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Indus FOREVER

Natural Vegetation Assessment

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Acronyms

AKPBS	Aga Khan Planning & Building Services
AOI	Area of Interest
ASTER	Advance Space-borne Thermal Emission Reflection Radiometer
AU	Animal Unit
BD	Beta Diversity
CC	Similarity Index
CCB	Citizen Community Board
cft	Cubic feet
DMY	Dry Matter Yield
EC	Electrical Conductivity
ERDAS	Earth Resources Data Analysis System
FCC	False Color Composites
GIS	Geographic Information System
GPS	Global Positioning System
Ha/Au/Yr	Hectares/Animal unit/Year
HANDS	Health and Nutritional Development Society
HDF	Hierarchal Data Format
HH	House Hold
I.V.	Importance Value
IFAP	Indus for All Programme
K	Potassium
KB feeder	Kalri-Baghar Feeder
Kg/ha	Kilograms per Hectare
KUH	Karachi University Herbarium
LBOD	Left Bank Outfall Drain
MAF	Million Acre Feet
P	Phosphorus
PUF	Proper Use Factor
R.C.	Relative Cover
R.D.	Relative Density
R.F.	Relative Frequency
RBOD	Right Bank Outfall Drain
RGB	Red Green Blue
SDR	Summed Dominant Ratio
SE	South East
SIDA	Sindh Irrigation and Drainage Authority
SPOT	Satellite Pour l'Oservation de la Terre
STDC	Sindh Tourism Development Corporation
TWINSPAN	Two Way Indicator Species Analysis
UTM	Universal Transverse Mercator
WAPDA	Water and Power Development Authority
WGS	World Geographic Survey
WWF	World Wide Fund for Nature

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Acknowledgement

Natural vegetation assessment over three years (2006 – 2008) and in three different seasons across four distinct ecosystems of the Indus Ecoregion was part of the overall ecological assessments under Indus For All Programme. The exercise could not be accomplished without untiring help of committed professionals who spent days and nights in the field during scorching summer and cold winters. This study also provided a chance of various universities from across the nation to work under one team for this noble cause. The galaxy of these young professionals under the able leadership and guidance of Professor Dr. Surayya Khatoon came up with outstanding findings and contributed substantially to the understandings of these ecosystems. The team was comprised of;

1. Professor Dr. Surayya Khatoon, Karachi University
2. Dr. Ghulam Akbar, Plant Ecologist, Team Leader, Indus For All Programme
3. Mr. Babar Khan, Coordinator, WWF-P, Islamabad
4. Dr. Rehmatullah Qureshi, Asstt. Professor, Arid Agriculture Univ., Rawalpindi
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12. Mr. Amanullah, NRM Officer Keti Bundar

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Executive Summary

Under Indus For All Programme, four sites of Indus Ecoregion, viz, Keti Bundar, Keenjhar Lake, Chotiari Reservoir and Pai Forest have been surveyed for floristic and vegetational analysis, in 2006 (fall season), 2007 (monsoon) and 2008 (late winter/ early spring). In addition to these localities, a fifth locality Shah Belo at Keti Shah (Sukkur District) was also surveyed in March 2008, which is a riverine forest. However, for now it has not been discussed in this report.

The study included inventorying of natural flora species through detailed survey of each site with specimen collection, phytosociological analysis using line transect method, calculation of carrying capacity by estimation of biomass production (weighing the palatable vegetation falling in the quadrats), and observations on problems/threats to biodiversity and ecosystem in each site. The collected specimens were identified and deposited in the Karachi University Herbarium (KUH). The phytosociological data were analysed by TWINSPAN software. The coordinates of exact sampling sites (transects) were marked with the help of GPS for future reference and for mapping of site based plant communities.

Keti Bundar was found to be floristically the poorest in all localities with a total of 117 species (α-diversity) in 83 genera and 36 families including 2 species of Pteridophytes in 2 genera and 2 families, 79 species of dicotyledonous angiosperms in 56 genera and 29 families, and 36 monocotyledonous angiosperms in 25 genera and 5 families. Poaceae with 28 species was the largest family, followed by Chenopodiaceae (9 species), Tamaricaceae (8 species) and Asteraceae (6 species). *Tamarix* was the largest genus with 8 species; all other genera were represented by less than 4 species. The dominant species of the inland vegetation were *Aeluropus lagopoides, Halostachys belangerana, Arthrocnemum macrostachyum, Tamarix indica, Salvadora persica* etc. which are all halophytes, indicating the hypersaline conditions even in the inland habitat. In mangrove ecosystem in the creeks, *Avicennia marina* was found to be the dominant species with small stands of *Aegiceras corniculata* at few places, particularly those which receive some freshwater from River Indus. In addition to these two species *Rhizophora mucronata* was found planted at some places. The mangrove forests were found to be on decline with stunted growth of *Avicennia marina* trees. At many places immature and stunted trees were found without any full grown mature tree. It is obvious that the propagules establish and germinate, but fail to reach maturity due to nutrient deficiency and hyper salinity, both in turn due to extremely reduced flow of Indus water thus reduced amount of silt reaching the delta. The degradation of mangrove ecosystem was noticed not only due to the local pressures of grazing and wood harvesting, but also due to erosion by sea. Full grown trees of *Avicennia* were found uprooted at many places due to wave action. This phenomenon may be attributed to the combined effect of lack of fresh sediment deposition, natural subsidence of land and general sea level rise due to climate change. It is obvious that without ensuring certain amount of Indus River freshwater going into the delta, the mangrove ecosystem of the Indus Delta would be destroyed in near future, depriving the country of all its fishery resources and livelihood and houses of local people forcing them to migrate to other areas. The carrying capacity of Keti Bundar was found to be quite poor with an average of 21.8 Ha/Au/Yr.

Keenjhar Lake was found to be the richest site floristically, with an α- diversity of 263 plant species in 55 families. Of these, one was Pteridophyte, 185 dicotyledonous angiosperms in 120 genera and 44 families, 77 monocotyledonous angiosperms in 44 genera and 10 families. Poaceae was the largest family with 51 species, followed by Fabaceae (20 species), Cyperaceae and Asteraceae (15 species each) and Convolvulaceae (12 species). *Cyperus* was found to be the largest genus with 9 species, followed by *Eragrostis, Heliotropium, Tamarix,* (6 species each), *Convolvulus, Euphorbia* and *Indigofera* (5 species each). Beside high diversity, another uniqueness of this site is a high number (70) of such species which are not found in any

other Indus For All Programme current sites. The dominant species of this site included *Prosopis juliflora, Blepharis sindica, Fagonia indica, Aristida adscensionis, Cynodon dactylon, Phyla nodiflora* etc. Fifty six species were recognized as wetland species and hydrophytes. The carrying capacity in 2008 survey was found to be extremely low with 57/Ha/Au/Yr. The major threats to the ecosystem were recognized as pollution (from upstream industries, agricultural fields, livestock farms and poultry farms in close vicinity of lake); will planned tourism, aquatic and terrestrial alien invasive species and overgrazing by livestock.

The Chotiari reservoir was the second richest site with an α ¯ diversity of 211 species in 123 genera and 49 families. Out of these 3 were Pteridophytes in 3 genera and 3 families, one Gymnosperm, 144 dicotyledonous angiosperms in 86 genera and 39 families, and 63 monocotyledonous in 33 genera and 6 families. The number of species exclusively found in this site was 40, second after Keenjhar. The dominant species of this site were *Calligonum polygonoides, Crotalaria burhia, Calotropis procera etc.* which are all tough xerophytes. Along water reservoir, 41 wetland species were recognized, but true hydrophytes were exceptionally few in number. The carrying capacity of this site was found to be extremely low in 2008 with an average value of 55 Ha/AuYr. It was recognized that the construction of Chotiari reservoir has badly affected the ecosystem by water logging and salinity due to water seepage from reservoir, destruction of thick forest by submersion, and loss of aquatic plants diversity due to changes in water level, dissolved oxygen, pH and methane emission form decaying vegetation. The major threats to this site were recognized as water logging and salinity, over grazing, and terrestrial and aquatic alien invasive species.

The α¯ diversity of Pai forest *i.e.* the total number of species was 122 in 87 genera and 34 families. Out of these, one was Pteridophyte, 94 dicotyledonous angiosperms in 66 genera and 31 families, and 27 monocotyledonous angiosperms in 21 genera and 3 families. The largest family was Poaceae with 21 species. However, this is the lowest number of grass species among all sites. Other larger families were Fabaceae (8 species), Amaranthaceae (7 species) and Euphorbiaceae (6 species). The dominant species of this site were found to be *Prosopis juliflora, Prosopis cineraria, Salvadora oleoides, Capparis decidua, Desmostachya bipinnata, Acacia nilotica, Suaeda fruticosa* etc. This indicates the extent of encroachment by the invasive species *Prosopis juliflora*. The carrying capacity of the ecosystem was quite low with an average value of 12 Ha/Au/Yr. The major threats to this ecosystem were recognized as deficiency of irrigation water, grazing pressure by livestock, illegal cutting of trees and the alien invasive species *Prosopis juliflora* which is replacing the native species.

Cumulatively in all sites, Poaceae was found to be the largest family with 36 genera and 68 species followed by Fabaceae with 13 genera and 27 species, Cyperaceae with 6 genera and 22 species and Asteraceae with 12 genera and 17 species. Other families were represented by less than 15 species per family. Among woody genera *Tamarix* was found to be the largest genus with 11 species, with its highest diversity in Keti Bundar (8 species). The total number of species in all sites (γ- diversity) comes to be 348 in 197 genera and 68 families.

Among locality pairs, Keenjhar and Chotiari have shown the highest value of Similarity Index thus the lowest β- diversity, and less similarity thus highest β- diversity was found between Keti Bundar and Chotiari. However, the value of similarity index have shown increasing trend with decreasing values of β- diversity over the survey years with more adequate sampling. The overall β- diversity of all sites comes to be 1.95 after 2008 survey.

The primary productivity of all sites was quite low, being particularly low in the winter season. It was, however in conformity with the usual average of arid lands, liable to vary drastically year to year according to rainfall. The carrying capacity was accordingly low, therefore, exposing the

ecosystems to the threat of desertification due to overgrazing. The large number of livestock poses tough competition to wild herbivores.

The significant findings of vegetation assessment over three years included three new species the floral world *(Tamarix, sporobolus Fimbristylis)* and a new species of *Tamarix,* new records including *Chenopodium opulifolium, Euphorbia helioscopia, Lotus krylovii* and *Tamarix szovitsiana*. Besides this, *Ranunculus scleratus, Potentilla henyii* and *Tamarix sarenensis* have been collected after a gap of 35-50 years.

Twenty endemic species were recognized from the province of Sindh, of which 10 are restricted to Sindh only and 10 occur in some nearby parts of other provinces, as well. Except 3 species all endemic species fall in the categories of rare to endangered, with 2 species of *Asparagus* already extinct. Three species of *Abutilon* and one sub-species of *Acacia nilotica* are endangered due to persecution and habitat destruction.

1. Introduction

The province of Sindh falls in the category of arid lands with scanty and unpredictable rainfall. The importance of the biodiversity of arid and semiarid lands is recently being increasingly recognized as these dry lands occupy more than 40 percent of Earth's land surface have to support more than one billion people (Hassan 2003, Donaldson *et al.* 2003). The natural flora and vegetation being the primary producers play the most pivotal role in every ecosystem by providing food and shelter to the natural fauna and livestock. In arid ecosystems, one of the most important ecological services of natural vegetation is the control or erosion. The process of desertification is known to be associated with decreasing species diversity and habitat degradation (Xueli and Halin 2003).

Sindh while situated in arid zone largely depends on the River Indus for its economic, ecological and social well being. Presence of mighty Indus in Sindh also somewhat ameliorates the otherwise hostile climate of the area in which biodiversity persists in healthier way. The Indus River traverses the entire length of Sindh, meandering and giving-off many natural and semi-natural lakes and water reservoirs thus giving rise to a mosaic of habitats such as aquatic, coastal, and riparian habitats. Riparian habitats are often notably species rich places, with a variety of microhabitats within which numerous plants species coexist (Swanson *et al.* 1988, Gregory *et al.* 1991; Urban *et al.* 2006).

Both the terrestrial vegetation along the banks and macrophytes greatly influence the aquatic ecosystems, as the detritus from the former contributes more than 90% of organic matter input, while the composition of the aquatic flora influences littoral phytoplankton, zooplankton, invertebrates communities and fish communities (Smith & Smith 1998; Nurminen 2003).

Indus River is one of the large rivers of the world and the largest river of Pakistan with a basin area of 963480 Km^2, a length of 2898 Km and a discharge of 269.1 Km^3 per year, it ranks 19^{th} in the world by basin area and length, and 17^{th} by volume (Archibold 1996). This river is crucially important for sustaining the people and economy of Pakistan. For this reason, the ecosystem of river, its associated lakes, and delta face tremendous anthropogenic pressure. The anthropogenic pressure is complex of factors, with the form of land-use having a great impact on species diversity of a given area (Sundik-Wojcikowska and Galeria 2005). This is why the need for vegetation surveys and cataloguing has become increasingly important in recent years (Ninot *et al.* 2000). Up-to-date information on biodiversity is critical for the proper management and conservation of any area, thus the first step towards conservation should be to compile a species inventory or check-list (Klopper *et al.* 2007). Inventorying is considered as fundamental starting point in the conservation and sustainable use of biodiversity while monitoring guides us how biodiversity changes with the passage of time due to natural and anthropogenic causes (Stork *et al.,* 1995). Generally, monitoring of biodiversity is almost non-existent in Pakistan (Khatoon & Ali, 2003, 2004). However, monitoring cannot be done without prior inventorying. Local inventories (α – diversity) ultimately help in understating and analyzing diversity at landscape (ß – diversity) and regional (γ – diversity) scales (Khatoon *et al.*, 2005).

The inventorying of plant biodiversity and vegetation studies has been conducted in four selected localities of Indus Ecoregion (Keti Bundar, Keenjhar, Chotiari and, Pai). The Indus Ecoregion lies almost entirely in the province of Sindh from its border with Punjab to the coast of Arabian Sea and is one of the 40^{th} most significant ecoregions on regional level for its ecological significance and representation of earth's biodiversity richness. The Indus Ecoregion partially or fully covers 18 districts of Sindh including Thatta, Badin, Hyderabad, Dadu, Nawabshah, Sanghar, Khairpur and Umer Kot. It includes the lower reaches of River

Indus, the riverine forests, freshwater lakes, brackish water, salt lakes and the Indus delta along with mangrove forests. The present studies have been conducted to provide a baseline for the conservation and sustainable use of biodiversity and for monitoring any change in the future due to natural and anthropogenic factors.

1.2 Objectives*:*

I. Inventorying of the species of natural flora in the selected habitats within each of the four Indus for All Programme sites to serve as baseline for monitoring any changes in environment and biodiversity in the future.

II. Conduct phytosociological studies for delineation of plant communities.

III. Assess the carrying capacity of representative programme sites.

IV. Analyze threats to natural vegetation and present recommendations for vegetation management and habitat recovery for long term biodiversity conservation of each site.

1.3 Literature Review:

Eco-region is defined as a "region which is relatively large unit of land or water that contains a distinct assemblage of natural communities, sharing a large majority of their species and ecologically in ways that are critical for their long term persistence" (Ahmed 2004). The concept of "Eco-region" stemmed from the WWF's Global 200 Eco-regions developed on science-based ranking of the earth's most outstanding terrestrial, fresh water and marine habitats to serve as a blue print. Indus Ecoregion has been identified as one of such sites in G200 based on its diverse spectrum of coastal, lowland and mountain vegetation and habitats. According to Archibald (1996), the Sahara Desert occupying 9 million km² in N. Africa extends through Egypt to the deserts of Arabian Peninsula which continues eastwards into Iran, Afghanistan and Pakistan, and finally terminates in Thar Desert in Pakistan and NW India. This is why the vegetation of Indus Eco-region is of Saharo-Sindian type (Stewart 1982, Ali & Qaiser 1986). While mentioning the Sindh flora, Stewart (1982) mentioned that "Sindh is a continuation of the great desert belt, south of the Mediterranean, stretches clearly across North Africa, Arabia and southern Iran to the foot of Himalayas along the Indus and its great tributaries. Some of these Saharo-Sindian plants are found in the Kashmir valley at 1600 m. This North African desert flora is also dominant in the Great Indian Desert to the south of Sindh and Punjab desert. In Balochistan it is found in the coastal plain and up to c. 1400 m". Sindh has four distinct vegetation zones viz., (i) Tropical Thorn Forest with small and sparsely scattered trees with little ground cover. The main plant species are Khabbar (*Salvadora persica*), *Salvadora oleoides*, Babool (*Acacia nilotica*), Ber (*Ziziphus mauritiana*), *Ziziphus nummularia*, Kandi (*Prosopis cineraria*) and Lai (*Tamarix* spp.). The original tropical thorn forest is, however, mostly replaced by the agricultural lands, diminishing many useful species of the forest like *Salvadora oleoides*. Therefore, the Tropical Thorn Forest in the subcontinent (Khan 1994), with its remaining parts is continuously falling prey to extending agriculture, forestry, human settlement etc. (ii) Reverine forests comprising *Acacia nilotica, Populus euphratica, Prosopis cineraria* and *Tamarix* spp. (iii) Wetland vegetation dominated by *Phragmites, Typha, Nelumbo, Nymphaea*, and other aquatic flora and (iv) Coastal vegetation comprised mainly by mangroves such as *Avicennia marina, Aegiceras corniculata, Ceriops tagal* and, *Rhizophora* sp. Stewart (1982) mentioned that Sindh is much like Egypt. It is a desert through which a great river flows and life of the region is dependent on the water of the Indus River as Egypt is on that of the Nile. Most of the area around Indus in Sindh roughly 70 – 80 miles on each side of the river is great alluvium plain. Most of the entire region in Sindh does not rise 200 m in elevation. There are areas of desert scrub which cannot be irrigated from the Indus due to higher levels and there are about 1200 square miles of riverine forests.

Stewart (1982) further mentioned that flora of Sindh is poor compared with that of rest of the areas of Pakistan because of fewer habitats and less climatic and altitudinal variations. In spite of this limitation, flora of Sindh is of great interest and there are many different habitats with rich plant biodiversity.

The history of plant collection goes back to 1838 in the British era with Major Nathaniel Vicary being the first plant collector. He was followed by Griffth (Sup't of Calcutta Botanic Garden Dr. David Ritchie), who collected during 1839-40 and J.E. Stocks (1848). The latter collected most extensively in Sindh and also in Balochistan (Stewart 1982). There is no checklist or flora exclusively for Sindh. From the older times Floras for various parts of Sindh are available such as "Flora of Indus Delta" (Blatter *et al.* 1929), "Plants of Karachi and Sindh" (Hasnain and Rahman 1957), "The Vegetation and Range Flora of Thar Desert" (Chaudhri and Chuttar 1966), "The Flora of Karachi" (Jafri 1966). Recently the "Flora of Pakistan" (Nasir & Ali 1969-1989, Ali & Nasir 1989-1991, Ali & Qaiser 1992-1998, 2000-2007) has covered Sindh along with other parts of Pakistan. However, the plants of Sindh are scattered in the 215 fascicles of Flora of Pakistan and it is not an easy task to get the whole picture of Sindh's flora from these fascicles. Besides this, some families are yet to be published while the earlier published families are in fact in need of revision. Even those published recently are based upon the collections done mainly in 1970s and 1980s; therefore do not represent the present ground realities in face of rapidly changing environmental conditions due to natural and anthropogenic factors. As a matter of fact, Floras can never be definitive as new facts, information, and new records are always coming to light (Hedge 1991).

1.3.1 Indus Delta

The Indus delta occupies a total area of 600,000 hectares, of which 160,000 hectares are occupied by water channels and creeks (Meynell and Qureshi 1995, Kella 1999, Keerio 2004, Mirza *et al*., 1983). The Indus delta, ranked seventh largest in the world, is unique by the fact that it experiences the highest wave energy among all river deltas in the world. During monsoon season (May-September), the delta front receives more wave energy in a single day than the Mississippi delta receives in the entire year (Wells and Coleman 1984).

The delta bears seventeen major and numerous minor creeks (Hoekstra *et al.* 1997, Anwar 2004). According to Blatter *et al.* (1929) every creek had been an outlet of Indus River at one or the other time in history. The most characteristic feature of Indus delta are the mangrove swamps on vast mud flats formed by sediment deposited by River Indus. Mangroves, variously described as "Coastal woodlands", "mangals", "tidal forests" and "mangrove forests", are the characteristic intertidal plant formations of sheltered tropical and subtropical coastlines (Duke 1992, Saenger 2002, Irfan and Khan 2001). Mangroves belong to different families of vascular plants. In fact there is no very hard and fast definition of mangroves, but usually woody intertidal species are regarded as mangroves. World over approximately 84 species in 39 genera and 26 families are recognized as mangroves, of which 63 exclusively occur in intertidal zone while 21 may extend beyond the upper tide levels therefore, variously termed as "non-exclusive", "back" or "associate" mangroves (Saenger 2002). Historical records tell that eight mangrove species were present in the Indus delta (Blatter *et al.* 1929), but at present time only three species (*Avicennia marina, Rhizophora mucronata, Aegiceras corniculata*) are found, of which *Avicennia marina* makes up to 95-98% of the mangrove forest (Meynell and Qureshi 1995, Hoekstra 1997, Anwar 2004, Ismail *et al.* 2006). On the entire coast of Pakistan, Indus delta bears the largest mangrove area with only small pockets on Makran coast. Till 1980s the mangroves were present on about 260,000 hectares of the Indus delta thus considered as the largest arid zone mangrove forests in the world, but in 1990s they dwindled to 160,000 hectares or even less (Meynell and Qureshi 1995, Anwar 2004).

Anwar (2004) mentioned that historically, mangroves in the Indus Delta were never managed scientifically rather used as hunting grounds by Talpur rulers and after creation of Pakistan they came under the control of the Board of Revenue which further distributed some land to Sindh Forest Department and the Port Qasim Authority. Hoekstra *et al.* (1997) stated that the people living in Indus Delta mangrove ecosystem are by birth Sindhi and belong to two main tribes; Mirbahar and Jats. Jats are further sub-divided into Dabbay and Faqirani. In Keti Bundar area people mainly belong to Baloch, Jat, Memon, Shaikh, Ganbeer, Badala, Dabla, Solangi, Sayed and Gugaand tribes. Most of the permanent settlements in Indus Delta are situated where drinking water is available. Some of the fishermen from such settlements reside temporarily in mangrove area either on their boats or in temporary structures. In Keti Bundar area settlements are situated either within mangroves or near inland.

Hoekstra *et al.* (1997) reported that climatically Indus Delta can be designated as subtropical maritime desert. There are two distinct seasons; summer (March – June) and winter (November to February). Average annual rainfall is about 221 mm and in some years virtually there is no rainfall during the monsoon season. Winds blow from the west from March to October and from north-east from November to January. During peak monsoon season, wind speed rises to an average of 8 knots. *Avicennia marina* attains about 10 m height in the regulalrly inundated areas. They further mentioned that mangrove vegetation is characterised by a woody plant formation consisting of *Avicennia marina*, *Ceriops tagal* and *Aegiceras corniculata*. However, density varies between places. *Avicennia marina* is the dominant composition and occurs as almost monotypic stand throughout the area. This species attains about 10 m height in the regularly inundated areas. With the increase in elevation and decrease in flooding frequency by the tides, the tree height reduces greatly and takes a bushy appearance. *Ceriops tagal* and *Aegiceras corniculata* are found on relatively high ground particularly along the raised levees. In the soft substratum flooded regularly by the tides, *Porterasia coarctata (Oryza coarctata),* locally known as Son grass, forms a grass vegetation type. This grass community is considered as a pioneer stage in mangrove succession. *Aeluropus insignis* (locally called Lunando grass); a halophytic grass also forms distinct vegetation type in the raised land. Hoekstra *et al.* (1997) and Suarez *et al* (1998) mentioned that salt marshes vegetation is characterised by halophytic vegetation consisting mostly of *Arthrocnemum indicum*, *Suaeda fruticosa* and *Tamarix dioica*. Their findings about the land vegetation types are given in table 1.

