coastal areas, the trend is likely to continue and biodiversity will suffer irreversible losses.

e. Meandering and Erosion of Creeks

The meandering of small creeks and channels is also one of the cause of natural death of Mangroves stands. This natural process causes a change in the mangrove habitat because, some areas are cut-off from regular flood waters, while others receive additional soil deposits, resulting in high lying areas. The erosion of creek banks destroys woody vegetation on these banks. This phenomenon is particularly evident along creeks near the sea where tidal movements are fastest.

B. Internal Factors

Apart from external factors described above there are several factors resulting from action of the people and authorities using/controlling the mangrove ecosystem resources. The important internal factors are: browsing by camels and grazing by cattle on the mudflats, fodder harvesting, wood harvesting and effluents from Left Bank Outfall Drain (LBOD).

a. Over Harvesting

Over harvesting mangroves and fish by coastal communities is another cause of mangrove cover degradation. It is, however, difficult to determine the extent of damage due to use by local communities. Mangrove forests have remained

a source of fuel, timber, and fodder for coastal communities in almost all estuaries. As a consequence of increased population and poor physical infrastructure, demand for mangrove wood for fuel increased at the local level. Lack of alternate fuel wood aggravated the problem. Alternatives, such as kerosene oil or natural gas, are either not available or too expensive for the local communities. Although Timer (*A. marina*) wood is not good/desirable fuel wood compared to Rhizophora species due to lower calorific value and tendency to smoke, it is still used extensively by local people for domestic use. It is rarely sold outside the coastal areas. The use of mangroves fuelwood is directly related to the population of the people living in the coastal zone. The diagnostic survey of Indus delta shows that 25% of households depend on mangrove wood for cooking & heating purpose. The use of mangroves as fuelwood has been reduced in Port Qasim areas due to provision of alternate source of fuel mainly due to establishment of industrial units. But in the rest of the mangrove areas the Timer fuelwood is still in use and the mangroves in those areas are under tremendous pressure. Each family uses 173 kg. of mangrove wood per month giving a total annual consumption of 18,000 tons.

b. Browsing by Camels and Grazing by Cattle on the Mudflats

Browsing by camel and grazing by cattle is a unique use of Indus delta Mangrove ecosystem. It is estimated that a total of 16,000 camels and 3,200 cattle are using the ecosystems resources and consume about 19.5 m kg of grasses and 67 million kg of leaves. These activities take place most of the year by herds owned by villagers living inside, fringes of the inter-tidal zone and also herds from further inland during the monsoon season. Camel browsing in the mangrove forest is extremely harmful to the growth and regeneration of mangroves. However, the impact of camels is limited to certain pockets in the dense forest of the Indus Delta, and the associated threats to mangroves have tended to be insignificant given a decline in the camel population in coastal areas. The decline in the camel population has been caused by both a reduction in camel exports to the Middle East and an increase in the relative profitability of cattle and buffalo over camels.

c. Fodder Harvesting

The leaves of the predominant mangrove species i.e. Avicennia marina (Timer) are liked fodder for animals. These are regularly collected by the villagers residing in and around the coastal mangroves for feeding their cattle. This activity puts considerable pressure on the existing mangrove stands resulting in overgrazing, browsing and lopping. The mangroves are populated with cattle, goats, sheep, camels and cows beyond their capacity to produce fodder to feed them.

d. Disposal of Left Bank Outfall Drain (LBOD) Effluents

In the recent past Left Bank Outfall Drain (LBOD) has been constructed with the primary aim to reclaim the agricultural lands by reducing the water table thereby reducing the salinity. LBOD was designed to address the problem of water logging and salinity by providing a comprehensive system of surface and sub-surface drainage through a network of lateral and spinal drains to transport excess salts and drainage effluents to the coastal zone near the Indian border. The substantial quantities of saline drainage effluents with a salinity as high as 30 mS/cm and more are being discharged into the delta. These quantities of saline water and salt load per year when added to the coastline creeks increase the salinity of the area which is detrimental to marine life, mangroves and coastal communities.

e. Progressive Decrease of Mangrove Vegetation

A major portion of mangrove forests was surveyed in early 1960s by the Sindh Forest Department (SFD) and the mangrove forest area was estimated at 344,846 ha. This survey of the mangrove forests was, however, limited to two compact blocks of land transferred to the SFD in 1958. A second survey for the entire mangrove forest area of the Indus delta was made by the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) in 1979 with the use of Landsat MSS imagery of December, 1973, December 1976 and December 1978 and are estimated at 0.60 mil. ha. A third survey has been made by SFD for the area under its control in 1985 using the Landsat data and ground survey. The area of 64,400 ha transferred by the SFD to the Port Qasim Authority for Muhammad Bin Qasim Port in 1973 has been excluded. The latest survey has been made by thee consultants with the interpretation from March 1990 Landsat imagery and ground check.