Table 1: State of terrestrial vegetation in Indus Delta

Land Vegetation Type	East Shah Bundar	Central Shah Bundar	West Shah Bundar Kharochan	Keti Bundar	East Karachi	Port Qasim
Mangroves	Dense	sparse	Sparse	Sparse	Medium	Dense
Mud flanks / Blanks	Large	Large	Large	Large	Medium	Small
Salt Marshes	Large	Large	Large	Large	Large	Small
Sand dunes strand	Small	small	Medium	medium	Small	Large

Haq (2006) reported that salinity causes unfavourable environment and hydrological situation that restricts the normal production in coastal areas in Bangladesh throughout the year. The factors responsible for the development of saline soil are tidal flooding, inundation of seawater and upward or lateral movement of saline ground water during dry season. To explore the possibilities of increasing potential of these saline lands for increased production of crops the appraisal of present status of land areas affected by salinity is pre-requisite.

Saifullah (1997) while discussing management of Indus delta mangroves mentioned that in fact management of coastal zone of Indus delta is the management of mangroves. As late as 1980s mangroves grew all along 240 km long coastline and occupied approximately an area of 600,000 hactares (40% of the entire tidal belt and 10% of the Indus delta fan) and they were rated as the 5th or 6th largest mangrove forests of the world and certainly the largest in the arid climate. However, due to extreme tampering in the environment both in the upstream area and the Indus delta itself, these mangroves are disappearing at a faster rate. He gave a detailed account of the economic, social and environmental benefits of mangroves and discussed various causes that have lead to the deterioration of this important ecosystem. Ismail *et al.* (2006) mentioned that heavy metals pollution is also among various threats that Indus delta mangroves are facing. This threat has emerged in the last two decades in areas situated in vicinity of industrial and agricultural activities. Ismail *et al.* (2006) further mentioned that sediments of Mangroves are the biogeochemical sink for heavy metals accumulation due to various factors such as presence of high concentration of organic matter and sulphides. According to (Singh *et al.* 2002, Aziz and Khan 2000, Hegemeyer, 1997, Popp, 1994, Roth, 1992, Tomlinson 1986) the sustained and ample supply of river freshwater along the deltaic coast and its mixing with the seawater through tides is a source of species richness. The diversity of species composition evolves as a result of varying degree of adaptations to saltwater/brackish water.

Estuaries present a unique coastal ecosystem with typical environment and biodiversity which is different from general coast. Estuaries represent regions where fresh water of river mixes with the sea water (Khatoon *et al.* 2005). River estuaries are regarded as the areas where juvenile fish abode due to rich food and absence of predators. Both the terrestrial vegetation along the banks and the macrophytes greatly influence the riverine and estuarine ecosystems as the detritus from the former contributes more than 90% of organic matter input while the aquatic flora influences littoral phytoplankton, zooplankton, invertebrate communities, and fish communities (Smith and Smith 1998, Nurminen 2003). Sohag (2001) defined estuary as the area where river water mixes and dilutes the sea water. He pointed out that it is difficult to precisely locate the merging point of river and sea water due to varying river discharges, tidal actions and wind forces. However, in case of Indus, the upper limit of estuarine area starts at certain distance downstream of Kotri Barrage.

Blatter *et al.* (1929) compiled “The Flora of Indus Delta” which not only provides a historical overview of the vegetation in deltaic region but also enables plant scientists to compare recent floristic composition with that of 1929 and examine vegetation changes, if any, with respect to human and natural causes. They documented an overall 332 plant species in the Indus delta (279 indigenous and 53 introduced) belonging to 220 genera and 61 families. Out of these, 211 and 67 species belonged to dicotyledons and monocotyledons, respectively. Authors summarized dominant plant families in the Indus Delta in the following table. The data reveal that Gramineae and Leguminosae were the largest families representing 14.3 % and 8.2 % plant species, respectively and Cucurbitaceae and Solanaceae being the smallest, each representing only 2.5% of the plant species of the Indus Delta (Table 2).

Table 2: Floral Composition of Indus Delta in 1929 (Blatter *et al.* 1929)

Families	Species	Percentage of the total	Families	Species	Percentage of the total
Gramineae	40	14.3	Malvaceae	10	3.5
Leguminosae	23	8.2	Boraginaceae	9	3.2
Compositae	18	6.4	Tiliaceae	8	2.8
Convolvulaceae	16	4.6	Asclepiadaceae	8	2.8
Euphorbiaceae	11	3.9	Chenopodaceae	8	2.8
Amaranthaceae	11	3.9	Cucurbitaceae	7	2.5
Cyperaceae	11	3.9	Solanaceae	7	2.5

Blatter *et al.* (1929) further mentioned that out of 279 species that made up the flora of the Indus Delta, 226 species were found in other parts of Sindh, as well. There were only 54 species which are not found in extra-deltaic Sindh. They added further that there were 6 endemic species that included *Gossypium bakeri*, *Asparagus deltae*, *A. gharoensis, Periploca* sp., *Convolvulus* sp. and *Andrachne* sp. The latter three were believed to be new species which they planned to describe later.

Fig: 1

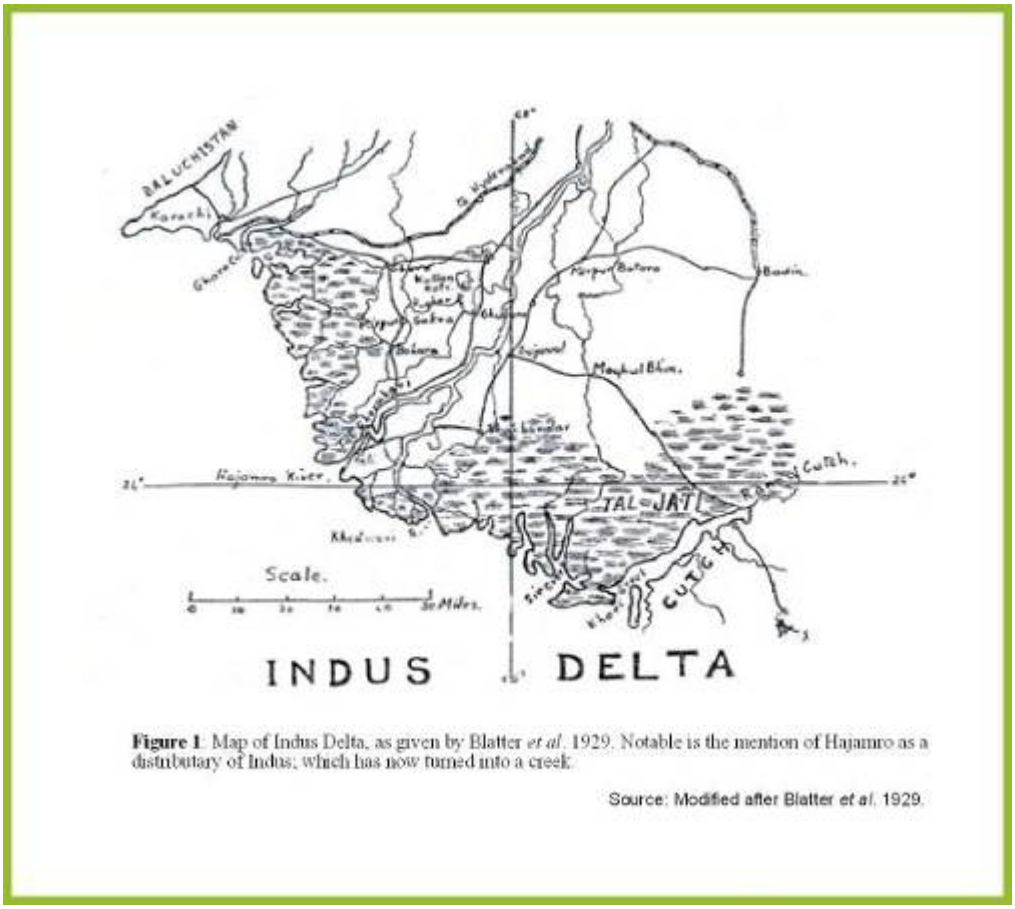


Figure 1. Map of Indus Delta, as given by Blatter *et al*. 1929. Notable is the mention of Hajamro as a distributary of Indus; which has now turned into a creek.

Source: Modified after Blatter *et al*. 1929.

Prominent genera in Indus delta included *Euphorbia, Heliotropium, Cyperus, Abutilon, Indigofera, Tamarix, Grewia, Corchorus, Crotalaria, Acacia, Ipomea, Solanum, Barleria, Suaeda, Asparagus, Saccharum, Echinochloa, Eragrostis and Eleusine.* They treated Mangroves of Indus Delta separately and mentioned presence of eight species that included *Rhizophora mucronata, Rhizophora conjugata Ceriops candolleana, Ceriops roxburghiana, Bruguiera gymnorhiza, Sonneratia acida, Aegiceras majus and Avicennia officinalis.* They provided a detailed account of species with respect to different physiographic units and covered vast area now comprising Thatta district (including current Badin district) and up to the boundaries of Karachi and Hyderabad districts. They mentioned that in Keti Bundar species like *Tamarix troupii, Thespesia populnea, Ipomoea aquatica, Peplidium humifusum, Tecomella undulata, Phyllanthus distichus, Cocos nucifera, Phoenix dactylifera, Pandanus tectorus, Cyperus tegetum, Echinochloa crus-galli, Phragmites Karka and, Oryza coarctata were widely present.* They mentioned that in Hajamro River (now creek) they found *Aeluropis villosus* grass and eight species of mangroves namely *Rhizophora mucronata, Rhizophora conjugata Ceriops candolleana, Ceriops roxburghiana, Bruguiera gymnorhiza, Sonneralia acida, Aegiceras majus and Avicennia officinalis*. They also reported dense forests of *Populus euphratica* and *Acacia farnesiana* in Hajamro creek which are absolutely absent now.

1.3.2 Wetlands:

The International Convention on Wetlands defined the wetlands as, “Area of marshes, fens, peat lands or water, whether natural or artificial, permanent or temporary with water, that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6 meter” (Simon 1993, Singh *et al.*, 2002). The definition given by IUCN (1991) reads as “submerged or water saturated land, both natural and man made, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed 6 meter”. Imran & Khatoon (2005) mentioned that wetlands are those areas where inundation must take place at least for 14 days and saturation for 60 consecutive days. They further mentioned that there are various types of wetlands such as wooded land, peat land, flood plains and mangrove swamps, etc. Each wetland is rich in floral diversity; however, it is hard to define any wetland plant. According to a broader definition, all those plants that at least spend part of their life cycle in partially submerged conditions are regarded as aquatic or wetland species. They further discussed that in older times wetlands were considered as places where mosquitoes and other harmful insects reside but now with the growing understanding, these areas have been recognised due to their diverse ecological services and useful living resources such as reducing silt load from incoming waters, reducing erosion by buffering wave action and harbouring fish, medicinal and edible plants and maintaining healthy web of life. Mitsch *et al.* (1993) described the scientific understanding about the wetland has increased and so have their function. Authors mentioned that wetlands are amongst the most productive ecosystems often referred to as “biological supermarkets” because of the rich bio-diversity they harbour.

A number of scientists have highlighted the importance of wetlands as being valuable educational tools and enclosed experimental areas. They mentioned that these important water bodies act as a valuable wildlife refuges providing over-wintering facilities for migratory and resident birds and provide them feeding, nesting and resting grounds. They also support local economy and cottage industries, sustain agriculture, industry, tourism and commerce, and provide outstanding opportunities of recreation for both local communities visitors (Barbier 1989, Barbier *et al.* 1996, Scodari 1990).

Amjad and Kidwai (2002) mentioned that coastal and estuarine wetlands are of high value to mankind and environment where socio-economic activities are highly concentrated. These wetlands serve as habitats for spawning, rearing and nursery grounds for production of shrimps, lobsters and fish and also provide breeding, rearing, staging and wintering grounds for a number of globally important fish, shellfish species and millions of waterfowl. Bush (1997) stated that wetlands clean impurities from the system and can be regarded as the kidneys of the landscape. Sindh province has many wetlands, which are either connected with River Indus or too many other seasonal rivers and streams. Some of these wetlands are of international importance such as Ramsar Sites like Haleji and Keenjhar Lakes. A large number of migratory birds visit these water bodies for wintering. Although fish and other aquatic fauna and the water birds of these wetlands have been documented but inventory of the plant species, which are primary producers, is lacking. Wetlands in general are more diverse and more productive than other terrestrial ecosystems. The greater diversity is due to greater number of ecological niches because of water depth and nutrient levels that give rise to various vegetation zones such as free-floating hydrophytes in the deeper water, emergent aquatics rooted in mud towards the margins of wetlands, and semi-aquatic plants at the margins of the wetlands (Bush 1997, Khatoon & Ali 1999). The floral diversity supports myriad other life forms, ranging from zooplankton to insects and other invertebrates, fish, birds and mammals. Apart from housing unique wildlife, wetlands also provide a number of other benefits such as reducing floods, erosion control and storing carbon and nutrients in the forms of biomass and serving as biological filter to remove the pollutants from the system thus

purifying the water of Lakes and rivers (Khatoon & Ali 1999). Kazmi *et al.* (2006) described that wetlands are the most productive environments and cradle of biodiversity. Wetlands provide countless benefits ranging from rich biological diversity to improved water quality, water storage and ground water recharge. Authors mentioned that wetlands in Pakistan cover 9.7% (78,000 km^2) of the total area; however, this important resource is under tremendous pressure of degradation. Kazmi *et al.* (2006) carried out a GIS-based wetlands inventory of the lower Indus for monitoring the spatial and temporal changes in the wetlands over the last ten years. Amjad & Qidwai (2002) regarded wetlands as "supermarkets" based on their rich biodiversity, extensive and rich food webs and high productivity. Authors mentioned that it was 1967 when the importance of wetlands in Pakistan was first brought to the international community and in 1976 Pakistan became signatory to the Ramsar Convention. Authors in their study presented detailed account of the fresh water, brackish water and coastal wetlands of Sindh highlighting not only biodiversity profile of selected wetlands of the area but also the issues that are confronting these important ecosystems in terms of their sustainability and environmental quality.

Leghari *et al.* (1999) conducted a study on biodiversity of Chotiari reservoir and mentioned that Chotiari reservoir is formed of a group of sub-tropical lakes and is located about 30 – 35 km on the eastern side from Sanghar town. The reservoir covers an area of about 37 km^2 and after completion of the entire work it will cover about 86 km^2 areas. The reservoir is interconnected between several lakes namely Bakar, Gun Wari, Tajar, Phuleli, Seri and Sao Naro. These lakes are surrounded by Nara canal, which is a major source of water to these lakes. On the eastern side, the reservoir extends into the Thar Desert. The reservoir has a depth from 3 to 26' with sandy, silty and muddy bottom, which provides a suitable surface for the growth of algal and aquatic plant species.

Leghari *et al.* (1999) further reported that very little work is reported on the Chotiari reservoir. They mentioned that on the moist, water logged and swampy soil as well as in shallow water area species like *Typha elephantiana, Typha dominghensis, Phragmites vallotoria, Cyperus* spp*., Polygonum barbatum, Fimbristylis* spp*., Scripus* spp*., Ipomoea aquatica, Marsilea minuta, Equisetum debile* and *Riccia* spp*. a*re found. Some of these species are used in packing and cottage industry for making mats. In the lakes there is a thick growth of submerged vegetation with floating leaves and are important in the nutrient cycling and respiratory gases. They often provide very dense habitats, which supply food and shelter to small organisms such as fingerlings and zooplankton. These plants also serve as a food source of migratory waterfowl and fishes. The major submerged plants are *Ceratophyllum demersum, Najas* sp*., Utricularia auro, Potamogeton* spp*., Hydrilla verticillata, Myriophyllum tuberculatum* and *Vallisneria spiralis.*

In the shallow and deep water there is growth of plant *Nelumbo nucifera* and *Nymphaea lotus*. The parts of these plants are used as human food. The plants floating on the water surface include species like *Riccia carporus, Potamogeton natans, Azolla pinnata, Salvinia molesta, Spirodella polyrhiza* and *Lemna* sp.

1.3.3 Riverine Forests

According to Wani *et al.* (2004) riverine forests occupy 0.332 million hectares area (m ha) in Pakistan that is about 7% of total forest in forestland. The Sindh province owns 0.272 m ha Riverine forests, which is about 82% of total riverine forest area in the country. These figures depict that the Sindh province is rich in riverine forests. Riverine forests are one of the important ecosystems of Sindh. All these forests along River Indus used to get annual inundation during monsoon before the construction of dykes along Indus. Khan & Repp (1961) mentioned that ecological conditions in these forests are very favourable in the sense that annual flooding leave the soils in these forests saturated for rest of the year for luxuriant plant growth. They further stated that by March, seven months after flooding, soil still have

18% moisture content by fresh weight. The vegetation in riverine forests is much influenced by the frequent change in erosion and deposition due to changing course of the *River Indus*. The pioneer vegetation on newly deposited soils consists of species like *Saccharum bengalense*, *Saccharum spontaneum, Tamarix dioica, Tamarix indica and Populus euphratica.* Climax vegetation, however, is comprised of *Acacia nilotica, Prosopis cineraria* and *Cynodon dactylon.* Under arid conditions vegetation is comprised of species like *Prosopis cineraria, Salvadora persica, S. oleoides, Capparis decidua, Acacia senegal, A. jacquemontii, Cymbopogon jawarancusa, Aristida* spp. and *Ziziphus nummularia* etc. Champion *et al.* (1965) described the similar trees and shrubs of southern Sindh. During their visit to riverine forest of Rajri situated at 20 miles north of Hyderabad, they found 20 – 25 years old graceful trees of *Populus euphratica* of 5 – 6 feet girth. Unfortunately, today we do not have even such stretch of vegetation in the entire lower Indus region that can be regarded as 'forest'. Ahmad (1953) described that forests in Sindh are two types; one that are situated inside flood embankment along River Indus are called 'Riverine Forests' and those which are situated outside embankment are called 'Inland Forests'. Riverine forests are further sub-divided into one called Pakko situated away from riverbank and other, which are situated near to the riverbank on sand and silt deposits and called Kacho forests. Kacho area is flooded even with little rise in the river. Author mentioned Babul (*Acacia nilotica*), Kandi (*Prosopis cineraria*), Bhan (*Populus euphratica*) and Lye (*Tamarix aphylla*) as the major tree species of riverine forests. While discussing the historical background of riverine forests of Sindh, Ahmad (1953) mentioned that before construction of Lloyd Barrage (Sukkur Barrage) during 1932-33, all the forests were open to inundation and there was plenty of water for forest growth. Forestry was considered as easy task just broadcasting the seeds of *Acacia nilotica* before Aabkalani (flood) season and clear felling the crop after completion of crop rotation. After construction of Sukkur Barrage a protective bund along River Indus was constructed to safeguard the irrigation network, communication network and agricultural fields. By doing so some of the riverine forests falling outside the bund were deprived of floodwater from the River Indus. Such forests are termed as the Inland Forests (Ahmad 1953, Khattak 1976). Qadri (1955) mentioned that one of the geographical features of Sindh is the River Indus that flows on a ridge almost through the axis of this region, with the country sloping away from this on both sides. On account of this unique feature, the countryside is always flooded when the water level in the river attains dangerous heights. To protect the countryside from floods, earthen banks were constructed at about 12 to 25 miles apart and generally the activities of river are contained within these bunds. The land in between such embankments are regarded as riverine forests and stretch over about half a million acres and are under the control of Forest Department. Qadri (1955) further mentioned that on an average 18000 acres of riverine forests are eroded every year by River Indus. However, the river forms almost equal amount of area every year, as well. Thus such erosions and accretions continue every year. Khattak (1976) while describing the history of riverine forests in Pakistan mentioned that major tree species in the northern zone in riverine forests is Kandi (*Prosopis cineraria*) while in southern zone, Babul (*Acacia nilotica*). Bahan (*Populus euphratica*) and Lai (*Tamarix spp*.) occur in zones, former on fresh alluvium and the latter in low lying areas. Babul requires inundation of about 2 – 4 feet annually for adequate growth and is replaced by Kandi in high lying areas, which do not get inundation to this depth. Kandi predominates in the northern zone due to incidence of frost and low inundation as compared to the southern zone. Khattak (1976) further mentioned that edaphic factors in riverine forests generally determine the productivity of the forests and the species composition. Since edaphic factors keep on changing, therefore, it becomes difficult for long term planning of these forests.

Sohag (2001) described that riverine forests are an important land use closely associated with soil resources, water management, wildlife conservation and fisheries in addition to being an important sources of food and fodder. The trees lying on the flood plain frequently require floodwater for their growth. However, frequency of such discharges of the river has considerably reduced after the construction of upstream hydraulic structures. Due to gradual

decrease of inundation, riverine forest area is shrinking alarmingly while less salt tolerant species have almost disappeared.

1.4 Materials and Methods:

The methodology of this study is comprised of the following steps;

I. Comprehensive review of literature of vegetation, ecology, socio-economic conditions and past management approaches of each site.

II. Detailed vegetation survey of the study sites for taxonomic and phytosociological analysis.

III. Brief socio-economic overview to determine the impact of anthropogenic activities on the natural vegetation.

IV. Working out the forage production, carrying capacity / grazing capacity in different parts of the study sites.

1.4.1 Floristic Survey

Extensive vegetation surveys were carried out during fall season of 2006 (September 16 – 22), summer season of 2007 (July 23 to August 09) and spring season of 2008 (February 01 – 14) of the four programme sites. GPS (Global positioning System) was used in determining exact location of the sampling points. The species were identified with the help of various Floras (Jafri, 1966; Ali & Nasir 1989-1991; Ali & Qaiser, 1992-1998, 2000-2007; Nasir & Ali 1970-1989; Matthew, 1981-83; Batanouny, 1981; Boulos, 1991; Shetty & Singh, 1987 & 1991; Bhandari, 1978; Qureshi, 2004; Stewart 1972). The voucher specimens are deposited in the Karachi University Herbarium (KUH).

1.4.2 Phytosociological Survey

Field vegetation parameters like plant composition, cover, frequency and density were recorded along each transect line of 50 m using the line intercept method (Canfield 1940, Mueller-Dumbois & Ellenburg, 1974; Kent & Coker, 1992) and placing 1 m^2 quadrat at every 10 m interval on the same transect. Plant biomass was assessed by clipping the palatable vegetation falling in each quadrat and then taking mean biomass of 5 quadrats of each transect (Anon 1962, Anon 1968, Thalen and Junk 1979, Cook & Stubbendieck 1986, Saeed *et al.* 1987, Rashid *et al.*, 1988, Bonham 1989, Khan *et al.* 1989, Marwat *et al.* 1990, Wahid 1990; Dasti & Agnew 1994). In case of grasses, clipping was carried out leaving 30 cm stubble height while in case of palatable shrubs and trees only fresh growth of current year was removed (Holechek and Briske 1989; ESCAP 1994). The fresh samples of clipped vegetation were oven dried at 60 ^{o}C for 48 hours to ascertain the dry matter yield (DMY) for each sample. The DMY was then calculated on hectare basis.

Cover, composition, frequency, relative cover, relative frequency, and relative density were determined using following equation (Smith, 1974; Shaukat *et al.* 1976; Chul & Moody 1983; Shukla & Srivastava 1992, Smith & Smith 1998).

$$\text{Cover (\%)} = \frac{\text{Total intercept length of species}}{\text{Total transect length}} \times 100$$

$$\text{Species Composition (\%)} = \frac{\text{No of individuals of a species}}{\text{Total no. of individuals of all spp.}} \times 100$$

$$\text{Frequency (\%)} = \frac{\text{No. of qdts in which a species occurred}}{\text{Total no. of quadrats sampled}} \times 100$$

$$\text{Species Relative Cover (RC)} = \frac{\text{Total intercept length of a sp.}}{\text{Total Intercept length of all spp.}} \times 100$$

$$\text{Relative Freq. (RF)} = \frac{\text{Frequency of a sp.}}{\text{Total frequency of all spp.}} \times 100$$

$$\text{Rel. Density (RD)} = \frac{\text{Total individuals of a spp.}}{\text{Total no. of plants of all spp.}} \times 100$$

After assessing the above-mentioned parameters, importance value (I.V.) for each species in each sample was calculated as under:

$$\text{I.V.} = \text{Rel Cover} + \text{Rel. Freq.} + \text{Rel. Density}$$

Summed Dominance Ration (SDR) for each species was calculated using following formula.

$$\text{SDR} = \frac{\text{I.V.}}{3}$$

On the basis of Importance Value or SDR, sampled vegetation was delineated into different plant communities. The community within each stand was named after the species having highest Importance Value irrespective of its habit. When two or more species closely approached each other in order of Importance Value, the community shared the names of these dominants. The name of the species with highest I.V appears first followed by other dominant species. The generic names of the dominants are used for naming the community provided they do not overlap. Species other than the dominants were classified into co-dominants, associates and rare. During the vegetation sampling, phenology of the plant species was noted and photographs taken. Soil samples at 30 cm depth were also taken for subsequent analysis of macronutrients and soil texture.

1.4.3 Measurement of Carrying Capacity:

Carrying capacity refers to the maximum number of individuals of a species that can be sustainably supported by the resources of an ecosystem for an indefinite period (Bush 1997). For livestock, it may be defined as the maximum stocking rate possible without inducing damage to vegetation or related resources such as soil, water and wildlife (Huss., 1979).
For calculating “Carrying Capacity” following steps have been taken into account (ESCAP 1994).

- Determined available dry matter forage (kg/ha) for each plant community.
- Worked out animal intake considering one cow weighing 350 kg as one animal unit (AU) that requires 7 kg dry matter forage / day or 210 kg dry matter forage per month or 2520 kg dry matter forage/year.

As a general rule, 60% of the available forage was considered as “Proper Use Factor (PUF)” considering “take half and leave half”

Carrying capacity was calculated in terms of number of hectares required for sustainably supporting one animal unit per year.
Following formula was used to calculate carrying capacity

$$\text{Carrying Capacity (Hectare/AU/Year)} = \frac{\text{Animal Unit forage requirement kg/year}}{\text{Available forage kg/ha}}$$

1.4.4 Multivariate Analysis:

The cover estimates of all the species recorded from the programme sites were examined using Two Ways Indicator Species Analysis (TWINSPAN), as a classified technique following the procedures of Hill and Similauer (2005).

1.4.5 α, β and γ-Diversity:

The division of diversity into alpha (α), beta (β) and gamma (γ) components, to characterize diversity on different scales was first proposed by Whittaker (1972). Alpha diversity is within-area diversity, measured as the number of species occurring within an area of a given size. Gamma diversity is also a measure of within-area diversity but it refers to overall diversity within a large region or biodiversity at the landscape level. Beta diversity is the degree of species change along a given habitat or physiographic gradient, as such it is a measure of between-area diversity. It is normally represented in terms of the similarity index or of species turn-over rate (Kalin-Arroyo *et al.* 1995, Smith and Smith 1998, Al-Sheikh and Ghnaim 2004, Jafari *et al.* 2004).

α, β and γ-diversity were measured in terms of species richness, *i.e.,* the number of species irrespective of the relative abundance of individual species. Therefore α – diversity is simply the number of species in one locality, the γ-diversity was calculated by adding the four α – diversities (*i.e.,* number of species in each locality or study site) but avoiding duplicate counting of species common to two or more localities.

The similarity index (CC) between locality pairs was calculated by the formula:

$$CC = 2S_s / S_j + S_k$$ (Sørensen 1948)

Where S_s is the number of species common to both the localities, while S_j and S_k are the number of species in locality 1 and locality 2, respectively.

The β – diversity was calculated as $\beta = \gamma/\bar{\alpha}$ or $BD = S_c / S$, in which S_c is the number of species in a composite sample (combining α samples) and S is the mean number of species in α-samples (Whittaker 1972). For comparing locality pairs, S_c was taken as the total number of species in the two localities excluding duplicate counting of shared or common species, while S was calculated irrespective of duplication.

1.4.6 Soil Analysis

Composite soil samples were taken at 15 to 30 cm depth from at least five selected transects from each of the four sites during vegetation surveys of 2007 and 2008. These samples were analyzed to determine physical (soil texture) and chemical parameters like EC, pH, Organic matter, P and K.

1.4.7 Satellite Remote Sensing Based Forest Change Mapping and Monitoring of Mangrove Forests of Keti Bundar.

GIS team of WWF – Pakistan was facilitated by the Indus For All Programme to undertake Satellite Remote Sensing Based Forest Change Mapping and Monitoring of Mangrove Forests of Keti Bundar during February 2008. Material and Methods and the findings of this study are included in this report separately at pages 33 – 49.

1.4.8 Problems and threats:

Problems and threats to each site were also recognized based on discussions with local people, concerned government officials, personal observations and literature survey; and suggestion/recommendations were made for their mitigation.

2 - Keti Bundar
Coastal / Deltaic Ecosystem

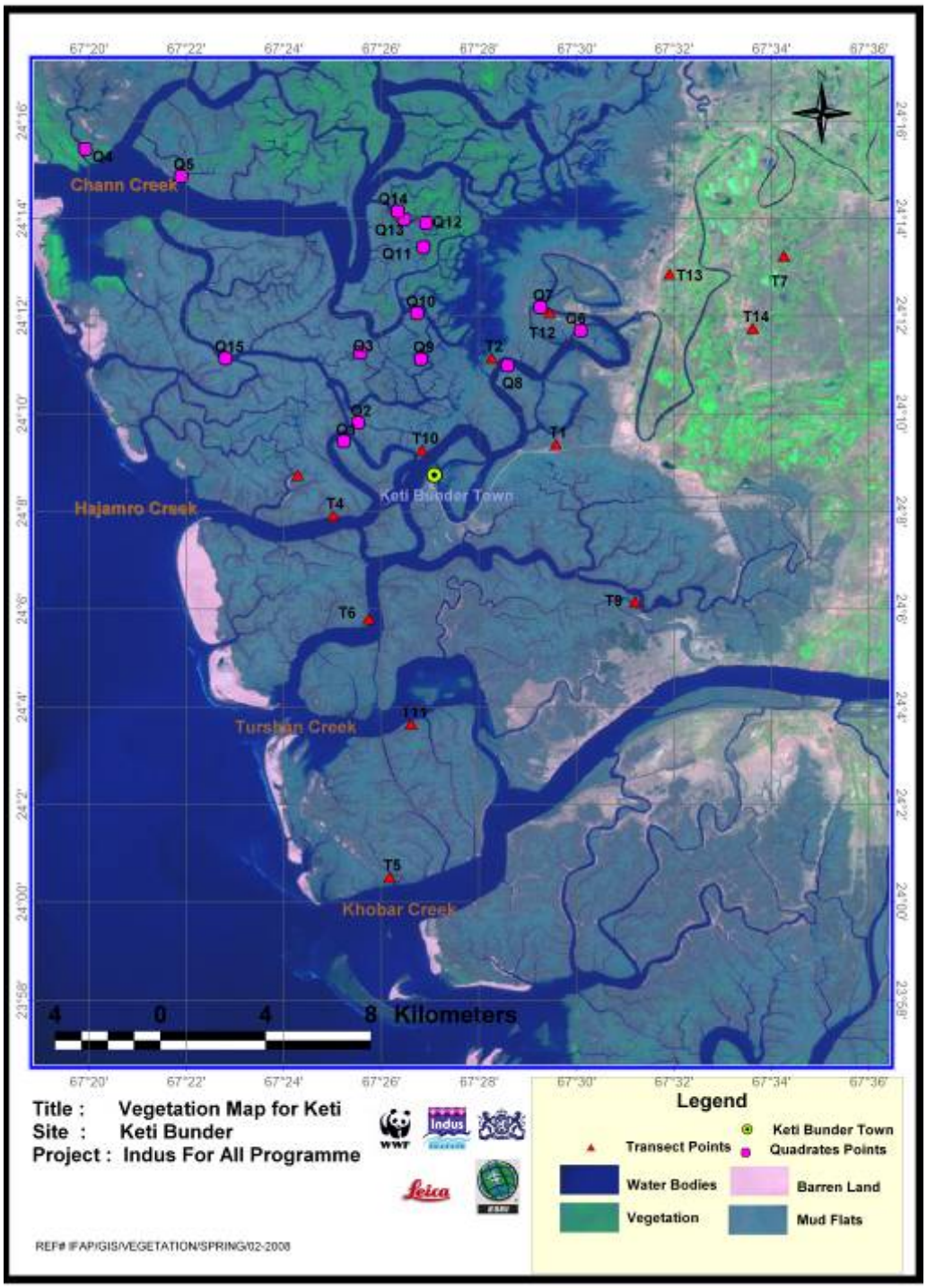


Figure 2. Satellite image of Keti Bundar Programme site showing major creeks

2.1 Brief History of Keti Bundar

Keti Bundar is located at a distance of about 200 km SE of Karachi in Thatta district of Sindh province. It is a Taluka (Tehsil) of Thatta district and consists of a total of 42 dehs (cluster of villages) that spread over a total area of 60,969 hectare. It is believed that the sea has engulfed 28 dehs and the total affected area in Keti Bundar is around 46,137 hectare (WWF 2004). Hoekstra *et al.* (1997) mentioned that Keti Bundar Tehsil includes a total of 19 Dehs and 29 villages while total human population is around 12000.

Historically Keti Bundar was a port city before the construction of any dams and barrages on Indus river. At that time river was navigable up to Thatta and even upwards.

At present, it is one of the major towns along the Pakistan coastline that is facing environmental degradation and loss of livelihood opportunities for the locals. Local elders mention that the location of Keti Bundar town has changed thrice during the past 70 years due to progressive intrusion of the seawater. There are four major creeks in the area viz. Chann, Hajamro, Khobar and Kangri with innumerable small creeks. For sweet water (drinking and farming), Keti Bundar and other coastal region depend entirely on Indus River and its distributaries.

Keti Bundar is located in Indus Delta experiencing warm monsoon climatic regime. Mild winters extend from November to February while summer season extends from March to October. Most of the annual precipitation falls during monsoon, which is erratic in distribution. Mean annual rainfall is 220 mm. January is the coolest month with minimum temperature of 9.5 ^{o}C while in June – July minimum and maximum temperatures range from 23 ^{o}C – 26 ^{o}C and from 30 ^{o}C - 36 ^{o}C, respectively. Humidity is generally higher in the morning than in the afternoon. It also varies from place to place depending upon the proximity to the sea. Wind is another important feature of coastal zone. It is variable and is faster during summer (7.4 to 20.5 km/h) than winter (Qureshi 1985).

Before construction of upstream barrages, river water used to reach the tail end during low tides round the year. However, upstream dams and barrages have considerably reduced the river flow to the extent that Kharo Chan and Shah Bundar area that had good agrarian economy in the past and produced plenty of high quality red rice, are now facing acute water shortage. During aabkalani (flood season), water is stored in ponds for subsequent human and livestock use. The agriculture has now deteriorated due to water logging and salinity of lands. During off season (May to August), local people were dependent on agriculture practices in the past and fish during other months of the year (Qureshi 1985). Scarcity of fresh water in the area from the Indus and seawater intrusion into the land has been degrading the area.

Figure 3 - Camels inside sea water in Keti Bundar

Communities in and around main creeks in Keti Bundar area have cattle, buffaloes and camels. Camels have popularly supposed to have aversion to water and not to thrive in damp areas but in Delta region, camels feed on mangrove foliage, wading in the mud and swim in the creeks (Hoekstra *et al.* 1997). Faqirani Jat community in Keti Bundar kept majority of the camels. During monsoon season, camels of inland communities are also grazed in creeks

area. According to one estimate there are about 5000 camels in mangrove areas (Hoekstra *et al.* (1997), however, Qureshi (1985) reported a total of 16,000 in the entire Delta region. Correct estimates are still required particularly in creeks adjacent to Keti Bundar where lot of camel grazing is obvious. Camels are generally kept to raise cash income through sale of one year old males. These animals are also kept for sacrifices on Eid festival. Milking of camels is generally for family consumption. Camels generally browse *Avicennia marina* foliage, however, in Kharochan area they also graze on grasses growing on mud flats. In mangrove area, camels are not herded and they keep on grazing free. Drinking water to camels is provided through boats. Camels stay permanently in mangroves year-round except for two months (June – July) when they are moved to some high lying areas near the sea for mating. Some of the herders reported to move camels to an open area during June/July due to presence of biting flies in mangroves (Hoekstra *et al.*1997)

The earlier authors have described two systems of mangrove management; formal and non-formal. In the formal system, Forest Department issues permits to local communities in 'Protected Forests' in exercise of their customary rights for collection of wood and livestock grazing against a nominal fee. However, neither such fee has been collected for the last 15 years nor access been denied to any body except replanted areas (Hoekstra *et al.*1997). In non-formal system of management, Jat community being more influential in exploitation of vegetation and fish resources of mangrove ecosystem have sub divided the mangrove areas of Keti Bundar among villagers. An island allocated to a particular village is permanently utilised by that village for grazing camels. When such islands become devoid of vegetation due to continuous grazing, they are allocated another island.

2.2 State of Biodiversity

2.2.1 Natural Vegetation: Keti Bundar being a deltaic region mainly consists of Mangrove forests. These forests are managed by Sindh Forest Department. They fall under the category of "Protected Forests" vide West Pakistan Government Notification No. S.O.A. (X) F&A/581X-(32) dated August 29, 1958 and the land, water Lakes and dhoras in Keti Bundar falling under the jurisdiction of this notification are regarded as Wildlife Sanctuary vide Government of Sindh Wildlife & Forest Department Notification No. WL&FT (DCF-GEN-269).77 dated September 25, 1977.

In Keti Bundar, mangroves cover an area of 40874 ha out of which 14733 ha area falls under dense mangroves while remaining area constitutes normal and sparse vegetation (Qureshi 1985). Dense forests are found in narrow stretches or in blocks along creeks with profuse growth of *Avicennia marina* locally known as Timer. Qureshi (1985) mentioned that eight species of mangroves have been reported to occur in the area but four species have been lost from Indus Delta including Keti Bundar during the past 70 years. Of the remaining species, only *Avicennia marina* constitutes major mangrove spp proportion *i.e*., 95% on the islands of the creeks while others such as *Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculata* have only 5% spread on the islands of the creeks. The locals use mangrove trees for fodder and fuel wood, camel browsing and hut making. Mangroves are the breeding ground for variety of fish shrimps, crabs and other invertebrates. They are also of great significance as a source of nutrients for fisheries. Hence, the livelihood of the community is correlated with the health of mangrove and is important to the local and national economy.

The inland areas also mostly have halophytic vegetation consisting of Chenopods, *Tamarix species* and *Salvadora persica.*

2.2.2 Agriculture: Although agricultural practices are not very common, yet vegetable, betel leaf, sugarcane, wheat, fruits (chiku, banana, mango, water melon) are grown in the inland area of Keti Bundar taulka.

2.3 Livelihood/ Social aspects

Majority of population are fishermen and belong to Baloch, Jat, Memon, Shiekh, Dabla, Solangi, Syed and Gug tribes. Traditionally agriculture, livestock and fishing were three major sources of livelihood of the community of this area. Due to reduction in freshwater supplies and seawater intrusion into the land, the agriculture of inland areas is on decline causing high pressure on fishing, grazing and exploitation of mangroves for fuel and timber. Presently there are three dominant sources of livelihood which include fishing about 90%, agriculture and livestock rearing about 8% and services in various sectors about 2%. The women of the area have more freedom as compared to other agricultural and pastoral communities; however, they are not involved in livelihood activities and are responsible mainly for household chores and the livestock. People are mostly illiterate and their economic conditions look poor. Mostly the population resides on the creek banks or near mainland. The education level of people is very low and their hygienic conditions are not satisfactory.

Indus for All Programme carried out socio-economic assessment in 34 villages of Keti Bundar situated inside creeks as well over inland area (Annexures A - VII to A - XV). A quick view of the village profiles indicates that predominance of fishing and net making occupations are most obvious of these villages. Village Faqiriani Jat is famous for camel rearing and also has well known for artisans who undertake boat painting and engine repairing work. Due to out-migration of households from Hajamro and Chann creeks to mainland areas, a new village Meero Dablo (36 HH) has come into existence just outside the Keti Bunder protective bund and in front of the Forest Department's jetty. Bhoori village is famous for the buffaloes due to prevalence of pastures occupied by palatable grass species. Dablo is the major caste group, especially in creek villages followed by Jat; a camel herder tribe and Sholani Baloch; a farming tribe. Trading community is represented mainly by the Memons of Keti Bunder.

There is only one high school located in Keti Bundar. Electricity is available at Keti Bunder and two inland villages. It is also available at Tippun (a village in Hajamro creek) mainly through a wind turbine erected by WWF - Pakistan. The area is totally deprived of any water supply system, except for Bhoori village which has 10 hand pumps providing sweet water because the village is located in Khobar creek; which is currently the main course of Indus River falling in the Arabian Sea. Communities purchase drinking water on comparatively high prices thus facing an added stress on their subsistent livings.

A recent socio-economic study undertaken by Indus for All Programme revealed that the average household size of Keti Bundar area has 6.6 members. About one-fifth of households have only 3 members and such households were predominant at Keti Bundar. The study also revealed that about 78.4% households are engaged in fishing followed by daily labour, business and other miscellaneous occupations. In creek areas a fraction of the households (1 – 2%) possess small and large ruminants.

Proportion of family members engaged in different occupations depicts that 3% households possess poultry birds. The study examined that local population heavily rely on natural resources such as drinking water (94%), fish (88%), fuel wood (75%), and pastures (37%), a majority of the households in creeks and inland areas believe that natural resources such as drinking water, fish and forests have declined over the past five years. About 48% of respondents agreed that irrigation water resources have depleted during the last five years. Over 70% of respondents agreed that the fisheries have declined, while 64% agreed that forest resources have sharply depleted during the last 5 years. Depletion of fisheries, being the primary source of livelihood, was perceived to be highest at Keti Bundar (87% of respondents).

2.4 Results

2.4.1. Flora of Keti Bundar

2.4.1.1 Creek Flora: Creek flora included the dominant species *Avicennia marina* along with *Arthrocnemum macrostachyum, Aeluropus lagopoides, Sporobolus virginicus,* occasional *Salvadora persica, Aegiceras corniculata*, and *Oryza coarctata*. The later three species were

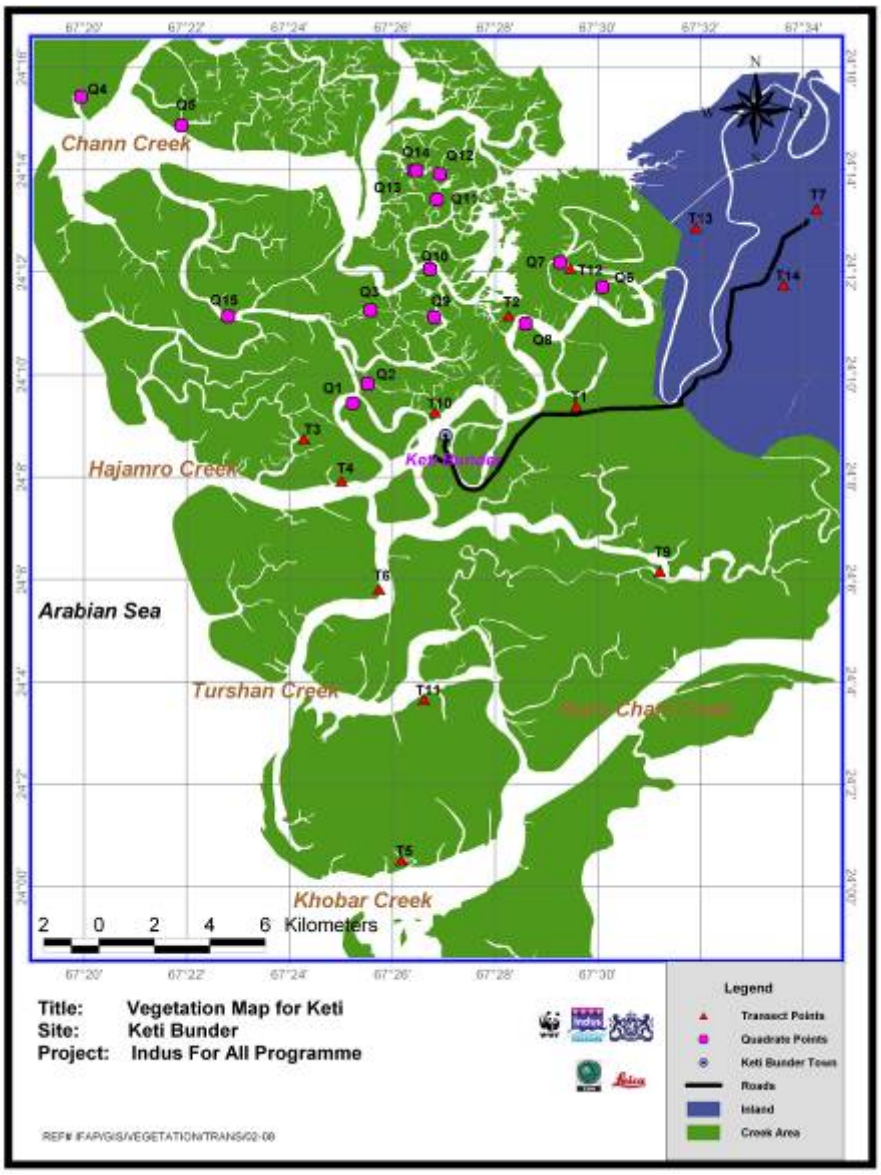


Figure 4. Map showing location of 10 x 10 m Quadrats and transects in Keti Bundar area

recorded mostly from those creeks where river water flows during flood season. Other creeks with hyper saline conditions generally had only *Avicennia, Arthrocnemum. Aeluropus* and *Sporobolus*. While *Avicennia marina, Aegiceras corniculata, oryza coactata* and *Sporobolus virginicus* were exclusively present on intertidal mudflats, *Arthrocnemum* and *Aeluropus*

occurred inland as well. *Aegiceras corniculata* was also observed in Chann creek forests which are managed by the Sindh Forest Department. A transect-wise details of the flora of Keti Bundar over three years is given in Annexure A – I.

To assess the cover of *Avicennia marina*, fifteen 10 x10 m quadrats were taken in various creeks (Annexure A – IV (a) to A – IV (b). A summary of the results of these quadrats is provided below in Table 3.

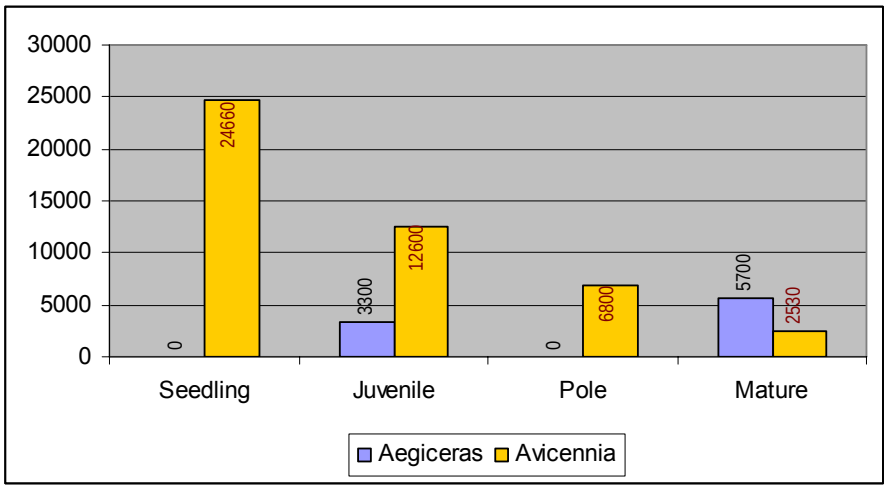
Table 3. Mangroves: Age- wise Cover Percentage

S.#	Age Class	Total Quadrats	Age class occurrence	Percentage
01	New germination	15	4	26.7
02	Pole	15	2	13.3
03	Juvenile	15	5	33.3
04	Mature	15	6	40.0

The newly germinated seedlings represent almost 27% of the entire age classes found in creek areas of Keti Bundar, however, not all the seedlings attain maturity mainly because of increased salinity, low silt and grazing by livestock. The mature and juvenile age classes are the dominant (40 and 33%, respectively) among all the four classes and these mainly reflect trees found in Chann and its associated creeks. These forests are although in stable form, however, increasing soil erosion by the advancing sea and wood cutting pose continuous threats to their existence.

While comparing two mangrove species; *Aegiceras corniculata* and *Avicennia marina*, it is interesting to note that the former species is still found in Chann and Hajamro creeks, however, new germination of *Aegiceras* is absent. This should be a matter of concern for the management to investigate the reasons of the absence of new recruitment (Figure 5). Per hectare numbers of plants of *Avicennia marina* are in fairly good numbers across all the age classes. A further detail of these samplings could be found in Annex A-IV (b).