Fig. 4 shows the status of Mangrove forest areas over the years 1960 - 90.It is apparent from Fig.1 that the trend of mangrove vegetation development is in the decreasing trend over a 30 year period of time.

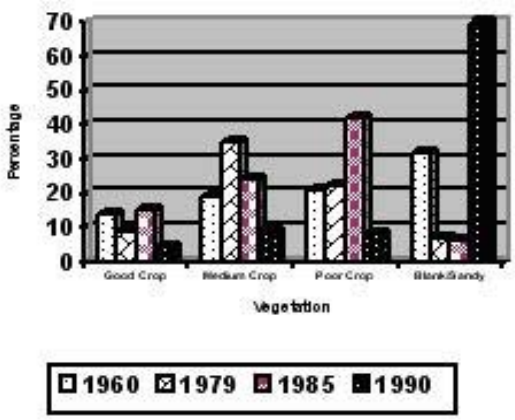
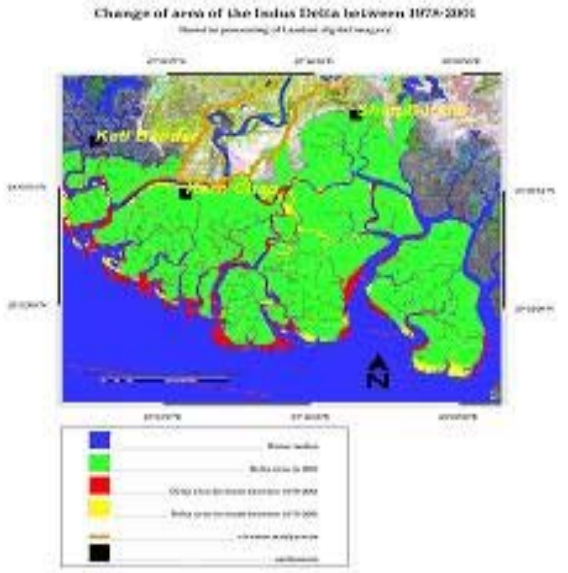
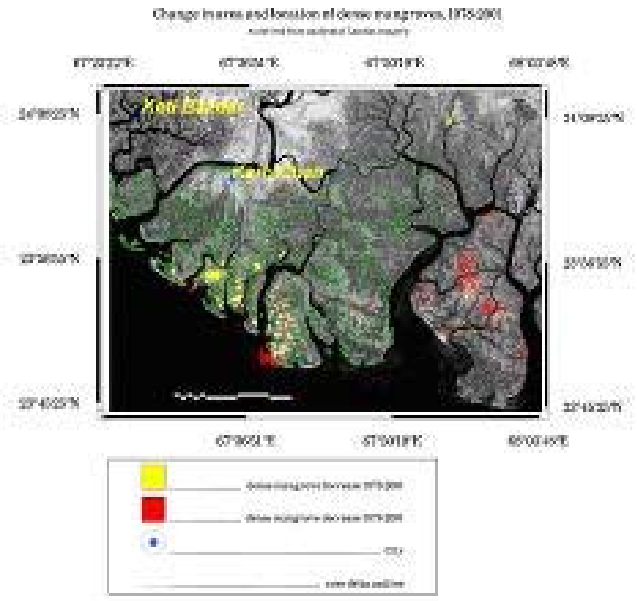


Fig.4 Status of mangroves in Indus

III. Change Analysis Using Satellite Imagery

The distribution of mangroves according to satellite imagery reveals that there is a large decrease in dense mangrove cover in the south-eastern part of study area, but an increase in the central part. This distribution of mangroves is greatly influenced by the amount of surface run off and alluvium deposited at the mouth of river by seasonal floods . Sparse areas are mostly muddy substrate and no inundated channels or creeks. These areas support thin, relatively sparse monospecific stands of *Avicennia* The loss of mangrove species over the last 50 years is highly consistent with the reduction of fresh water and silt supplies to the Indus Delta. The survival of salt-tolerant *Avicennia marina* in the Delta provides evidence of higher levels of salinity in and around the mangrove forests. Recent Landsat picture of mangrove cover in the Delta also suggests quantitative and qualitative decline of mangroves over the last two decades. Although the Water Accord of 1990 guarantees a minimum of 10 MAF of water annually for the Delta, the high public subsidies to irrigation water for agriculture upstream provide negative incentives for the conservation of water resources. In the event of any significant water shortage, the Delta is likely to receive a smaller quantity. If the mangroves are to be conserved effectively, a larger water supply has to be assured. This would require improved water-use efficiency in the upstream areas.