Figure 5 - Comparison of *Aegiceras* and *Avicennia* in Different Age Classes (Numbers /Ha)



It was observed that most of the relatively dense and mature forests of mangroves are situated in Chann and its associated sub-creeks. The density of these mangrove forests

varies from one place to another mainly because of over-cutting by local communities and grazing by camels. Moreover, a recent phenomenon of deforestation by sea waves is most obvious and dramatic. A quick study conducted by Indus for All Team revealed that such bank erosion is happening at 14 m per month. The rate of this erosion may accelerate during summer months when the sea is rougher and waves are stronger.

Hajamro, another large creek of Keti Bundar is mostly devoid of mature mangrove forests and it occupies mostly seedlings and juvenile plants. This is probably due to over exploitation by the local communities over the past decades. However, some patches of good mangroves were observed near Khobar creek where River Indus joins the Arabian seas. Over here the mud flats were dominated by a palatable Son grass (O*ryza coarctata*). Another rhizomatous halophytic grass *Aeluropus lagopoides* is widely found on mud flats all over the creeks of Keti Bundar and appeared as distinct plant community on some places.

2.4.1.2. Mainland flora

After the 2008 survey, the total number of inland natural plant species comes to be 113. By adding four intertidal species the total number of species from Keti Bundar is now 117, in 83 genera and 36 families (Table 5). In this, Pteridophytes are represented by 2 families, 2 genera and 2 species, Angiosperms-Dicots by 29 families, 56 genera and 79 species, Angiosperms-Monocots by 5 families, 25 genera and 36 species. Poaceae comes to be the largest family with 28 species, followed by Chenopodiaceae (9 species), Tamaricaceae (8 species) and Asteraceae (6 species). *Tamarix* with 8 species was the largest genus. Any other genus was not represented by more than three species. Besides the natural flora, twelve cultivated species were also recorded (Table 4). The detail of the contribution of individual families to the natural flora of Keti Bundar is shown in Figure 6.

Table 4 - Cultivated plant species recorded at Keti Bundar

Sr :	Family	Plant species	Life form	Habit
1	Arecaceae	*Cocos nucifera* L.	Phanerophyte	Tree
2	Caricaceae	*Carica papaya* L.	Phanerophyte	Tree
3	Cucurbitaceae	*Luffa cylindrica* (L.) Roem.	Phanerophyte	Climber
4	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Phanerophyte	Subshrub
5	Malvaceae	*Thespesia populnea* (L.) Sol. ex Corr.	Phanerophyte	Tree
6	Musaceae	*Musa paradisiaca* Linn.	Cryptophyte	Tree – like herb
7	Myrtaceae	*Conocarpus erectus*	Phanerophyte	Tree
8	Myrtaceae	*Eucalyptus camaldulensis*	Phanerophyte	Tree
9	Palmae	*Phoenix dactylifera* L.	Phanerophyte	Tree
10	Poaceae	*Oryza sativa* L.	Therophyte	Herb
11	Rhamnaceae	*Ziziphus jujuba* Mill.	Phanerophyte	Tree
12	Solanaceae	*Capsicum annuum* L.	Therophyte	Herb

2.4.1.3 Overall Scenario of the Flora:

In Keti Bundar, 117 species were recorded in 36 families. The largest genus was *Tamarix* with 8 species. The largest family was Poaceae with 28 species followed by Chenopodiaceae (9 species) and Tamaricaceae (8 species). Two mangrove species (*Avicennia marina and Aegiceras corniculata*) were recorded from inter-tidal zone in creeks. There were 79 and 36 dicot and monocot species, respectively while only three species of pteridophytes were observed (Figure 6) and *Aegiceras* was recorded both from Chann and Hajamro creeks. Other creeks had only *Avicennia* while plants of *Rhizophora mucronata* were also seen which

were raised by Sindh Forest Department. A picture of the contribution of different plant families to the over all flora of Keti Bundar is provided in Annexure A – II.

Figure 6 - Types of Plant Families in Keti Bundar
(Class Categories of Flora)

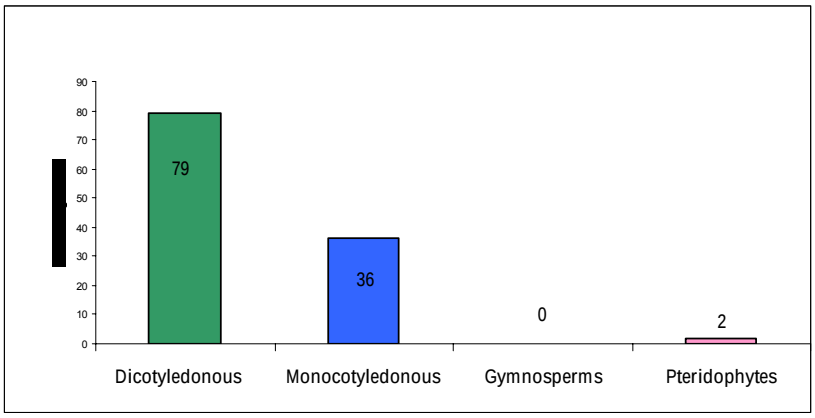


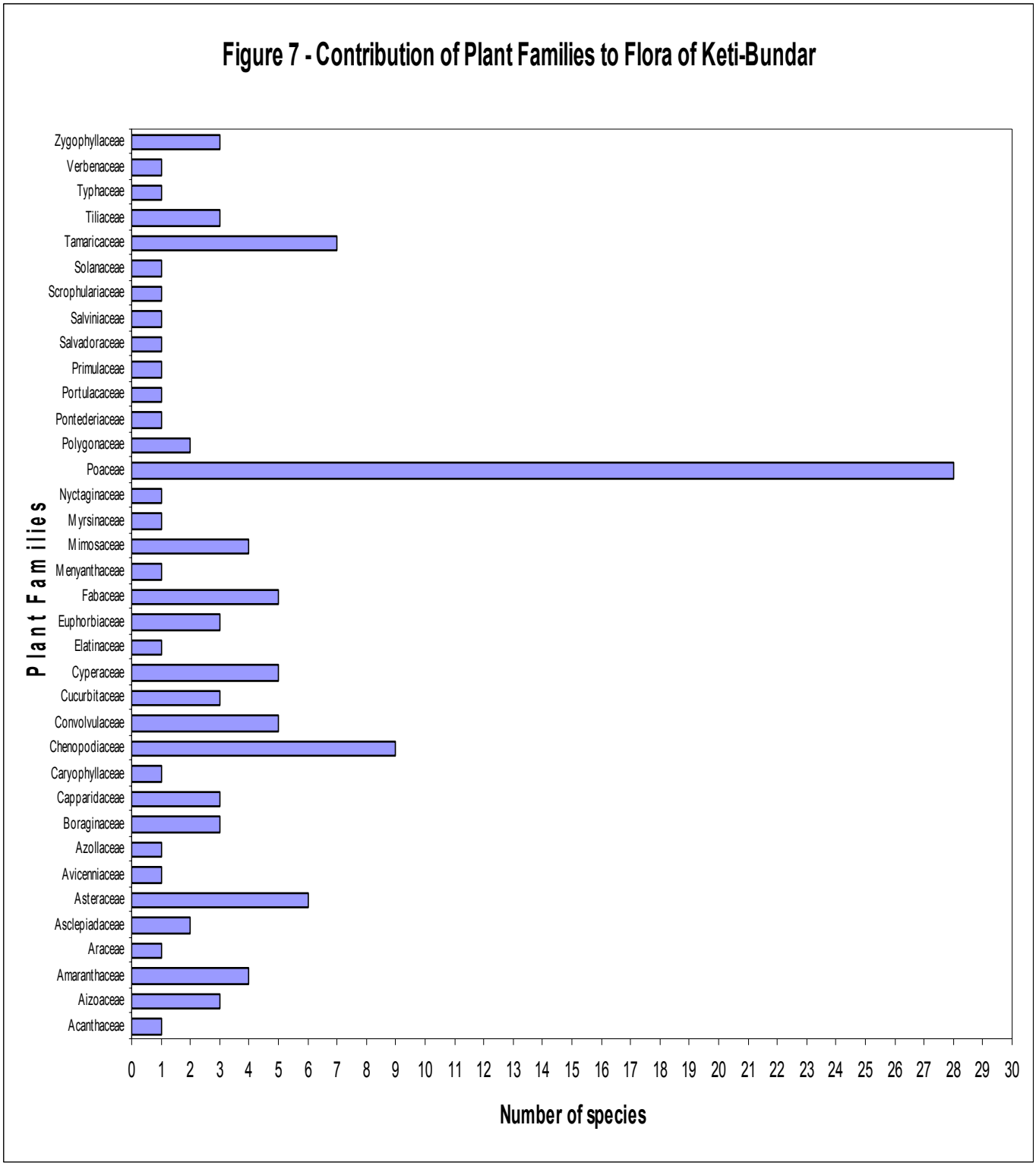
Table 5 - Cumulative plant species list recorded at Keti Bundar (Inland and creeks)

Sr#	Family	Plant species	Life form	Habit
1.	Acanthaceae	*Blepharis sindica* Stocks ex T. And.	Therophyte	Herb
2.	Aizoaceae	*Trianthema portulacastrum* L.	Therophyte	Herb
3.	Aizoaceae	*Trianthema triquetra* Rottl. and Willd.	Therophyte	Herb
4.	Aizoaceae	*Zaleya pentandra* (L.) Jeffery	Chamaephyte	Herb
5.	Amaranthaceae	*Achyranthes aspera* L.	Chamaephyte	Shrub
6.	Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Chamaephyte	Herb
7.	Amaranthaceae	*Amaranthus viridis* L.	Therophyte	Herb
8.	Amaranthaceae	*Digera muricata* (L.) Mart.	Therophyte	Herb
9.	Araceae	*Pistia stratioites* L.	Hydrophyte	Herb
10.	Asclepiadaceae	*Oxystelma esculentum* (L.f.) R.Br.	Cryptophyte	Climber
11.	Asclepiadaceae	*Pentatropis nivalis* (J.F.Gmel.) Field & J.R.I.Wood	Chamaephyte	Climber
12.	Asteraceae	*Conyza aegyptiaca* Ait.	Chamaephyte	Herb
13.	Asteraceae	*Eclipta prostrata* (L.) L.	Chamaephyte	Herb
14.	Asteraceae	*Iphiona grantioides Boiss.*	Chamaephyte	Herb
15.	Asteraceae	*Launaea procumbens* (Roxb.) Amin	Chamaephyte	Herb
16.	Asteraceae	*Sonchus asper* Fig.	Chamaephyte	Herb
17.	Asteraceae	*Sonchus oleraceus* L. Hill	Chamaephyte	Herb
18.	Avicenniaceae	*Avicennia marina* (Forssk.) Vierh.	Phanerophyte	Tree
19.	Azollaceae	*Azolla pinnata* R.Br.	Hydrophyte	Herb
20.	Boraginaceae	*Heliotopium ophioglossum* Boiss	Chamaephyte	Herb
21.	Boraginaceae	*Heliotropium crispum* Desf.	Camaephyte	Shrub
22.	Boraginaceae	*Heliotropium curassavicum* L.	Chamaephyte	Herb
23.	Capparidaceae	*Capparis decidua* (Forsk.) Edgew.	Phanerophyte	Shrub
24.	Capparidaceae	*Cleome brachycarpa* Vahl ex. DC.	Chamaephyte	Shrub
25.	Capparidaceae	*Cleome scaposa* DC	Chamaephyte	Herb

Sr#	Family	Plant species	Life form	Habit
26.	Caryophyllaceae	*Spergularia marina (L.) Griseb.*	Therophyte	Herb
27.	Chenopodiaceae	*Arthrocnemum macrostachyum* (Moric.)C.Koch	Chamaephyte	Herb
28.	Chenopodiaceae	*Arthrocnemum indicum (Willd.)* Moq.	Chamaephyte	Shrub
29.	Chenopodiaceae	*Atriplex stocksii* Boiss.	Chamaephyte	Sub shrub
30.	Chenopodiaceae	*Chenopodium album* L.	Therophyte	Herb
31.	Chenopodiaceae	*Chenopodium murale* L.	Therophyte	Herb
32.	Chenopodiaceae	*Halostachys belangerana* (Moq.)Botsch.	Chamaephyte	Shrub
33.	Chenopodiaceae	*Salsola imbricata* Forsk.	Phanerophyte	Shrub
34.	Chenopodiaceae	*Suaeda fruticosa* Forsk. ex J.F.Gmelin	Phanerophyte	Shrub
35.	Chenopodiaceae	*Suaeda monoica* Forsk. ex J.F.Gmelin	Phanerophyte	Shrub
36.	Convolvulaceae	*Convolvulus arvensis* L.	Therophyte	Climber
37.	Convolvulaceae	*Cressa cretica* L.	Chaemophyte	Herb
38.	Convolvulaceae	*Ipomoea aquatica* Forsk.	Hydrophyte	Herb
39.	Convolvulaceae	*Ipomoea carnea* Jacq.	Phanerophyte	Shrub
40.	Convolvulaceae	*Merremia aegyptia* (L.) Urban	Therophyte	Climber
41.	Cucubitaceae	*Coccinia grandis* (Linn.) Voigt	Chamaephyte	Climber
42.	Cucurbitaceae	*Cucumis melo* var. *agrestis* Naud.	Chamaephyte	Climber
43.	Cucurbitaceae	*Mukia maderaspatana* (L.) M.J.Roem.	Chamaephyte	Climber
44.	Cyperaceae	*Bolboschoenus glaucus* (L.) S.G.Smith	Hemicryptophyte	Sedge
45.	Cyperaceae	*Cyperus bulbosus* Vahl.	Cryptophyte	Sedge
46.	Cyperaceae	*Cyperus difformis* L.	Hemi cryptophyte	Sedge
47.	Cyperaceae	*Cyperus rotundus* L.	Cryptophyte	Sedge
48.	Cyperaceae	*Eleocharis geniculata* (L.) R.& S.	Hemi cryptophyte	Sedge
49.	Elatinaceae	*Bergia aestivosa* Wight & Arn.	Therophyte	Herb
50.	Euphorbiaceae	*Euphorbia granulata* Forsk.	Therophyte	Herb
51.	Euphorbiaceae	*Euphorbia serpens* Kunth	Therophyte	Herb
52.	Euphorbiaceae	*Phyllanthus maderaspatensis* L.	Therophyte	Herb
53.	Fabaceae	*Alhagi maurorum* Medic.	Phanerophyte	Subshrub
54.	Fabaceae	*Argyrolobium roseum* (Camb.) J. & S.	Therophyte	Herb
55.	Fabaceae	*Melilotus alba* Desr.	Therophyte	Herb
56.	Fabaceae	*Melilotus indica* (L.) All.	Therophyte	Herb
57.	Fabaceae	*Vigna trilobata* (L.) Verdc.	Therophyte	Herb
58.	Menyanthaceae	*Nymphoides cristata* (Roxb.) O.Ktze	Hydrophyte	Herb
59.	Mimosaceae	*Acacia nilotica* Delile	Phanerophyte	Tree
60.	Mimosaceae	*Prosopis cineraria* (Linn.) Druce.	Phanerophyte	Tree
61.	Mimosaceae	*Prosopis glandulosa* Torr	Phanerophyte	Shrub
62.	Mimosaceae	*Prosopis juliflora* Swartz	Phanerophyte	Shrub – Tree
63.	Myrsinaceae	*Aegiceras corniculata* (L.) Blanco	Phanerophyte	Shrub
64.	Nyctaginaceae	*Commicarpus boissieri* (Heimerl) Cufod.	Phanerophyte	Herb/subshrub
65.	Poaceae	*Aeluropus lagopoides* (L.) Trin. ex Thw.	Cryptophyte	Herbaceous Grass
66.	Poaceae	*Brachiaria eruciformis* (J.E.Smith) Griseb.	Haemicryptophyte	Grass
67.	Poaceae	*Brachiaria ramosa* (L.) Stapf	Haemicryptophyte	Grass
68.	Poaceae	*Chloris barbata* Sw.	Haemicryptophyte	Grass
69.	Poaceae	*Cynodon dactylon* (L.) Pers.	Cryptophyte	Grass
70.	Poaceae	*Dactyloctenium aegyptium* (L.) Willd.	Therophyte	Grass

Sr#	Family	Plant species	Life form	Habit
71.	Poaceae	*Dactyloctenium scindicum* Boiss.	Hemi cryptophyte	Grass
72.	Poaceae	*Desmostachya bipinnata* (L.) Stapf	Cryptophyte	Grass
73.	Poaceae	*Dichanthium annulatum* (Forssk.) Stapf	Hemi cryptophyte	Grass
74.	Poaceae	*Dichanthium foveolatum* (Del.) Roberty	Hemi cryptophyte	Grass
75.	Poaceae	*Diplachne fusca* (L.) P.Beauv. ex Roem & Schult.	Therophyte	Grass
76.	Poaceae	*Echinochloa frumentacea* Link	Therophyte	Grass
77.	Poaceae	*Echinochloa colonum* (L.) Link	Therophyte	Grass
78.	Poaceae	*Eragrostis cilianensis* (All.) Lut. ex *F.T.Hubbard*	Therophyte	Grass
79.	Poaceae	*Eragrostis ciliaris* (Linn.) R.Br.	Therophyte	Grass
80.	Poaceae	*Eragrostis pilosa* (Linn.) Beauv.	Therophyte	Grass
81.	Poaceae	*Eriochloa procera* (Retz) C.E. Hubbard.	Therophyte	Grass
82.	Poaceae	*Oryza coarctata* Roxb.	Cryptophyte	Grass
83.	Poaceae	*Paspalidium geminatum* (Forsk.) Stapf.	Hemi cryptophyte	Grass
84.	Poaceae	*Paspalum vaginatum* Swartz.	Hemi cryptophyte	Grass
85.	Poaceae	*Pennisetum purpureum* Schum.	Hemicryptopyte	Grass
86.	Poaceae	*Phragmites australis* (Cav.) Trin.	Cryptophyte	Tall grass
87.	Poaceae	*Phragmites karka* (Retz.) Trin. ex Steud.	Cryptophyte	Tall grass
88.	Poaceae	*Saccharum benghalense* Retz.	Hemicryptophyte	Tall grass
89.	Poaceae	*Saccharum griffithii* Munro ex Boiss.	Therophyte	Tall grass
90.	Poaceae	*Setaria verticillata* (L.) Beauv.	Therophyte	Grass
91.	Poaceae	*Sporobolus kentrophyllus* (K. Schum.) W.D. Clayton	Hemi cryptophyte	Grass
92.	Poaceae	*Sporobolus virginicus* (L.) Kunth	Cryptophyte	Grass
93.	Polygonaceae	*Persicaria glabra* (Willd.) Gomes de la Maza	Phanerophyte	Herb
94.	Polygonaceae	*Rumex dentatus* L.	Therophyte	Herb
95.	Pontederiaceae	*Eichhornia crassipes* (Mart.) Solma	Hydrophyte	Herb
96.	Portulacaceae	*Portulaca oleracea* L.	Therophyte	Herb
97.	Primulaceae	*Anagalis arvensis* L.	Therophyte	Herb
98.	Salvadoraceae	*Salvadora persica* L.	Phanerophyte	Tree
99.	Salviniaceae	*Salvinia molesta* Mitchelle	Hydrophyte	Herb
100.	Scrophulariaceae	*Bacopa monnieri* (L.) Wettstein	Chamaephyte	Herb
101.	Solanaceae	*Solanum nigrum* L.	Therophyte	Herb
102.	Tamaricaceae	*Tamarix alii* Qaiser	Phanerophyte	Tree
103.	Tamaricaceae	*Tamarix indica* Willd.	Phanerophyte	Shrub
104.	Tamaricaceae	*Tamarix kermanensis* Baum	Phanerophyte	Tree
105.	Tamaricaceae	*Tamarix pakistanica* Qaiser	Phanerophyte	Tree
106.	Tamaricaceae	*Tamarix passernioides* Del. ex Desv.	Phanerophyte	Tree
107.	Tamaricaceae	*Tamarix sarenensis* Qaiser	Phanerophyte	Tree
108.	Tamaricaceae	*Tamarix sultanii* Qaiser	Phanerophyte	Tree
109.	Tamaricaceae	*Tamarix sp. nov.*		
110.	Tiliaceae	*Corchorus depressus* (L.) Stocks	Chamaephyte	Subshrub
111.	Tiliaceae	*Corchorus tridens* L.	Therophyte	Herb
112.	Tiliaceae	*Corchorus trilocularis* L.	Therophyte	Herb
113.	Typhaceae	*Typha angustata* Bory & Chaub.	Cryptophyte	Reed
114.	Verbenaceae	*Phyla nodiflora* (L.) Greene	Chamaephyte	Herb

Sr#	Family	Plant species	Life form	Habit
115.	Zygophyllaceae	*Fagonia indica* Burm.f.	Chamaephyte	Herb
116.	Zygophyllaceae	*Zygophyllum propinquum* Decne.	Chamaephyte	Herb
117.	Zygophyllaceae	*Zygophyllum simplex* L.	Therophyte	Herb



2.4.2 Two Ways Indicator Species Analysis (TWINSPAN)

Vegetation assessment was carried out in 2006, 2007 and 2008 in different seasons. The year-wise cover data were compiled using spreadsheet in Microsoft® Excel® programme. These values ware then analyzed using software "*Two Ways Indicator Species Analysis (TWINSPAN*)" as mentioned earlier in Materials & Methods section. A detail of the analysis is provided in Annexure A – III. The results of the analysis are discussed as under:

2.4.2.1 *Aeluropus – Arthrocnemum* Plant Community (Year 2006)

This plant community was observed in 11 out of a total 13 transects. This community was found established on mud flats throughout all creeks. The dominant species of this community were *Aeluropus lagopoides* followed by *Halostachys belangerana.* Though there were a total of 67 plant species recorded from this area, yet community was formed by the two species. This community is of halophytic in nature belonging to families Poaceae and Chenopodiaceae and having life forms of Haemicryptophyte and Chamaephyte, respectively. Forage production at the sites represented by this community varied from 24.3 to 219.4 Kg/Ha.

Figure 8 – Sites representing *Aeluropus – Arthrocnemum* Plant Community (Year 2006)

2.4.2.2 *Aeluropus – Halostachys* Plant Community (Year 2007)

This plant community was found during summer 2007. The dominant plant species of this community *Aeluropus lagopoides* remained the same in spite of the increased number of sampling (13 transects), however, the associated plant species was found *Halostachys belangerana* which is again a halophytic shrub. This plant community once again represents inter-tidal zone. Replacement of *Arthrocnemum indicum with that of Halostachys belangerana* is probably result of increased number of transects which covered wider areas and hence based on overall cover the associated species of *Halostachys belangerana* was found prominent than *Arthrocnemum indicum.* Forage production at the sites represented by this community varied from 28.8 to 669.2 Kg/Ha.

Figure 9 – Sites represented by *Aeluropus – Halostachys* Plant Community (Year 2007)

2.4.2.3 *Aeluropus lagopoides – Sporopolus virginicus– Arthrocnemum indicum* (2008)

During Spring 2008, a total of 15 transects were taken to assess the natural vegetation in Keti Bundar area. Two plant communities emerged from the analysis by TWINSPAN. The community *Aeluropus lagopoides – Sporopolus virginicus– Arthrocnemum indicum* was almost same as that in the year 2006 except addition of another salt tolerant grass *Sporopolus virginicus* as co-dominant while *Arthrocnemum indicum* came up as associate. Normally grass species particularly *Aeluropus lagopoides* is regarded as a pioneer plant in the succession of mangrove forests. Although *Sporopolus virginicus* is a salt tolerant grass but it is not that hardy as that of *Aeluropus lagopoides* which occupies the landscape where areas frequently get inundated during high tides. In contrast *Sporopolus virginicus* is found in areas which have moderate saline water due to mixing of river water into sea water. Forage production at the sites represented by this community varied from 52 to 350 Kg/Ha.

Figure 10 – Sites represented by *Aeluropus lagopoides – Sporopolus virginicus– Arthrocnemum indicum* (2008)

2.4.2.4 *Arthrocnemum indicum - Halostachys belangerana - Tamarix indica* (2008)

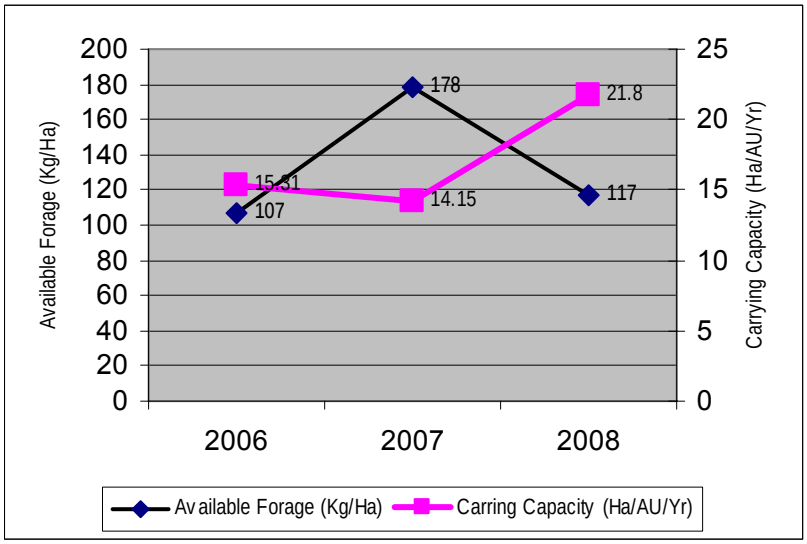
This was a second plant community that emerged in Spring 2008 and mostly represents salt pans of inland areas in vicinity to Keti Bundar*. Tamarix indica* is mostly found along roadside near Keti Bundar town. Over here other halophytic shrubs like *Halostachys belangerana* are common. This plant community is representative of partially sub-merged area. Forage production at the sites represented by this community varied from 58 to 350 Kg/Ha.

Figure 11 – Sites represented by *Arthrocnemum indicum - Halostachys belangerana - Tamarix indica* (2008)

2.4.3 Carrying Capacity:

Carrying Capacity of Keti Bundar was determined in terms of hectares per animal unit per year for three years (Figure 12). Maximum forage production and the carrying capacity was determined in year 2007 compared with rest of the two study years, however, the difference was minimum. Most of the mud flat pastures are grazed by buffaloes particularly those which are dominated by Son grass *(Oryza coarctata)* and other grasses like *Aeluropus lagopoides* and *Sporobolus virgincus.* While calculating carrying capacity and forage production in Keti Bundar creeks, Mangrove species were not taken into account primarily due to the fact that most of the dense mangroves are present in Chann creek which is not included in programme sites and secondly these are used mostly for camels. Chann Creek mangroves being situated in Wildlife Sanctuary are illegal to be used as fodder for any type of livestock. Three years comparative study reveals that forage production in creeks areas is almost persistent under present land use mainly due to (i) a year long growing season and (ii) a steady number of cattle inside the creeks. The transect-wise details of forage production and the carrying capacity is provided in Annexure A – V. A summary showing comparison of plant families, associated species and forage production is provided in Annexure A – VI.

Figure 12 – Carrying Capacity in Keti Bundar Area over Different Seasons and Years



2.4.4 Biodiversity Index & species Richness:

2.4.4.1 α- Diversity (i.e.,, the species richness and species diversity within each locality). With reference to species richness, α – diversity of Keti Bundar came up with 36 families, 83 genera and 117 species.

Among various families, Poaceae exhibited the highest species richness followed by Chenopodiaceae, Tamaricaceae and Asteraceae.

2.4.4.2 β -Diversity (i.e.,, the species turnover from one locality to other locality or diversity between localities)

Localities were compared in pairs with every possible combination. Keti Bundar and Keenjhar showed 2nd highest β -Diversity among all sites with 96 species in common. The localities pairs are shown in Table 6.

Table 6 - Similarity Index and β -Diversity of Keti Bundar

S. No	Locality pairs	2006			2007			2008		
		Shared species	CC	BD	Shared species	CC	BD	Shared species	CC	BD
1	Keti – Keenjhar	27	0.30	1.691	82	0.46	1.54	96	0.51	1.49
2	Keti – Chotiari	13	0.16	1.832	68	0.45	1.55	78	0.48	1.52
3	Keti – Pai	12	0.23	1.767	48	0.45	1.55	60	0.51	1.49

2.4.5 Significant findings

***Azolla pinnata**:* This pteridophytic species was collected first time form the inland area of Keti Bundar.

***Sporobolus virginicus**:* This species was previously recorded form inland localities in the Flora of Pakistan. In the present survey, it was recorded for the fist time from inter-tidal mudflats in Hajamro creek, Khobar creek and Kharo chhan.

Tamarix sarenensis & Tamarix sultanii: These species were recorded form Keti Bundar, these species are endemic to Sindh.

2.5 Discussion

Being a deltaic locality, the most prominent vegetation type of Keti Bundar are mangrove forests. As mentioned earlier, eight species of mangroves were present in the past but now only three are reported to occur in the Indus delta and in the present study only two mangrove species (*Avicennia marina* and *Aegiceras corniculata*) were observed growing naturally while third (*Rhizophora mucronata*) was re-introduced by Forest Department in north of Keti Bundar. The decline in the number of species itself indicates the gradual deterioration of Indus delta mangrove ecosystem. In the present study, *Aegiceras corniculata* and grass species *Oryza coarctata* were mostly found in those localities where there is some supply of freshwater. In other creeks only *Avicennia marina* was the mangrove species which is more salt-tolerant and rather aggressive species; but even *Avicennia* stands are gradually deteriorating as indicated by the 10 x 10 m quadrats data. Only few quadrats showed the mature *Avicennia marina* trees while others had only seedlings, juveniles and immature trees, indicating that although the propagules germinate and establish but fail to reach maturity. While mortality of seedlings may be due to exposed nature of habitat, hyper salinity, grazing by herbivores, etc. (Saifullah *et al.* 1994, 2007), the failure of juveniles to reach maturity is most probably due to nutrients deficiency as the fresh sediment is not coming in enough amount due to highly curtailed flow of River Indus into the delta. Historical records show that the original natural silt load carried by Indus into the delta was 300-400 million tons per year that contributed to seawards growth of land area at the rate of 3 square miles per year as measured between 1873 and 1904 (Blatter *et al.* 1929). The silt load or sediment forms mud flats in front of river mouth which are stabilized by the growth of grasses and mangroves contributing to increase in mainland area of delta. The mud flats provide not only support to

the mangroves but they are also nutrient-rich. The most extensive and luxurious mangroves are invariably associated with mud and muddy soil found along deltaic coasts, in lagoons and along estuarine shorelines (Saenger 2002). Both freshwater flow and silt load of Indus river continued to decrease with the construction of dams and barrages upstream. According to Saifullah (1997), the annual silt load at Kotri barrage has decreased from 200 million tons to 50 million tons during 1955 to 1984. The sediment reaching the delta has been as low as 10 million tons/year (Meadow and Meadow 1999). The uprooting of mature *Avicennia* trees due to erosion observed during present study appears to be due to the lack of deposition of fresh sediment, further aggravated by the sea level rise due to global warming resulting in the receding coast-line and sea intrusion. The lack of sediment deposition has far reaching effects. The natural land subsidence rates in river deltas are higher than other parts of the coast, which are normally compensated by the new sediment deposition, but the lack of sediment may result in local relative sea level rise and intrusion of salt water in the inland aquifers leading to biodiversity loss in coastal ecosystems (Haq 1999). It means that in case of general rise in sea level, the actual sea level rise would be greater for the deltas resulting in a greater inundation than other parts of coast, thus greater destruction and dislocation of people. These effects would be even more severe in the absence of mangroves.

The increase in salinity of the area is also indicated by the inland vegetation. *Aeluropus lagopoides, Arthrocnemun macrostachyum, Halostachys belangerana and Tamarix indica* are recognized as dominant species in Two Way Indicator Species Analysis (TWINSPN), which are all halophytic species. Besides these *Salvadora persica,* another halophytic species is also fairly common. Floristically as well, Chenopodiaceae and Tamaricaceae (all halophytes) are among the larger families, and among grasses about ten species are halophytes. It is interesting that Hoekstra *et al.* (1997) reported *Tamarix dioica* from the salt marshes of Indus delta but we did not find this species in delta area, neither any of its specimen is recorded from this area in the Flora of Pakistan. It therefore appears to be a case of misidentification. Similarly, the *Arthrocnemum indicum* mentioned by Hoekstra *et al.* (1997) must be actually *Arthrocnemum macrostachyum,* as the former is a rare species on Pakistan coast (Flora of Pakistan No. 204). The primary productivity in terms of DMY and carrying capacity were found to be quite low indicating that the ecosystem cannot sustainably support any large number of livestock.

2.5.1 Problems & Threats:

Keti Bundar is of great ecological and economic significance because of the mangrove ecosystems. These ecosystems almost entirely support shrimp and fishery production that earn 100 million US $ annually (Saifullah 1997). Normally mangrove ecosystems are pristine and do not require much management unless ecological processes are disrupted. In spite of overwhelming importance of mangroves in Pakistan, little attention has been paid to their management. Mangroves are disappearing at an alarming rate and main causes of such rapid decline are rooted among unawareness among policy makers, authorities and public at large (Saifullah 1997). Keti Bundar is one of the major towns in Indus delta that is facing a multitude of environmental degradation and loss of livelihood opportunities for the locals. Some of the serious problems leading to ecological degradation in this area are briefly described below.

2.5.1.1 Deficiency of Fresh Water Flow form Indus River: This is probably the most serious problem of Indus delta as a whole. Mangroves occur preferably in deltaic regions of the world because they grow better in low saline water and soft alluvial substrate. Their productivity increases proportionately with the increase of fresh water (Saifullah 1997). There has been a continuous decrease in Indus River discharge ever since the creation of Pakistan mainly because of extension in irrigated agriculture that forced to construct more upstream dams and barrages. Flow of River Indus has decreased from 150 MAF (before construction of dams and barrages) to a meager amount of 10 MAF. Gradual decrease in fresh water has triggered the

salinity, which is about 40 ppm at many places in the delta region. Such hyper salinity conditions also seriously decline mangroves growth. Moreover, the mangroves are threatened because of overexploitation, pollution, and a decline in fluvial discharge into the Indus delta (Downton 1982, Clough 1984, Ansari 1987, Naidoo 1987, IUCN 1988, Burchett *et al*., 1989, Qureshi 1993, Khan 1993, Gordon 1993, Karim and Karim 1993, Aziz and Khan 2001).

2.5.1.2 Reduced Siltation: Due to decrease in river flow there is less deposition of nutrient-rich silt. According to Saifullah (1997), the annual alluvial flow has decreased from 200 million tons in 1955 to 50 million tons at Kotri during 1984. Such decline in sediment is also hampering the mangroves growth.

2.5.1.3 Seawater Intrusion: The reduction in river flows into the sea has led to sea intrusion. This is the main problem that has degraded both underground and surface freshwater resources. Seawater has encroached into the creeks, delta, and channels causing the soil salinity of adjacent lands to exceed cultivable limits. Potable water has become scarce and wells that yielded freshwater a few years ago have turned brackish. The natural vegetation is also under stress due to hyper salinity and change of habitat. The fresh water and brackish water ecosystems have changed to marine ecosystem. In areas that do not have saline ground water, hand pumps constitute another source of fresh water. Unfortunately, Keti Bundar has no fresh water sources and people face serious problems for their day to day requirements. This seawater intrusion is deteriorating the floral diversity of mudflats.

Figure 13 - A considerable area of dense and mature forest in Chann Creek is being uprooted by strong waves and this process is continuous.

2.5.1.4 Overgrazing/Lopping and Browsing: There is a tremendous pressure of grazing by nomads and locals mainly by camels on mangroves in Keti Bundar. Camel grazing is widely prevalent in Chann creek and parts of Hajamro creek. The tribes in the area rear camels for income generation in addition to fishing. According to estimates, there are about 16000 camels and 11000 cattle, which survive on mangroves in Indus Delta (Qureshi 1993, Saifullah 1997). In creeks of Keti Bundar 6000 camels entirely depend on mangrove fodder. Other kind of livestock such as buffaloes and cows are also present. A lot of buffaloes were seen grazing openly in Khobar.

2.5.1.5 Deforestation of Mangroves: Local communities cut mangroves for fodder and fuel. According to an estimate 173 kg of wood is used per month per household (Saifullah 1997). Scenes of severe deforestation are common everywhere as one approaches in Chann creek. As told by the local people, mangrove wood is also exported to Karachi for fuel wood. Local fishermen and surrounding communities in major creeks use mangrove wood for fuel.

According to Hoekstra *et al.* (1997), the boat-based fishermen use about 53 to 120 kg wood for each fishing trip that lasts for 1 to five days. Wood collection for domestic use for permanent settlements depends very much on the proximity of the settlement to the mangrove vegetation and the availability of alternate sources of wood fuel or energy. Hoekstra *et al.* (1997) provided following details for multiple uses of mangrove wood in Indus Delta region.

Table 7 - Uses of wood by fishermen communities in Indus Delta

Harvest Purpose	Shah Bundar	Kharochan	Keti Bundar	East Karachi	Port Qasim
For sale	-	-	Xxx	Xxx	Xx
During fishing	X	X	X	X	X
For domestic use	X	Xxx	X	X	Xxx

Xxx = significant quantity xx = medium quantity x = small quantity

2.5.1.6 Over Fishing: The inhabitants in Keti Bundar depend mainly on fishing for their livelihood. They are overexploiting the fish resource and using unsustainable methods of fishing. Reduced river flow is also responsible for decrease in fishery resource. This shortage of fishery resource is diverting the people dependence more on mangroves for their livelihood.

2.6 Constraints for Agriculture development in Keti Bundar.

Agriculture development in the coastal belt is constrained by different physical, chemical and social factors.

- Constraints increase with increasing intensity of salinity. Soil salinity is the most dominant limiting factor in the region, especially during the dry season. It affects certain crops at different levels/ stages of growth, which reduces yield. A substantial area of land is tidally affected by saline water. Appropriate management practices for crop production in this area are not available.
- Scarcity of quality irrigation water during dry season limits cultivation of crops.
- Variability of rainfall, uncertainty also affects crop production. Drought also restricts cultivation.
- Crop choices are limited by salt tolerating ability of crops, narrow technological and Germplasm bases.
- Disease and pests. Extensive cultivation of a particular crop year after year makes the crop susceptible to pests and diseases attack.
- Soil texture of most of the saline soils varies from silt clay to clay. Land preparation is difficult when soil dries out. Deep and wide cracks develop and surface soil becomes very hard. This necessitates deep and rapid tillage operations.
- Water logging in low lands restricts potential land use.
- Lack of appropriate extension programmes for diffusion of modern technologies is also a big constraint in development.

- Big land ownership and unfavourable land tenure system and dominance of absentee farmers discourage adoption of modern technologies.
- Difficult communication and remote marketing facilities also retard Agriculture development of the area.

2.7 Suggestions for Improvement:

- **Coordinated Resource Management Approach:** For the management of mangroves coordinated resource management approach should be adopted as it is a cooperative method to resolve renewable resource management problems. It is a tool for coordinating planning, management and educational activities with the concerned government agencies like Sindh Forest Department, Coastal Development Authority and District Governments, civil society organisations and local farming and fishermen communities.

- **Rehabilitation of Mangrove Vegetation:** Afforestation should be carried out on blank areas through adopting proper silvicultural practices. This activity may be assigned to Sindh Forest department by providing adequate manpower having expertise in mangroves management. In addition to *Avicennia marina* other species like *Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculata* should be reintroduced to the area.

- **Political Will:** Awareness regarding importance of mangrove ecosystems towards their role in sheltering the coastline areas, economic development and environmental protection of the country should be created amongst the leadership at various levels. This will help in policy formulation and implementation of improvement works. Another important step is to organise communities through rigorous social organisation. The focus groups should be the people living inside creeks where most of the mangrove forests exist and fishing is practiced.

- **Alternate Sources of Energy:** To reduce the pressure on mangrove forests alternate sources of energy such as electricity, solar energy, wind energy and natural gas may be explored and provided.

- **Research:** Scientific studies on fresh water requirements of mangroves, choice of species, salt tolerance of various plants, etc may be carried out.

- **Environmental Flows:** There is a serious need that concerned federal and provincial government departments, academic institutions and the civil society organisations and those who control water flow in river such as WAPDA, Irrigation Departments along with representatives from the target communities should discuss and agree on a minimum quantity of water to make available to deltaic region year round for sustaining the ecological health. A number of studies have so far been conducted in the past to assess the optimum amount of environmental flows but there seems a serious lack of will to implement such decisions or accords. A further delay to decide and implement the desired amount of water will result in irreversible damage to the ecosystems in the deltaic region.

2.8 Conclusions

Keti Bundar ecosystem is in the process of deterioration at a very fast pace. The floral diversity is very low with respect to palatable grasses, trees and shrubs because of reduced supply of fresh water in the River Indus, seawater intrusion, overgrazing and, overexploitation etc. Salinity level in soil is on the increase, indicated by the dominance of halophytic species even in the mainland flora. The degradation of mangrove ecosystem and shrinkage in

forested area is occurring not only due to hypersalinity and local pressure of wood and fodder harvest, but also due to erosion by sea uprooting the full grown *Avicennia* trees. The increasing intensity of erosion is may be due to a combination factors such as lack of silt deposition due to meagre flow of river water into delta and the overall sea level rise due to climate change. Immediate rehabilitation measures through ensuring certain amount of Indus River freshwater flow into the delta, coordinated resource management approach; alternate sources of energy and creation of awareness amongst the leadership are required to restore the healthy ecosystem in the area.

2.9 Satellite Remote Sensing Based Forest Change Mapping and Monitoring of Mangrove Forests of Keti Bundar

GIS Team, WWF - Pakistan

2.9.1 Introduction

WWF has ranked the terrestrial Global 200 Ecoregions by their conservation status. Indus Ecoregion is one of the Global 200 Ecoregions. This ecoregion inhabits one of the only four obligate freshwater dolphin species, the Indus River Dolphin, more than 320 species of birds, 38 endemic fish species and marine turtles. Eight Ramsar sites are included in the Indus Delta ecoregion; Haleji Lake, Jubho lagoon, Keenjhar Lake, Nurri Lagoon, Deh Akro 11 Wetlands Complex, Drigh Lake, Indus Dolphin Reserve and Indus Delta.

Indus Delta occupies an approximate area of 600,000 hectares. Seventeen major creeks and innumerable minor creeks and extensive mud flats characterize it. It is classified as the fifth largest delta in the world.

The creeks of Indus Delta Ramsar Site provide support to marine cetaceans in the creeks, Smooth coated otter, Marsh crocodile and eight freshwater Turtle species. Recent surveys 2005 - 2006 indicated a variety of small marine cetaceans in the creeks such as Indo Pacific Humpback Dolphin (59), Bottle-nosed Dolphins (18) and Finless Porpoise (52) and these numbers increased to 976, 68 and 241, respectively in the beach surveys. Indus Delta also supports other marine life including economically important marine and freshwater fish resources. Due to unsustainable fishing practices and reduced water flows, fish catch has declined. Palla (*Tenulosa ilisha*) locally swims up from the Arabian Sea to spawn in freshwater. Many species have become extinct or are endangered, such as freshwater Gharial (extinct in the wild), Olive Ridley and Green Turtles. Hog deer that was common in the riverine forests area has become endangered.

It is estimated that about 160,000 hectares of Indus Delta is occupied by mangrove vegetation. Mangrove ecosystems are considered to be highly productive and support local fisheries resources. Mangrove forest is an integral part of inter-tidal zone of the coastal environment extending throughout the tropics and subtropics of the world (Giri and Delsol, 1993). The term mangrove forest does not imply woody plants alone but includes other flora and fauna which utilize a coastal, saline, depositional environment, involving a variety of coastal landforms, with typically anaerobic soil (Ashraf *et al.* 2004).

In the recorded history, first commercial use of mangroves is reported in 1842 immediately after the British occupation of lower Sindh, where river communication was established and firewood from these mangroves was used for the steamers and flotillas. This was abandoned after the development of railways in the region. Thereafter, local people for grazing and browsing of livestock, predominantly camels, used the coastal forest as a resource (Ahmad, 1983).

The construction of dams and six barrages and extreme irrigation has affected the flow of freshwater in the Indus estuary. The past several years have seen significant reductions in the flow of the river and consequent decline in sediment discharge which has severely impacted the mangroves. Several key species that once inhabited this region are no longer supported by the declining ecological conditions. Indus Delta mangroves are facing with several serious anthropogenic and natural threats and pressures, which have reduced their productivity and growth drastically. Major reported threats and stresses are listed as;

- Reduction in annual flow of freshwater;
- Reduction in silt and nutrients;
- Over cutting for fuel and fodder
- Over browsing by camels;
- Pollution from expanding domestic and industrial areas of Karachi and navigational activities
- Sea water intrusion
- Urbanization and industrialization (Keerio, 2004).

2.9.2 Study Area

The study area lies in Indus Delta and covers 14% of the deltaic area. It extends from 67º 32' to 67º 20' longitude and from 24º 46' to 24º 3' parallels and comprises over an area of 81,801 ha (818 $Km^{2)}$. Area comprises of four major creeks *i.e.,* Chann, Hajamro, Turshan and Kharo Chann (Figure 14).

Main vegetation types of the area are mangroves, mixed terrestrial vegetation (mainly *Prosopis juliflora* and halophtytic spp.*)* and marine algae.

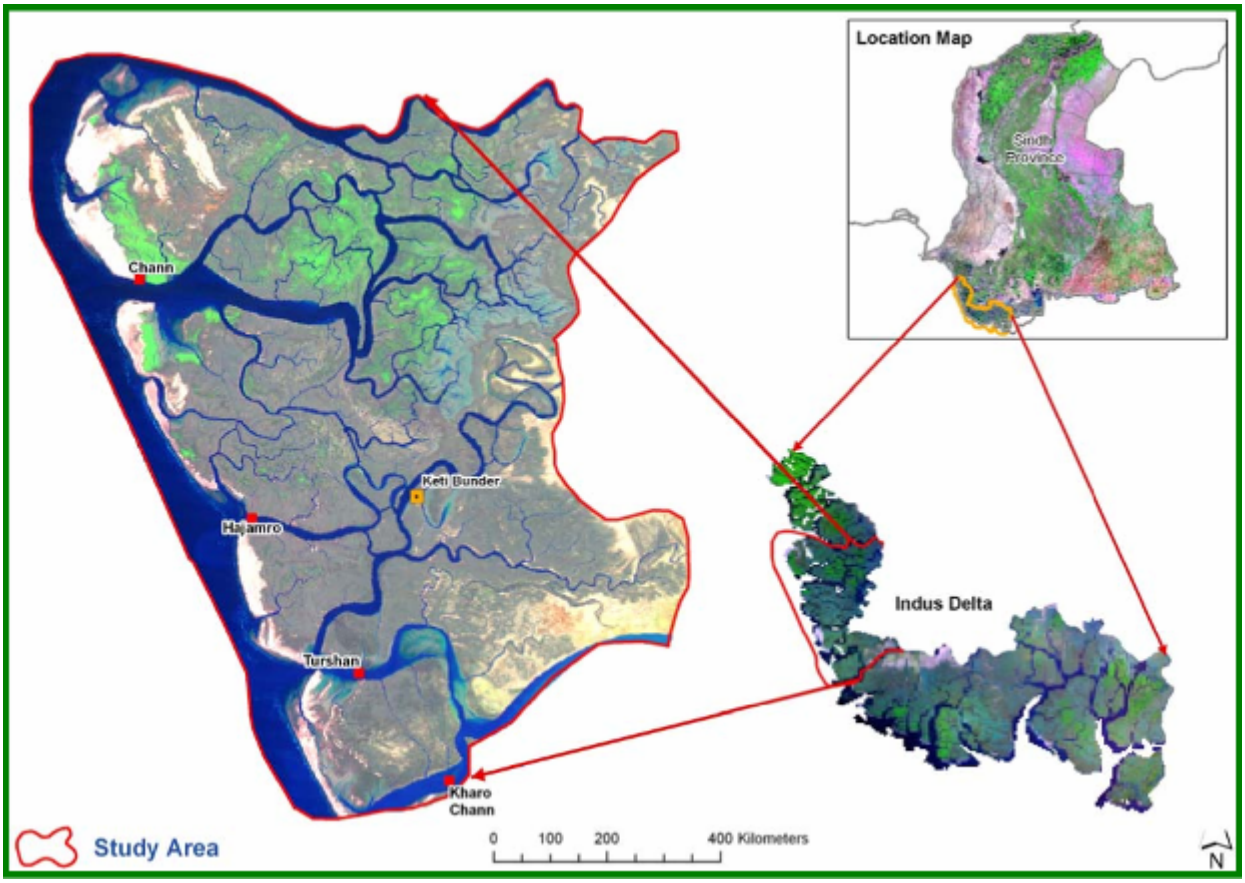


Figure 14. Location map of the study area

2.9.3 Purpose of the study

The report aims to map the current extent of mangrove forests and to do quantitative comparison of mangroves status over the fifteen year period by using recent and historic satellite images.