IV. ACTION PLANS FOR MANGROVE SUSTAINABILITY IN PAKISTAN

It is strongly recommended that the following action plans be taken up by the Pakistani's government to ensure the sustainability of her mangroves in the Indus Delta:

- ☑ The operationalization of an airborne hyperspectral remote sensing technique is implemented in order to map, identify and monitor individual species behavior due to high salinity, extent of degradation and new planting results through artificial planting in blank potential mudflats.
- ☑ Development of a DSS-GIS database for Indus delta Mangroves is maintained for proper management and monitoring development activities.
- ☑ The economic and environmental importance of mangroves is recognized in the national policies and priorities.
- ☑ Environmental Impact Assessments should be carried out by EPAs on a regular basis and published officially to strengthen the mandated efforts to increase public awareness about environment and promotion of research.
- ☑ The efficiency of water use at the system and farm levels in order to minimize increases in diversions upstream and to ensure an adequate supply of fresh water to the Delta is enhanced.
- ☑ Programs for education and awareness of fishing and other communities and their participation in management of mangrove forests are initiated.
- ☑ Allternate sources of fuelwood and fodder are developed in the coastal region.
- ☑ For a pragmatic solution to the increased water pollution in the marine environment, discharge of industrial and domestic effluents harmful to the mangrove ecosystem be strictly monitored by EPA, Sindh and other agencies.
- ☑ A process of stakeholder dialogue needs to be initiated to effectively address the causes of biodiversity loss and provide an open forum for discussion of the role and constraints of the various stakeholders. Such dialogue would play a role both in information dissemination and consensus-building.
- ☑ In-depth scientific studies on the fresh water requirements of mangroves in terms of quantity and distribution and the "willingness to pay" for alternate sources of fuel for household consumption on the part of coastal communities be carried out.

V. SUMMARY

The Indus delta mangrove is unique in being the largest area of arid climate. Recent satellite images indicate that about 160,000 ha of delta are covered by mangroves.

On one hand these forests produce 15 - 20 m wood/hectare, provide habitat for wildlife, place for grazing animals and on the other hand these support Pakistan's big industry of fisheries and shrimps and the Government of Pakistan is earning about 4 billion rupees annually. About 100000 fishermen are engaged in fishing and shrimp industry.

Factors responsible for the degradation of Indus delta mangroves resulting in resource base reduction are reduced flow of sweet water & silt from river Indus, inflow of pollutants from Industries, navigational activities & intermix of industrial effluents, browsing/ grazing by livestock, wood & fodder harvesting meandering and erosion of creek banks, over fishing and gradual rise in Sea level.

Other minor threats include lack of knowledge, mismanagement, over exploitation, browsing and less frequent and low tides over deltaic region.

Therefore, the need for monitoring of these depleting natural resources through latest airborne hyperspectral remote sensing techniques and rehabilitation of these forests through artificial planting of suitable species in the changed ecological conditions is extremely desirable.

REFERENCES

[1] Altaf A. Memon .2005.Devastation of the Indus River Delta. Proceedings, World Water & Environmental Resources Congress 2005,American Society of Civil Engineers, Environmental and Water Resources Institute, Anchorage, Alaska, May 14-19, 2005. (Note – Expanded version)
[2] Ansari T.A., 1993. Feasibility study for Rehabilitation of Indus Delta Mangrove Forests. Government of Sindh, Forest Department, Karachi
[3] Forestry Sector Master Plan, 1992.A comprehensive report on Sindh. Asian Development Bank and UNDP Prog. Pakistan
[4] IUCN, 1991.Possible Effects of the Indus Water Accord on the Indus Delta Ecosystem. Korangi Ecosystem Proj. Issues Paper No.1
[5] Mirza, M.I., 1983.Mangrove of Pakistan, PARC, Islamabad, p 63
[6] Qureshi, M.T. 1993. Rehabilitation and Management of Mangrove Forests of Pakistan.
[7] Qureshi, T.M and Khan, D. 1988. Experimental Plantation for Rehabilitation of Mangrove Forest in Pakistan. First Report UNDP/UNESCO Reg. Proj. for Res. and Training Prog. on Mangrove Ecosyst. in Asia and the Pacific (RAS/86/002). Sindh Forest Department, Government of Sindh, Karachi Pakistan.