2.9.4 Materials and Methods

2.9.4.1 Data Used: Georeferenced satellite images of Landsat, ASTER and SPOT were procured from the data vendors. The images were converted into metric coordinate system (i.e., Universal Transverse Mercator – UTM, Zone 42) with Spheroid and Datum as WGS 84. For this purpose 2nd order polynomial was used so as to incorporate the planimetric details in the image. The criteria used for Satellite data characteristics are provided in Annex IJ.

Due to the unavailability of temporal satellite data of same resolution, images of varied spatial resolution were used. The satellite image characteristics are shown in Table 8 below.

Table 8 -. Characteristic of Satellite Data

Satellite	Sensor	Spatial Resolution (m)	Acquisition date	Tide Height (m)
Landsat	TM	30	27-04-1992	Not available
TERRA	ASTER	15	24-12-2001	1.3
SPOT	SPOT-5	2.5 and 10	30-04-2007	3.2

2.9.4.2 Software Used: Image pre-processing and high resolution merge was performed by using ERDAS Imagine 8.7®. Onscreen digitization was done by using ArcView 3.1. All the maps were prepared in Arc GIS 9.0®. For documentation and analysis Microsoft Word and Excel were used.

2.9.4.3 Data Preparation

- **Image import :** Procured satellite images were in Tiff (SPOT and Landsat) and HDF (ASTER) image formats. Images were imported into .img format to make it compatible with the image processing software i.e., ERDAS IMAGINE 8.7

- **Truncation of Study Area:** The study area was truncated on the Area of Interest (AOI) *i.e.,* Chann, Hajamro, Turshan and Kharo Chann creeks. This process is shown in Figure 15.

Figure 15 - Truncation of the study area

2.9.4.4 Satellite Image Enhancement: The process of enhancing a low contrast satellite image to high contrast by the application of various algorithms is known as contrast enhancement. After import, satellite image exhibits inherent low contrast making the image darker with darker tones. In order to convert this low contrast image to a high contrast image

Standard Deviation Stretch and Brightness Contrast Control were used for image enhancement. These algorithms enhanced the low contrast of satellite images and made them more interpretable for further processing. Annexure J – III describes the spectral bands.

- **High Resolution Merge:** SPOT multispectral imagery has lower spatial resolution (10m) and four spectral bands as compared to its panchromatic layer that characterizes higher spatial resolution (2.5m) and a single spectral band. High-resolution merge with multiplicative and bilinear interpolation were used to improve the visual interpretability of the images. Output image (Figure 16) is a high-resolution (2.5m) multispectral image with improved / greater level of details which was integrated with GIS layers. The high resolution image significantly helped for the assignment of vegetation classes. Annexures J – I, J – II and J - IV show data specifications of the Spot 5, Aster and Landsat, respectively.

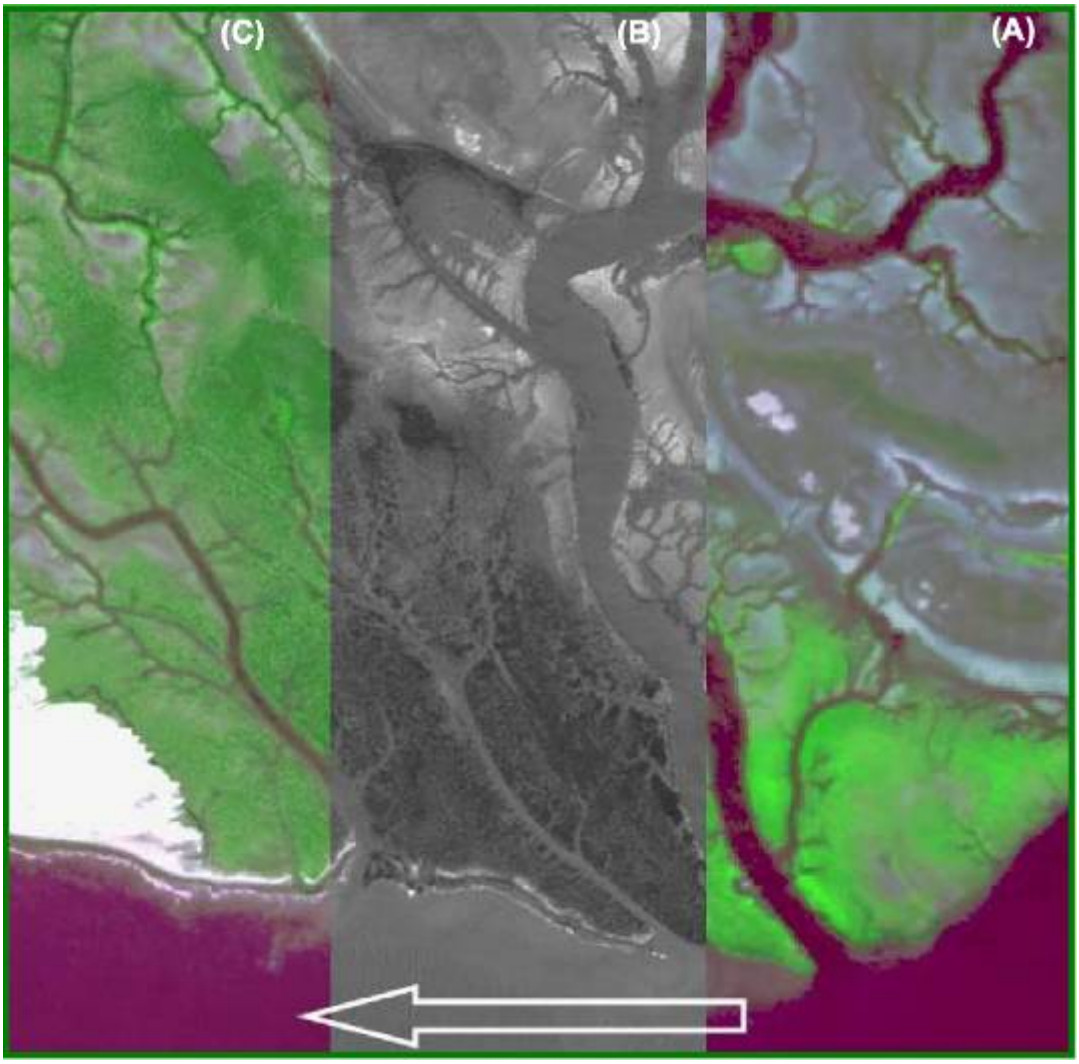


Figure 16 . Arrow define increasing level of resolution (A) multispectral, 10m (B) panchromatic, 2.5m (C) high resolution merged imagery

2.9.5 Ground Truthing

Ground truthing refers to the acquisition of knowledge about the study area from fieldwork, analysis of aerial photography, personal experience etc (Schradar and Pouncy, 1997). Main objective of the ground truthing was to correlate the reflectance values of the satellite image with the ground reality.

For ground truthing a field visit was arranged from 1st to 4th February 2008. Field visit was arranged with the co-operation Keti Bundar Site Office of Indus For All Programme. Land vehicle and boat were used to navigate in the field. Land vehicles were used to take observations of the easily accessible area by road. Whereas, the observations of mangroves along narrow creeks and around the peripheries of mud flats were made possible by boat. Sampling points were collected in five major creeks i.e., Chann, Kaangri, Hajamro, Khobar and Turshan.

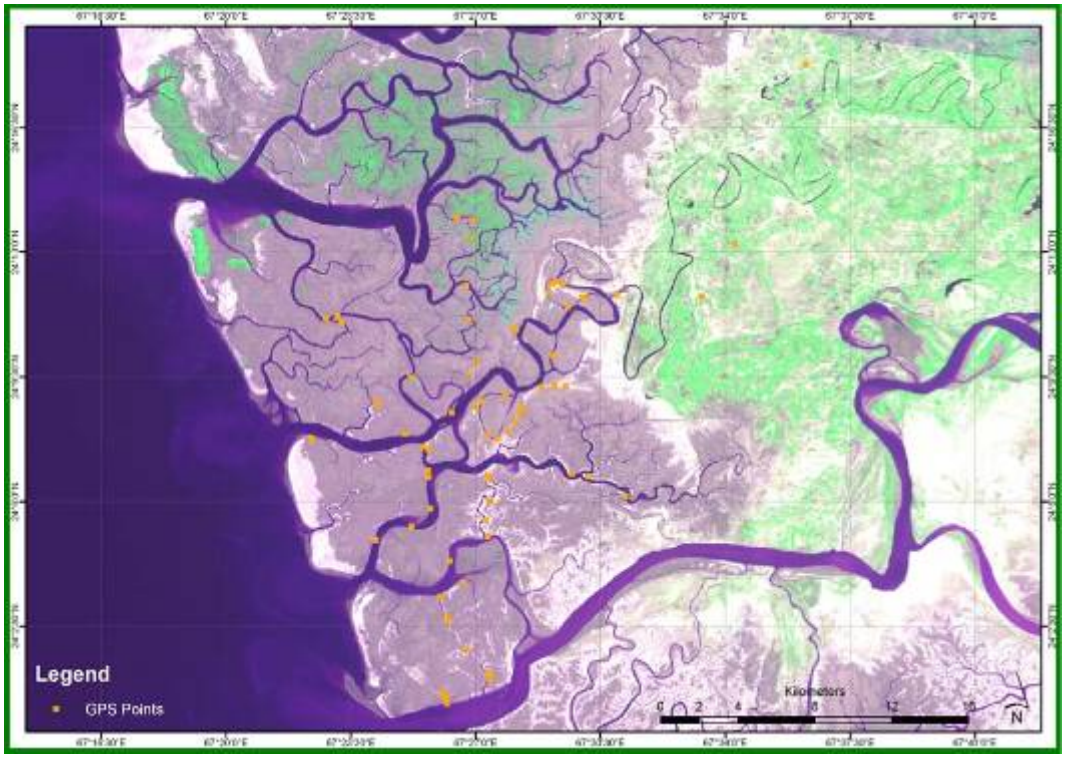
SPOT – 5 image with False Colour Composites (FCC) was used to develop field maps. A2 size maps were printed at a scale of 1:25,000 with geographic grid interval of 30 seconds. GIS layers of settlements and creeks were also overlaid on the maps.

Gamin 76CSX Global Positioning System (GPS) receiver and digital camera were used during the field visit. 57 waypoints were collected by using the GPS receiver at different spots of Keti Bundar area. Figure 17 shows collected GPS coordinates on map. Field observation forms were used for the mangrove data collection. Field observation form for the data recording of mangrove forest contained columns of latitude, longitude, cover, age class and description. Four categories of age class were defined on the basis of maturity i.e., new germination, juvenile, pole and mature. To record mangroves density four forest density classes were defined which are shown in Table 8.

Table 9 - Mangroves density classes with percentage tree cover

Mangrove Density Classes	% Tree Cover
Dense	**80 – 100**
Medium	**60 – 70**
Sparse	**40 – 50**
Very Sparse	**10 30**

Figure 17 - Field observation points in Keti Bundar



2.9.6 Field Observation Points

Avicennia marina was observed as a dominating species of mangroves in the area. Some large patches of *Aegiceras corniculata* and *Rhizophora mucronata* were also observed on the Northern side of the AOI.

O*ryza* (son grass) and Halophytic shrubs were the other main vegetation types mostly present in the southern side of the area. Most of the coastal vegetation mapping studies contains discrepancies in mangroves area estimation due to the mixing of the grasses/bushes. Ground control points for this class were collected so that this class could be efficiently mapped and segregated in the satellite image.

One of the major threats observed during field visit was the indiscriminate camel grazing and mangroves harvesting all over the area. This is mainly done by locals settled in Turshan, Hajamro and Khober creeks. This could be one of the reasons for the sparseness in the canopies and low occurrence of mangroves in the southern side of the project area. Annexure J – V describes the field observation points.

Figure 18 -- (a) Digital photograph of camel grazing (b) Halophytic area on satellite image and (c) digital photograph of the same area

Large patches of pole and mature mangroves were observed in Chann Creek area (Figure 19). The area is hard to access but the forest has been significantly managed by the Forest Department. At this site mangroves were dense and tree height varies from 1.5 - 4 meter approx.

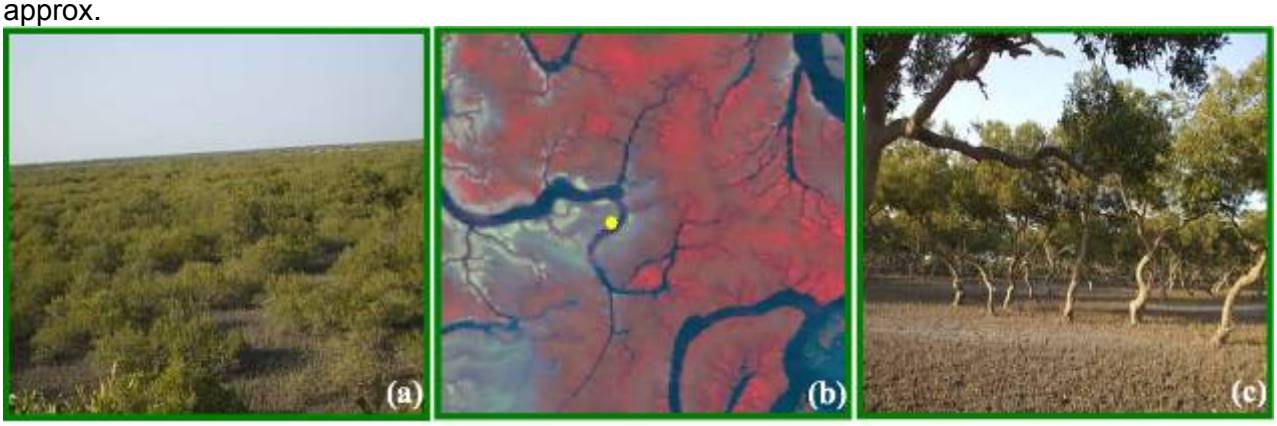


Figure 19 - (a) Digital photograph of mangrove forest in pole stage (b) GPS coordinates overlaid on satellite image and (c) Mature mangroves forest in Chann creek area

In Chann creek, area facing Arabian Sea has high rate of soil erosion (Figure 20). According to the local people, there was a large dense patch of mangrove forest 20-30 years back which is totally diminished in the sea water. For future monitoring, two mangrove trees were selected *i.e.,* one stable tree at the edge of mudflat while other 15.2 meter away. Future monitoring will lead to calculate per year erosion rate.

Figure 20 - Digital photo-mosaic of high erosion rate area of Chann creek, inset picture shows the tree marked for future monitoring

It was observed during the field survey that no algae was present on the mudflats when the atmospheric temperature was high whereas on the fourth day temperature was comparatively low (due to rainfall and cool sea breeze on 3rd and 4th day) and a thin layer of algae on large mudflats near Keti Bundar village was observed (Figure 21). According to the scientific research and discussion with the locals, algal phenology is season dependent *i.e*., lower the temperature, higher is the algal bloom. Algae due to the reflection of infrared radiation of electromagnetic spectrum appear in pinkish tone when seen in satellite image of SPOT with FCC 1, 2, 3.

Figure 21 - Algae (a) digital photograph, (b) satellite image and (c) close view of algae

2.9.7 Development of Forest Cover Maps

Satellite sensor record electromagnetic radiation response by the earth features in digital format. The response of spectrum values of different features depends on internal characteristics of particular features. On the basis of pixels spectral values, thematic layer is generated which is called as classification or landcover/landuse mapping. For the forest cover estimation from the images captured in 1992, 2001 and 2007, onscreen digitization methodology was adopted.

For better interpretation of satellite images different band combinations were used. Band combinations for SPOT, ASTER and Landsat varied depending upon the spectral resolution and availability of suitable bands for the vegetation mapping. For the mapping

and analysis of various vegetation types in ASTER satellite image, the band combination of 3n, 2, 1, as seen in Red, Green, Blue (RGB) was preferred to achieve maximum information of vegetative classes in band 3n of Near Infrared, band 2 and 1 in visible part of electromagnetic spectrum. FCC 4, 3, 2 for Landsat and 1, 2, 3 for SPOT were used for better visual interpretation.

On the basis of image interpretation keys *i.e.,* tone, texture, colour, shadow, association etc., different mangrove density classes were defined. Mangroves density layers were developed on the basis of sparseness and closeness of the canopies. Field data, spectral verification techniques and local area information were quite useful to account for the subtle variations in the forest cover map.

- Dense mangroves were in bright red tone with coarser texture. Coarser texture was due to the shadowing effect. Association with tidal creeks and the outer peripheries were also helpful in identification of this landcover feature.

- On the other hand medium and sparse mangroves were in a bit lighter tone and had smoother texture.

- Pink patches were early stages showing regeneration and new recruitment or sparseness of mangroves

- Halophytic shrubs due to low chlorophyll vigour and high spatial frequency appeared in maroonish grey colour.

- Pinkish to violet tinge was a sign of the presence of algae on mud. These areas were mostly on the inland side and were also closer to shallow/stagnant water. This association and field data significantly helped to segregate algal patches from mangroves.

For uniformity in visual interpretation, satellite images were interpreted and analyzed at a scale of 1:20,000 for Terra and SPOT satellite data, while for the LANDSAT data to accommodate the lower spatial resolution this delineation was made at a scale of 1: 25,000. SPOT 10m was used to delineate the forest classes whereas 2.5m high resolution merged image was used as an ancillary data in addition to ground truth data. Polygon based coding mechanism was adopted according to which each of the polygons was assigned with the appropriate ID of the representative class or species. IDs used for the representative land cover classes are shown in the Table 3.

Table 10 - Coding used to populate grid-based polygons

ID	Representative Land Cover Class
1	Dense Mangroves
2	Medium Mangroves
3	Sparse Mangroves
4	Very Sparse Mangroves
5	Saltbush/Grasses
6	Algae

2.10 Results and Discussion

2.10.1 Forest cover derived from 1992 satellite data

From the analysis of Landsat image of 1992, it was noted that the total mangrove cover of the area was 9,497 ha, out of which dense mangrove cover was about 1,966 ha (20%), medium mangrove cover was about 1,431 ha (15%), sparse mangrove cover was about 3,494 ha (37%) and very sparse mangrove cover was about 2,606 ha (28%). In addition thin algal mats have also been noted in the Landsat image of 1992, covering an area of about 200 ha (Figure 22). Halophytic shrubs and grasses cover an area of about 832 ha.

2.10.2 Forest cover derived from 2001 satellite data

Based on Aster image of 2001, the mangrove canopy cover analysis shows that the total mangrove cover in the area was about 7,559 ha. Dense mangrove cover was about 1,532 ha (20%), medium mangrove cover was about 1,265 ha (17%), sparse mangrove cover was about 2,880 ha (38%) and very sparse mangrove cover was about 1,882 ha (25%). Mix class of Halophytic shrubs / grass class covers an area about 508 ha.

In addition, some of the pure patches of algae were identified and delineated along the inland side which cover an area of 836 ha approx.

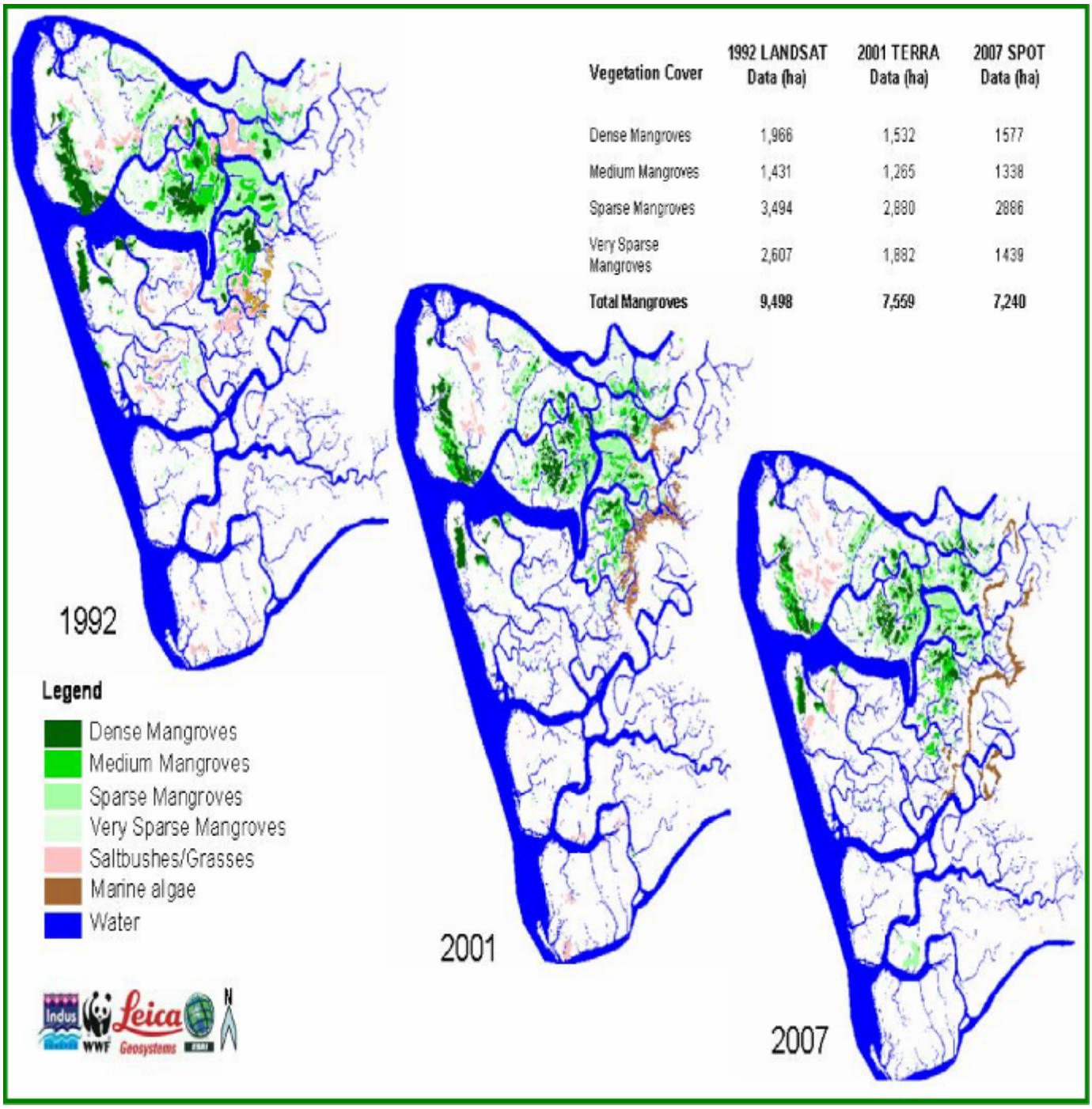
2.6.3 Forest cover derived from 2007 satellite data

From the analysis of SPOT image of 2007, it was noted that the total mangrove cover in study area is 7,241 ha, out of which dense mangrove cover is about 1,578 ha (22%), medium mangrove cover is about 1,338 ha (18%), sparse mangrove cover is about 2,886 ha (40%) and very sparse mangrove cover is about 1,439 ha (20%). In addition thin/sparse algal mats spread over 889 ha of land were delineated from 2007s dataset.

Table11 - Tabular representation of biomass change analysis (1992, 2001 & 2007)

Mangrove Cover	1992	2001	2007 (1	Change 992-2001) ha	Change (2001 -2007) ha
Dense	1,966	1,352	1,578	-343	-46
Medium	1,431	1,265	1,338	-166	-73
Sparse	3,494	2,880	2,886	-614	-6
Very Sparse	2,606	1,882	1,439	-725	+443
Total	**9,497**	**7,559**	**7,241**	**-1938**	**-318**
Saltbush/grasses	8,32	424	508	+402	+106
Algae	200	825	889	-635	-54

Figure 22. Forest cover maps derived from 1992, 2001 and 2007 satellite data

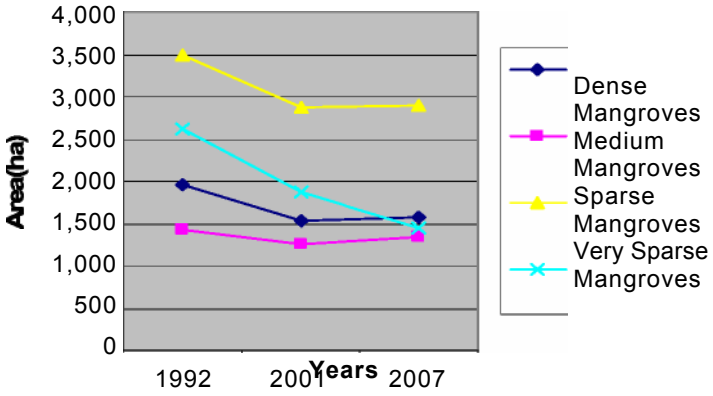


2.11 Change Analysis

2.11.1 Change in Mangrove Density Levels

Statistical values have been used to represent the change in mangroves density classes for three different dates. Graphical representation shows that there was decrease in different density levels of mangrove from 1992 to 2001. On the other hand a positive trend for dense, medium and sparse mangroves is analyzed in 2007. Very sparse mangroves show a negative trend which might be due to the high tide value at the time of acquisition of images.

Figure 23 - Graphical representation of change in



mangroves density levels from 1992, 2001 and 2007

2.11.2 Change in Mangrove Extent

Forest mapping is done by considering four density levels on the basis of percentage cover of the area. These four density levels *i.e.,* dense, medium, sparse and very sparse mangroves were merged into a single broad mangrove category for change analysis in terms of extent. Bar graph representing change status in mangroves extent at three different years *i.e.,* 1992, 2001 and 2007 is shown in Figure 24.

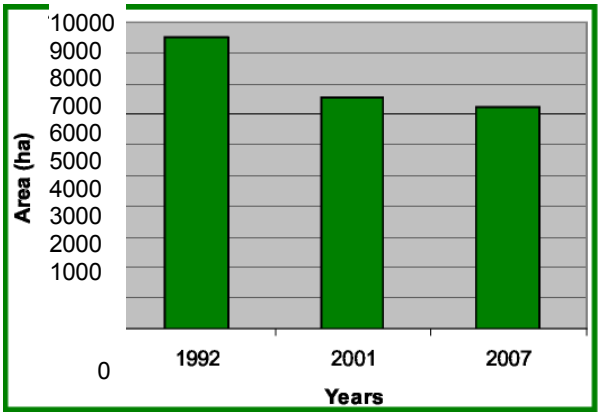


Figure 24 - Temporal (1992-2007) change of mangrove forest in Keti Bundar

For change trend analysis, four mangrove density levels were merged into a single mangrove class and different possible levels of change in mangrove status were mapped. Magnitude of change is shown in terms of intensity of the colours as shown in Figure 25.

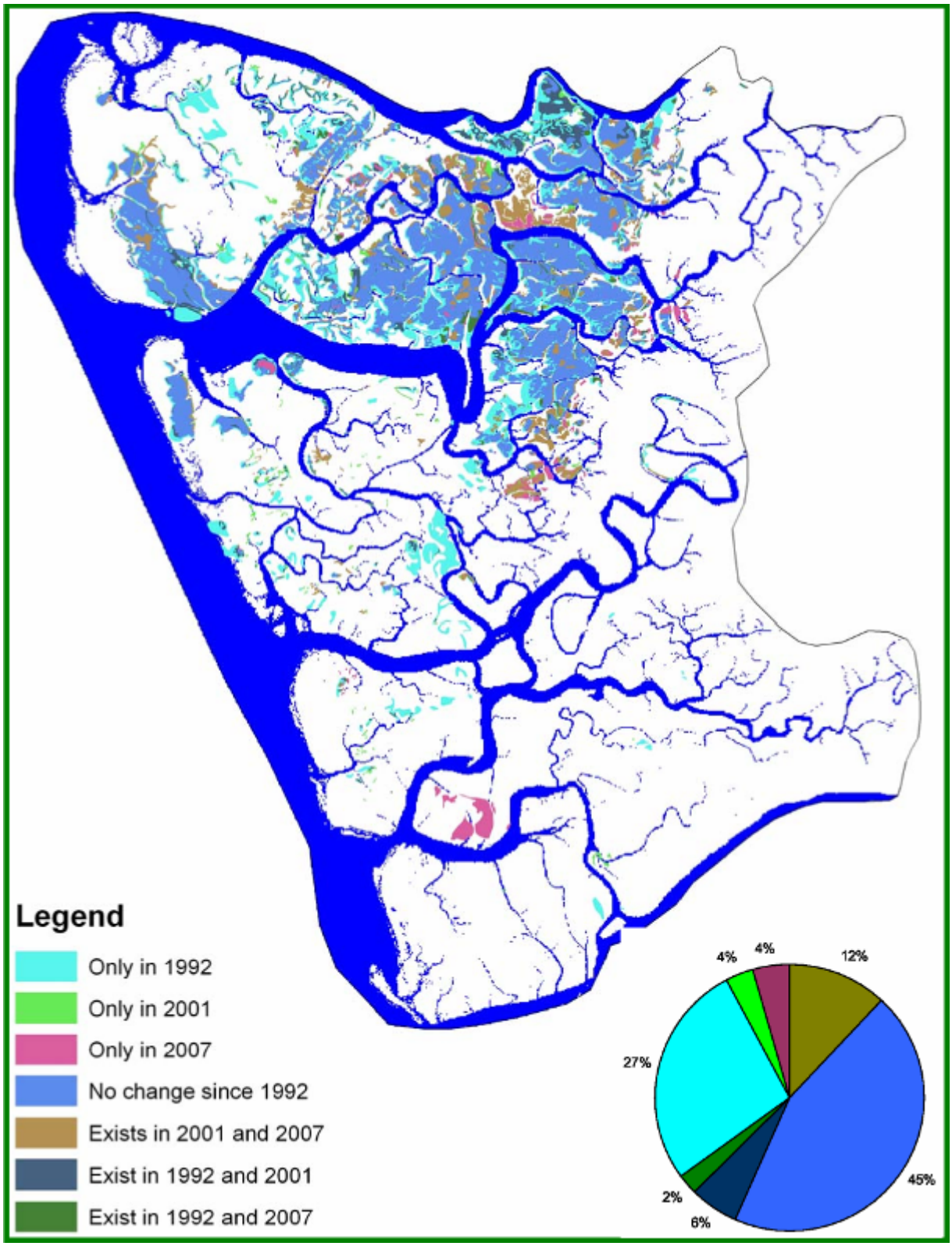


Figure 25 - Change status of mangroves extent from 1992-2007

2.11.3 Description of Mangroves Change Status (1992, 2001 & 2007)

"No change since 1992" class covers an area of 5336 ha. This class comprises of the mangroves extent that has not been changed from 1992 to date.

"Only in 1992' class represent mangrove that are present in 1992 and no more exists in 2001 and 2007 that might be due to deforestation, soil and wind erosion and less freshwater availability. This class covers a large extent of 3218 ha and is spread along the channels as well as on the mudflats.

"Only in 2001" class represent mangrove that are present in 2001 and not classified/identified in 1992 and 2007 imageries. This class defines mangroves that were regenerated within 1992-2001 but couldn't reach to maturity.

"Only in 2007" class represent mangrove that are present in 2007 data only and covers an area of 517 ha approx. This class mainly consists of mangroves that are regenerated in the area after year 2001.

"Exist in 1992 and 2007" This class covers an area of approx 282 ha and comprises of mangroves that exists both in 1992 and 2007 but were not present in 2001 data. The results show that there was decrease in its extent in 2001 but mangroves regroomed during 2001-2007.

"Exist in 2001 and 2007" class consists of mangroves that were not present in 1992 but exists in 2001 and 2007 data. This class covers an area of approx 1407 ha and highlights satisfactory increasing trend in mangroves extent.

"Exist in 1992 and 2001" class consists of mangroves that do not survive in 2007 but present in 1992 and 2001 imageries. This category highlights an alarming trend of mangroves decrease at specific areas and covers an area of approx 688 ha.

It is evident from the temporal satellite images that some areas are facing acute soil erosion by the Sea. Figure 26 highlights one example of such area in which dense mangrove patch (highlighted in yellow polygon) of 50 ha remained stable from 1975 to 1992, but totally vanished in 2007. This high erosion rate would result in the formation of new creek in future.

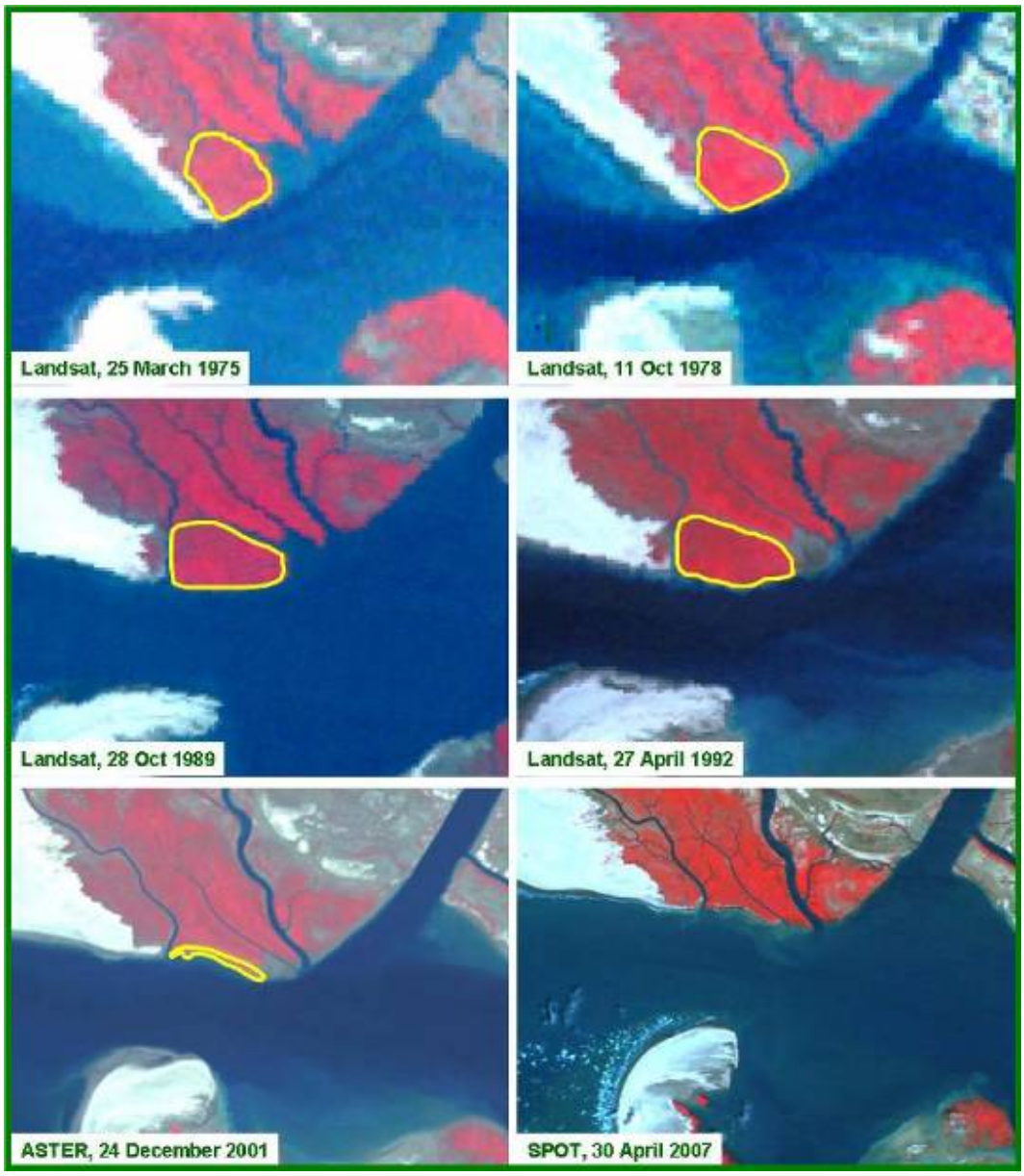


Figure 26 - An example of forest degradation due to erosion

In contrast to the above mentioned statements, mangroves in Chann creek area are comparatively in stable condition. Change analysis highlights that the mangroves in this area are mostly defined with “No Change class: or increased density classes”. Only in 2007 class covers an area of about 517 ha which is satisfactory and defines the reforestation and afforestation in the area. (Figure 27 – Mangroves in Chann)

The extent of algal bloom is not constant from 1992 to 2007. As discussed previously that algae remain present in the marine ecosystems but during low temperatures it proliferates. Another possible hypothesis for algal bloom in low temperatures could be

the increased concentration of pollutants. This could be attributed to the fact that the low temperature season is also the dry season with less water reaching the delta. This can cause concentration of organic pollutants which provide nutrients to algae to thrive. Furthermore, industrial pollutants from upstream also reach this area with add on effect to algal growth. As the water level increases upstream it dilutes both organic and inorganic pollutants, algae begin to shrink but at the same time temperature is also increasing. It seems possible that both temperature and water availability are important factors controlling algal growth. Analysis reveal an interesting result *i.e.,* extent of algae was 200 ha in April 1992 whereas 889 ha in April 2007 (Figure 28). The months of satellite image acquisition are same but there is huge difference in the algal extent. The difference appears to be the result of less freshwater availability and relatively more pollution due to the formation of new industries which enhance the eutrophication phenomenon.

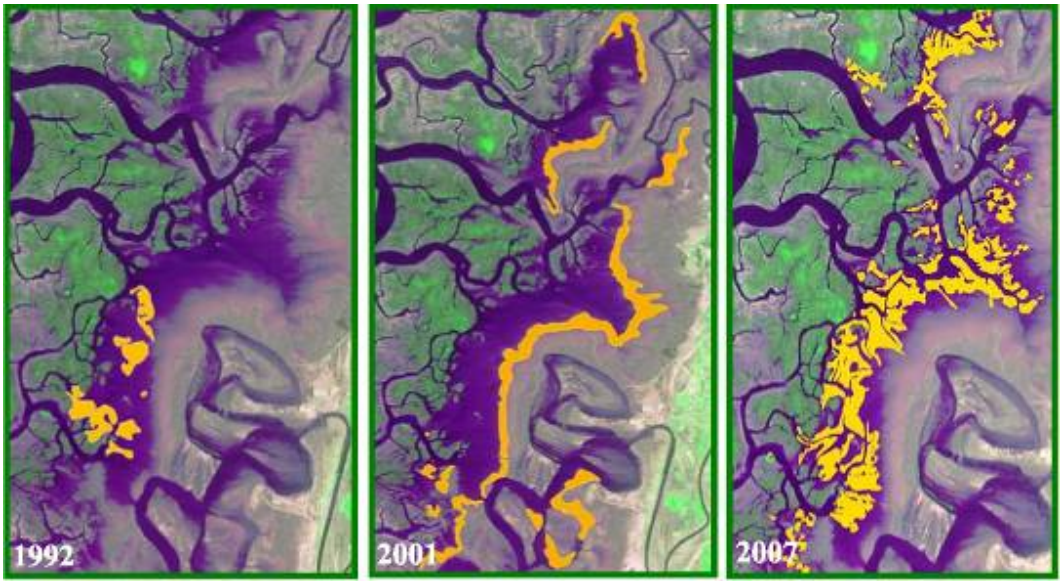


Figure 28 - Temporal change in algal extent, algae are displayed in orange colour

SPOT 2.5m high resolution merged image provided the opportunity to define vegetation classes with greater level of confidence. Pure and large dense patches of halophytic shrurbs were identified in the satellite images whereas sparse halophytic shrub patches on small area remained undefined due to the spectral and spatial limitations of satellite images.

One of the limitations of the study was the high tide value at the time of acquisition of SPOT image. Although best available recent SPOT image was acquired but the tide height was 3.6m at the time of acquisition of the image. In 2007's thematic layer, high tide value hampered the ability to identify very sparse mangroves class along the creeks and comparatively low elevation areas. That is why "Very Sparse Mangrove" class has less coverage area when compared with 2001 data.

2.12 Conclusions and Recommendations

The results of this study reveal that there has been a decrease of 1,938 ha of mangroves extent from 1992 to 2001. The mangrove forest degradation rate shows that 20% of mangroves present in 1992 vanished completely by 2001. A relatively positive trend of mangroves has been analyzed between 2001 and 2007 among three classes of mangrove; dense, medium and sparse. However, a decrease in 'very sparse mangroves' class was observed, which could be attributed to the fact that the 2007 satellite image, although the best available image, was captured during the high tide. A high tide image minimizes the reflectance of very sparse mangroves and result in less extent of this class.

Large mangrove forest clusters towards open sea are relatively intact with no variation in their middle regions. However, their peripheries are subject to the negative change due to the dynamic geomorphology of the area. The Mangrove forest towards the northern part of the Keti Bundar area (Chann creek area closer to the inland) is comparatively stable in condition. This can be because of the protection offered by the Sindh Forest Department.

Detailed field survey and SPOT 2.5m high resolution merged image significantly helped in segregating halophytic shrubs and grasses from mangroves. Field data collection form to record density classes helped in developing forest cover map more accurately.

Most of the coastal mapping studies contain discrepancies due to misclassification of algae as mangroves. In this study, algae were identified as a separate class that improved the accuracy and produced reliable data. It has been observed that algal belt increased from 200 ha to 889 ha in the fifteen year period. It is recommended to conduct further investigation to evaluate the occurrence and distribution of algae on large mud areas. Study of soil chemistry, pollution sources and seasonal variation in the algal extent would further benefit the programme in evaluating its impact on mangroves forest.

The study recommends developing a predictive model by using current and historic (if available) data with different temporal ranges from 1950 - 2007. The developed model could be used in defining change trend patterns more precisely. This will help in management and conservation.

It is also suggested to use remotely sensed data (landcover and soil classification maps) for the definition of suitable mangroves plantation sites. Temporal high resolution images can also be used to monitor the success of afforestation of mangroves.

3 - Keenjhar Lake
A Fresh Water body Ecosystem

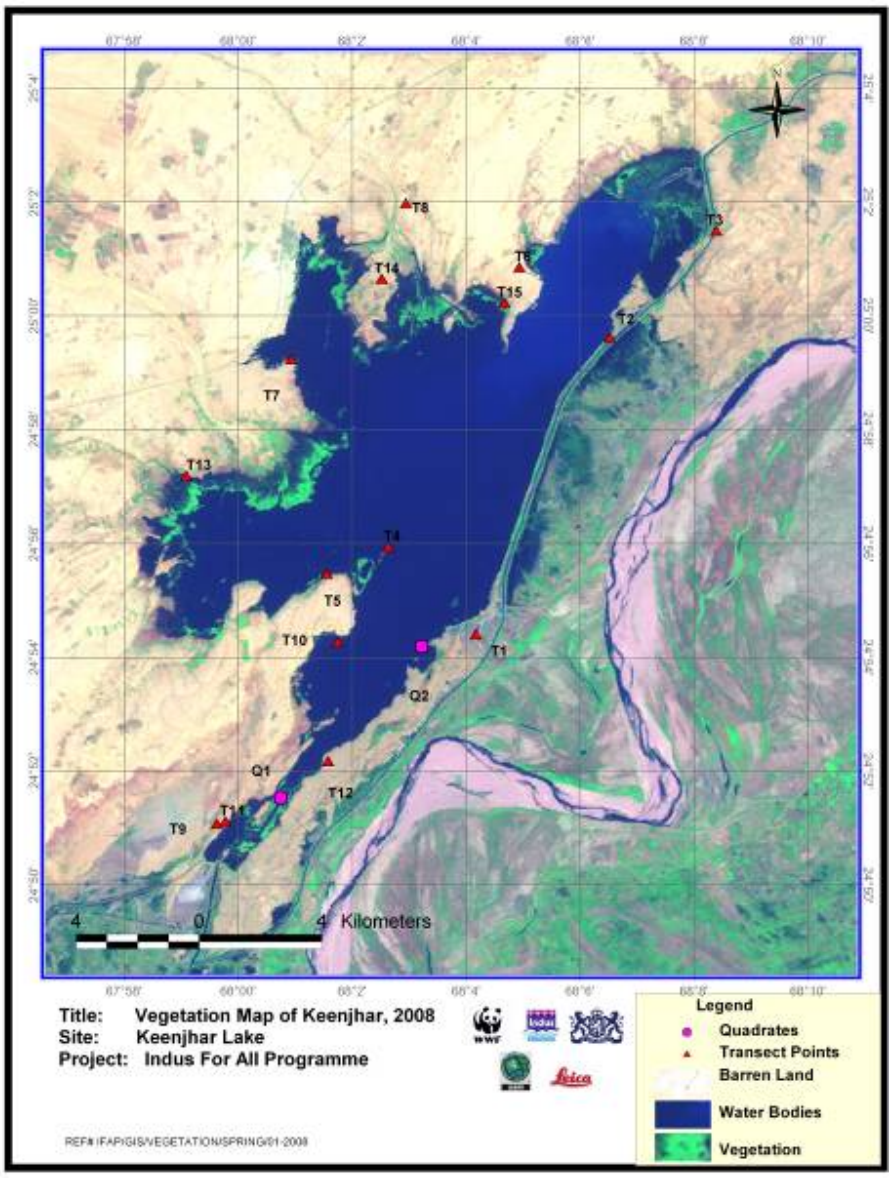


Figure 29. SatelliteImage of Keenjhar Lake

3.1 Brief History of Keenjhar Lake

Keenjhar Lake is situated at a distance of 113 km from Karachi and about 20 km North and North – East of Thatta town between the longitude of 68 and 69 ^{o} NE and latitude 24 and 25 ^{o}N. It is a freshwater Lake having an area of about 145 km^{2} (Anon 1999). The maximum depth of the Lake is 8m. Keenjhar Lake is located in stony desert, composed of alternating layers of limestone and sandstone. Historically it is formed by the union of two Lakes, Sonehri and Keenjhar through the construction of an embankment on their eastern side in 1950s. Originally these Lakes came into being when River Indus changed its course, cutting-off these Lakes. Before the construction of embankment, the Lakes were fed by a dozen hill torrents on the western side. Now it gets most of its water from Indus River through canal. With this background, Keenjhar may be regarded as semi natural Lake. The Lake is fed by the Kalri Baghar canal originating from Kotri Barrage that enters at the northwest corners, and by many small seasonal streams entering on the western and northern shores. The only outlet is through the Jam branch canal at the southeast corner of the Lake (Anon, 2006). The Lake is known as the largest freshwater Lake of the country and its main source is from Indus River, however, some proportion of water is contributed from the run off from the adjacent hills and torrents. The local villagers residing around the Lake are using water for their daily consumption (Anon, 2006). Keenjhar Lake is the main source of water supply to Karachi and parts of Thatta district.

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Anon (1999) described that at its initial stage the Lake was around 18.5 meters deep, however, due to subsequent siltation from River Indus the depth has reduced to 5-6.5 meters. There are about 62 small and large villages around the Lake which fall in four Union Councils viz: Sonda, Oongar, Jhimpir and Chatto Chan of Tehsil and District Thatta.

Sonahri, Chill, Ghandri, Chakro, Moldi, Dolatpur, Chilliya, Khambo, and Hilllaya are the major villages. Jhimpir town is also situated on the north western bank of the Lake. Before partition, it was surrounded by a population of about 40, 000 fishermen living in the villages mentioned above. However, with the construction of link canal and gradual shortage of water the population of fishermen communities started declining as evident from the table 12 (Anon 2006).

Table 12 - Comparison of Fishermen Population and Fish Production

Year	Population	Fish Production (Metric Tons)	No. of Boats
1988-89	24355	58000	2200
1998-99	11900	27000	1710
2005-06	10320	15650	820

Source: Anon (2006).

About 50,000 people are dependent on the Lake. There are four fish-landing centres at the Lake *Viz.,* Khumbo, Chilya, Sonheri and Jhimpir. Total 800 fishing crafts are operating in the area. The fishers have their own fishing territories and the local community defined them properly (Anon, 2006). For example, the people from the

Sonheri village have their own fishing grounds and they never fished in the territories of the Jhimpir areas (Anon 2006).

The main casts/ tribes present are Palari, Shora, Kapai, Gandara, Hilaya, Turk, Katiyar, Khaskheli and Sarki etc. The major occupation of the community is fishing and agriculture. People belonging to Palari, Shora, Hilaya and Turk tribes are involved in agriculture around the Lake. Pesticides are widely used in the cultivated area. People have livestock especially buffaloes, goats and cows etc. and they graze them in the buffer zone and around the Lake. Other casts are involved in fishing and commonly known as Mirbahar. The fishing practices of the local communities are generally sustainable. The locals hardly use small mesh size nets to catch the fish. The permanent circular nets placed in the Lake locally known, as “Gol Jaar” is also sustainable way of fishing.

The level of education is low. Twelve primary schools for boys and one high school for boys are present in the area. Health and Nutrition Development Society (HANDS), has also established a community school in one of the villages in collaboration with Gandhara Welfare Association. However, for girl’s education the priority has not been given, therefore, the illiteracy rate among the women is near to 99%.

The civil dispensaries are present in the four union councils of the area but due to weak monitoring by the health department they are not working properly. Generally people are suffering from malaria and gastrointestinal diseases.

Due to decline in fisheries some people are also involved in the mining of stones from the nearby stony hills. Some communities are also earning income from the local tourists coming from Karachi, Hyderabad and Thatta for recreational purpose. They have the speedboats and they usually charge Rs. 1000 to Rs. 1500 per day based on the time and trip. These boats do not have any safety gears on them, therefore lots of accidents have been occurring in the past and many people lost their lives.

Sindh Tourism Development Corporation has developed a Tourist Center there with Air-conditioned Lodges and visitor’s facility. The facility has been developed in a stretch of about 2 km towards eastern side of the Lake and they charge an entrance fee from vehicles and/or visitors into this area.

Irrigation department has a small set up and have a rest house. Towards south-western side of the Lake the Karachi Water Sewerage Board has its own set up to regulate the outlet of the Lake. Pakistan Army has also established a rest house on the eastern side of the Lake.

Fisheries Department is also active in the area. It has established a modest facility over Keenjhar Lake and owns a large set up in Chillya, which is about 10 km away from here. In Chillya, Fisheries Department has training centre and a hostel along with fish hatchery.

3. 2. State of Biodiversity:

Keenjhar Lake was declared Wildlife Sanctuary in 1977 under Sindh Wildlife Protection Ordinance, 1972. The sanctuary has a buffer zone of 5 km. It has also been designated as Ramsar site during 1976 (Anon 1999).

3.2.1 Flora: The Lake has a rich flora of submerged, floating and emergent aquatic plants such as *Potamogeton spp., Najas minor, Nelumbo nucifera, Nymphaea spp., Cyperus spp., Phragmites spp., Typha spp.,* etc. These provide both food and shelter to fauna species. Many birds reside in the thick growth of *Typha* and *Phragmites*. The land around the Lake has a rich diversity of semiaquatic to dry land plant species.

3.2.2 Fauna: Keenjhar Lake is rich in fish fauna. It includes *Ambassis nana*, *Badis* spp*. Puntius sarana, Puntius ticto, Catla catla, Channa* spp*. Cirrhinus mrigala, Ctenopharyngodon idellus, Gadusia chapra, Glossogobius spp. Labeo rohita, Labeo gonius, Notopterus notopterus and, Rasbora rasbora,* etc. The livelihood of the local communities mainly depends on these resources. Anon (1999) mentioned an annual production of about 700 metric tonnes of fish but there is a potential of producing around 10, 000 metric tonnes. There has been reduction in the fish stock due to overexploitation.

Keenjhar Lake is an important breeding and wintering and staging area for a wide variety of terrestrial and migratory birds. About 65 species of waterfowl have been recorded. Amjad and Kidwai (2002) (gave following account of annual waterfowl census at Keenjhar Lake.

Table 13. Population of migratory birds over different years

Year	Total Number of Birds Recorded
1970s	50,000 – 150,000
1987	135,000
1988	205,000
1990	89,784
2000	30,220
2001	38,958
2002	30,610

Source: Amjad & Kidwai (2002)

Breeding birds include Night heron, Cotton teal, Pheasant tailed jacana, Purple Moore hen, besides some passerines. The Cotton teal has disappeared in the recent years and have not been seen on the Lake for few years. Mammals include Jackals, Fox, Porcupine, Mongoose and Rodents. Pangolin is also recorded. Among reptiles snakes like cobra and Saw scaled viper is common. Monitor lizards, Spiny tailed lizard are also distributed here.

3.2.3 Agriculture: Rice, sugarcane, maize and vegetables are grown in buffer and adjacent areas of the Lake. An account of cultivated plants (woody perennial and herbaceous) is provided in Table 14 below.

Table 14: Cultivated plant species recorded at Keenjhar Lake

Sr :	Family	Plant species	Life form	Habit
1	Boraginaceae	*Cordia myxa* L.	Phanerophyte	Small tree
2	Caesalpiniaceae	*Cassia alata* Linn.	Phanerophyte	Shrub
3	Caesalpiniaceae	*Parkinsonia aculeata* L.	Phanerophyte	Tree
4	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Phanerophyte	Subshrub
5	Mimosaceae	*Leucaena leucocephala (Lam.) ed Wit.*	Phanerophyte	Tree
6	Moraceae	*Ficus benghalensis*	Phanerophyte	Tree
7	Moraceae	*Ficus religiosa*	Phanerophyte	Tree
8	Pedaliaceae	*Sesamum indicum* L.	Phanerophyte	Shrub
9	Verbenaceae	*Clerodendrum inerme* Gaertn	Phanerophyte	Shrub

3.3 Socio-economic status of communities around Keenjhar Lake

Keenjhar Lake is one of the major fresh water reservoirs located at Thatta district of Sindh province, covering an area of about 14,000 ha. The Lake is rich in fish fauna and support the livelihood of about 50000 people. It is important breeding and wintering area for a wide variety of birds.

This artificial reservoir has been formed out of natural depressions called Sonehri and Keenjhar Dhandh (depression). The Lake is a vital wetland area of great ecological, biological and economic significance. Keenjhar is the major source to provide domestic and industrial water supplies to cosmopolitan city of Karachi.

The communities are living in the settlements of the different sizes of villages and hamlets in the programme area. Thirty eight villages are located with two Kms radius having population of 18792 members with 2610 households and average household size is 7.2. Housing infrastructure around the Lake is very poor, 73.3% of the houses are Kacha houses made up with thatch material and consisting of one to two rooms.

The communities at Keenjhar Lake, in general, are practicing the same cultural norms and Sindhi is the predominate language of the area. Gandhra, Mirbahar, Manchri and Machhi casts are fishermen, Hillaya, Dars, Autha and Katiar are farmers, while Palari Jakhra are the herders. Tables showing different parameters of the socio-economic profile of the communities of Keenjhar Lake are provided in Annexures B – VI to B – XIV.

3.3.1 Infrastructure and social services:

Lake is the main source of drinking water for the communities; about 78% people are getting their drinking water from the Lake; whereas 14% people are getting water from nearby canal. Area is deprived of sewerage facility, whereas only 27 houses have toilet facilities in their houses. About 44% villages have access to the electricity; no gas facility is available in the entire Lake area.

3.3.1.1 Education: About 60% population around the Lake is illiterate; however the ratio of primary education is reported as 30%, which is indicating that primary schooling has been available there in recent years. Only 5% people are educated up to middle and 3%

up to matric and graduation level, whereas female illiteracy is 88%. 63% villages have primary boy's schools with average 2 rooms building and two teachers for 83 students. About 2.6 % villages have middle school facilities with 6 rooms building and 4 teachers for average 50 students, there is no high school for boys and girls in Lake area. Thirty six percent villages have primary girl's schools with 2 rooms and 2 teachers, where as 2.6% villages have facility for the girls middle school with 6 room building, but no female staff is appointed yet for these girls' middle schools.

3.3.1.2 Health: Health and hygiene condition of the area is very pathetic. Incidence of Malaria, Diarrhoea, skin disease, typhoid and Jaundice were reported in all programme villages, but the incidence of the skin disease and malaria was found at alarming level. There is dearth of health infrastructure, only 3% villages have dispensaries and one village has Basic Health Unit, no Rural Health Centre or hospital is available in the program site, 60 % people are visiting private clinics. On an average the private clinics and other health facilities are available at a distance of 10 km from their villages.

Professional maternity services are also missing in the area and 87% births are being attended by local birth attendants. Only 1% cases are being handled by the trained Lady Health Visitors (LHVs) and about 12% cases are being handled at hospitals and private clinics due to some complexities. Child and mother mortality rate is reported 7 % and 1%, respectively

3.3.1.3 Livelihood sources and poverty level: There is mix of four major occupations around the Lake, Fishing, Agriculture, stone mining and mate making. However, fishing is continued to be dominant occupation of the programme area. About 44% community members are engaged with fishing, followed by 22% as agriculture labourers and 8% engaged in stone mining. Poverty has remained one of the most serious problems of the area. Decline in fish catch, poor infrastructure, lack of employment opportunities, lack of productive assets, inadequate technical capability and use of inappropriate technology is the main factors responsible for their poverty level. Using the poverty line of Rs. 1000 per capita income (2004-5 national poverty line of Rs.878 and adding inflation rate of 7.5 per year) about 62 % people around Lake are living below poverty line with average per capita income of Rs. 971.

3.4 Results

3.4.1 Flora of Keenjhar

Likewise other sites, vegetation assessment of Keenjhar Lake were carried out over three years (2006, 2007 and 2008). The cumulative number of species after these assessments comes to be 263 in 165 genera and 55 families. Among these, Pteridophytes are represented by one species in one genus and one family, Dicot Angiosperms by 185 species in 120 genera and 44 families and Monocot Angiosperms by 77 species in 44 genera and 10 families. The complete list of species is given in Table: 12. Poaceae with 51 species comes to be the largest family followed by Fabaceae with 20 species, Asteraceae and Cyperaceae with 15 species each, and Convolvulaceae with 12 species. The details of contribution of all recorded families in the flora of this site are given in the Table: 30. Among genera, *Cyperus* with 9 species is the largest followed by *Tamarix, Heliotropium* and *Eragrostis* with 6 species each, *Euphorbia, Indigofera* and *Convolvulus* with 5 species each. In addition to natural flora,

nine species of cultivated plants were also recorded (Table 13). Transect-wise details of the Phytosociological aspects of the Keenjhar Lake over three study years is provided in Annexure B – I.

Table 15 - Flora of Keenjhar Lake.

S.#	Family	Plant species	Life form	Habit
1.	Acanthaceae	*Barleria acanthoides* Vahl	Phanerophyte	Shrub
2.	Acanthaceae	*Barleria hochstettri* Nees	Chamaephyte	Shrub
3.	Acanthaceae	*Barleria prionitis* L.	Phanerophyte	Shrub
4.	Acanthaceae	*Blepharis sindica* Stocks ex. T. Anders.	Therophyte	Herb
5.	Acanthaceae	*Ruellia patula* var. *alba* Saxton	Chamaephyte	Shrub
6.	Aizoaceae	*Trianthema portulacastrum* L.	Therophyte	Herb
7.	Aizoaceae	*Trianthema triquetra* Rottl. and Willd.	Therophyte	Herb
8.	Aizoaceae	*Zaleya pentandra* (L.) Jeffery.	Chamaephyte	Herb
9.	Amaranthaceae	*Achyranthes aspera* L.	Chamaephyte	Subshrub
10.	Amaranthaceae	*Aerva javanica* (Burm.f.)Juss ex J.A. Schultes	Phanerophyte	Shrub
11.	Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Chamaephyte	Herb
12.	Amaranthaceae	*Amaranthus graecizans* L.	Therophyte	Herb
13.	Amaranthaceae	*Amaranthus viridis* L.	Therophyte	Herb
14.	Amaranthaceae	*Digera muricata* (L.) Mart.	Therophyte	Herb
15.	Apocynaceae	*Rhazya stricta* Decne	Phanerophyte	Shrub
16.	Araceae	*Pistia stratioites* L.	Hydrophyte	Herb
17.	Arecaceae	*Nanorrhops ritcheana* (Griff.) Aitch.	Phanerophyte	Shrub
18.	Arecaceae	*Phoenix sylvestris* L.	Phanerophyte	Tree
19.	Aristolochiaceae	*Aristolochia bracteolata* Lamk.	Cryptphyte	Herb
20.	Asclepiadaceae	*Calotropis procera* (Ait.) Ait.f.	Phanerophyte	Shrub
21.	Asclepiadaceae	*Caralluma edulis* (Edgew.) Benth. & Hook.	Cryptophyte	Herb
22.	Asclepiadaceae	*Glossonema varians* (Stocks) Hook.f.	Chamaephyte	Herb
23.	Asclepiadaceae	*Leptadenia pyrotechnica* (Forsk.) Dcne.	Phanerophyte	Shrub
24.	Asclepiadaceae	*Oxystelma esculentum* (L.f) R.Br.	Cryptophyte	Subshrub
25.	Asclepiadaceae	*Pentatropis nivalis* (J.F.Gmel.) Field & J.R.I.Wood	Chamaephyte	Climber
26.	Asparagaceae	*Asparagus dumosus* Baker	Cryptophyte	Shrub
27.	Asteraceae	*Blumea obliqua* (L.) Druce	Chamaephyte	Herb
28.	Asteraceae	*Conyza aegyptiaca* Ait.	Camaephyte	Herb
29.	Asteraceae	*Echinops echinatus* Roxb.	Therophyte	Tall herb
30.	Asteraceae	*Eclipta prostrata* (L.) L.	Chamaephyte	Herb
31.	Asteraceae	*Grangea maderaspatana* (L.) Poir.	Therophyte	Herb
32.	Asteraceae	*Iphiona grantioides* Boiss	Chamaephyte	Subshrub
33.	Asteraceae	*Launaea procumbens* (Roxb.) Amin.	Chamaephyte	Herb
34.	Asteraceae	*Launaea remotiflora (DC.) Stebbins*	Therophyte	Herb
35.	Asteraceae	*Pluchea arguta* Boiss.	Chamaephyte	Subshrub
36.	Asteraceae	*Pluchea wallichiana* DC	Phanerophyte	Shrub
37.	Asteraceae	*Pulicaria boissieri* Hook.f.	Chamaephyte	Herb
38.	Asteraceae	*Sonchus asper* L. Hill.	Therophyte	Herb
39.	Asteraceae	*Sonchus oleraceus* L.	Therophyte	Herb
40.	Asteraceae	*Vernonia cinerascens* Schultz. Bip.	Phanerophyte	Shrub
41.	Asteraceae	*Xanthium strumarium* L.	Phanerophyte	Shrub

S.#	Family	Plant species	Life form	Habit
42.	Avicenniaceae	*Avicennia marina* L.	Phanerophyte	Tree
43.	Boraginaceae	*Coldenia procumbens* L.	Chamaephyte	Herb
44.	Boraginaceae	*Cordia gharaf* (Forsk.) Ehren. ex Asch.	Phanerophyte	Tree
45.	Boraginaceae	*Heliotropium calcareum* Stocks	Chamaephyte	Subshrub
46.	Boraginaceae	*Heliotropium crispum* Desf.	Chamaephyte	Subshrub
47.	Boraginaceae	*Heliotropium curassavicum* L.	Chamaephyte	Subshrub
48.	Boraginaceae	*Heliotropium ophioglossum* Stocks ex Boiss.	Chamaephyte	Subshrub
49.	Boraginaceae	*Heliotropium ovalifolium* Forsk.	Chamaephyte	Herb
50.	Boraginaceae	*Heliotropium strigosum* Willd.	Chamaephyte	Herb
51.	Boraginaceae	*Sericostoma pauciflorum* Stocks ex Wight	Chamaephyte	Subshrub
52.	Boraginaceae	*Trichodesma indicum* (L.) R. Br.	Chamaephyte	Subshrub
53.	Brassicaceae	*Farsetia hamiltonii* Royle	Therophyte	Herb
54.	Burseraceae	*Commiphora stocksiana* (Engler) Engler	Phanerophyte	Large shrub – tree
55.	Burseraceae	*Commiphora wightii* (Arn.) Bhandari	Phanerophyte	Shrub – tree
56.	Caesalpiniaceae	*Senna holosericea* (Fresen.) Greuter	Chamaephyte	Subshrub
57.	Caesalpiniaceae	*Senna italica* Mill.	Chamaephyte	Subshrub
58.	Capparidaceae	*Cadaba fruticosa* (L.) Druce	Phanerophyte	Shrub
59.	Capparidaceae	*Capparis decidua* (Forsk.) Edgew.	Phanerophyte	Large Shrub
60.	Capparidaceae	*Capparis spinosa* L.	Phanerophyte	Subshrub
61.	Capparidaceae	*Cleome brachycarpa* Vahl ex DC.	Chamaephyte	Herb
62.	Capparidaceae	*Cleome scaposa* DC.	Therophyte	Herb
63.	Capparidaceae	*Cleome viscosa* L.	Therophyte	Herb
64.	Capparidaceae	*Gynandropsis gynandra* (L.) Briq.	Therophyte	Herb
65.	Capparidaceae	*Maerua arenaria* (DC) Hook.f. & Thoms	Phanerophyte	Shrub
66.	Caryophyllaceae	*Polycarpaea spicata* Wight & Arn.	Therophyte	Herb
67.	Caryophyllaceae	*Spergularia marina* (L.) Griseb.	Therophyte	Herb
68.	Chenopodiaceae	*Atriplex stocksii* Boiss.	Chamaephyte	Subshrub
69.	Chenopodiaceae	*Chenopodium album* L.	Therophyte	Herb
70.	Chenopodiaceae	*Chenopodium murale* L.	Therophyte	Herb
71.	Chenopodiaceae	*Haloxylon stocksii* (Boiss.) Benth. & Hooker	Phanerophyte	Shrub
72.	Chenopodiaceae	*Salsola imbricata* Forsk.	Phanerophyte	Shrub
73.	Chenopodiaceae	*Suaeda fruticosa* Forsk. Ex J.F. Gmelin	Phanerophyte	Shrub
74.	Convolvulaceae	*Convolvulus arvensis* L.	Chamaephyte	Climber
75.	Convolvulaceae	*Convolvulus glomeratus* Choisy.	Chamaephyte	Runner
76.	Convolvulaceae	*Convolvulus prostratus* Forssk.	Chamaephyte	Herb
77.	Convolvulaceae	*Convolvulus rhyniospermus* Hochst. ex Choisy	Chamaephyte	Herb
78.	Convolvulaceae	*Convolvulus scindicus* Boiss.	Chamaephyte	Subshrub
79.	Convolvulaceae	*Cressa cretica* L.	Therophyte	Herb
80.	Convolvulaceae	*Ipomoea aquatica* Forsk.	Hydrophyte	Herb
81.	Convolvulaceae	*Ipomoea carnea* Jacq.	Phanerophyte	Large Shrub
82.	Convolvulaceae	*Ipomoea sindica* Stapf	Therophyte	Climber
83.	Convolvulaceae	*Merremia aegyptia* (L.) Urban	Therophyte	Climber
84.	Convolvulaceae	*Merremia hederacea* (Burm.f.) Hall.f.	Chamaephyte	Climber
85.	Convolvulaceae	*Seddera latifolia* Hochst. & Steud.	Chamaephyte	Subshrub
86.	Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Therophyte	Herb

S.#	Family	Plant species	Life form	Habit
87.	Cucurbitaceae	*Coccinia grandis* (L.) Voigt	Phanerophyte	Climber
88.	Cucurbitaceae	*Cucumis melo* var. *agrestis* Naud.	Therophyte	Climber
89.	Cucurbitaceae	*Cucumis prophetarum* L.	Chamaephyte	Climber
90.	Cucurbitaceae	*Luffa echinata* Roxb.	Chamaephyte	Climber
91.	Cucurbitaceae	*Mukia maderaspatana* (L.) M.J.Roem.	Chamaephyte	Climber
92.	Cyperaceae	*Bolboschoenus affinis* (Roth.) Drobov	Cryptophyte	Sedge
93.	Cyperaceae	*Bolboschoenus glaucus* (L.) S.G. Smith	Cryptophyte	Sedge
94.	Cyperaceae	*Cyperus alopecuroides* Rottb.	Cryphotphyte	Sedge
95.	Cyperaceae	*Cyperus articulatus* L.	Cryptophyte	Sedge
96.	Cyperaceae	*Cyperus exaltatus* L.	Cryptophyte	Sedge
97.	Cyperaceae	*Cyperus bulbosus* Vahl.	Cryptophyte	Sedge
98.	Cyperaceae	*Cyperus laevigatus* L.	Cryptophyte	Sedge
99.	Cyperaceae	*Cyperus longus* L.	Cryptophyte	Sedge
100.	Cyperaceae	*Cyperus pygmaeus* Rottb.	Hemicryptophyte	Sedge
101.	Cyperaceae	*Cyperus rotundus* L.	Cryptophyte	Sedge
102.	Cyperaceae	*Cyperus stoloniferus* Retz.	Cryptophyte	Sedge
103.	Cyperaceae	*Eleocharis geniculata* (L.) Roem. & Schult.	Hemicryptophyte	Sedge
104.	Cyperaceae	*Fimbristylis bisumbellata* (Forssk.) Bubani	Hemicryptophyte	Sedge
105.	Cyperaceae	*Pycreus dwarkensis* (Sahni & Naithani) Hooper	Hemicryptophyte	Sedge
106.	Cyperaceae	*Schoenoplectus litoralis* subsp *thermalis* (Trabut) S.Hooper	Crytophyte	Sedge
107.	Elatinaceae	*Bergia suffruticosa* (Delile) Fenzl.	Chaemaephyte	Subshrub
108.	Euphorbiaceae	*Euphorbia caducifolia* Haines	Phanerophyte	Large Shrub
109.	Euphorbiaceae	*Euphorbia clarkeana* Hk.f.	Therophyte	Herb
110.	Euphorbiaceae	*Euphorbia granulata* Forsk.	Therophyte	Herb
111.	Euphorbiaceae	*Euphorbia hirta* L.	Therophyte	Herb
112.	Euphorbiaceae	*Euphorbia serpens* Kunth	Therophyte	Herb
113.	Euphorbiaceae	*Phyllanthus maderaspatensis* L.	Therophyte	Herb
114.	Euphorbiaceae	*Phyllanthus reticulatus* Poir.	Chamaephyte	Shrub
115.	Fabaceae	*Alhagi maurorum* Medic.	Phanerophyte	Subshrub
116.	Fabaceae	*Alysicarpus ovalifolius* (Schumach.) J. Leonard	Therophyte	Herb
117.	Fabaceae	*Argyrolobium roseum (Camb.)* Jaub. & Spach.	Therophyte	Herb
118.	Fabaceae	*Crotalaria burhia* Ham. Ex Bth.	Phanerophyte	Subshrub
119.	Fabaceae	*Crotalaria medicaginea* Lam.	Therophyte	Herb
120.	Fabaceae	*Cyamopsis tetragonoloba* (L.) Taub.	Therophyte	Shrub
121.	Fabaceae	*Indigofera argentea* Burm.f.	Chamaephyte	Herb
122.	Fabaceae	*Indigofera cordifolia* Heyne ex Roth	Therophyte	Herb
123.	Fabaceae	*Indigofera hochstetteri* Baker	Therophyte	Herb
124.	Fabaceae	*Indigofera linifolia* (L.f.) Retz.	Therophyte	Herb
125.	Fabaceae	*Indigofera oblongifolia* Forsk.	Phanerophyte	Shrub
126.	Fabaceae	*Rhynchosia minima* (L.) DC.	Chamaephyte	Climber
127.	Fabaceae	*Melilotus alba* Desr.	Chamaephyte	Herb
128.	Fabaceae	*Melilotus indica* (L.) All.	Chamaephyte	Herb
129.	Fabaceae	*Taverniera cuneifolia* (Roth.) Arnott	Phanerophyte	Subshrub
130.	Fabaceae	*Tephrosia purpurea* (L.) Pers.	Chamaephyte	Subshrub
131.	Fabaceae	*Tephrosia strigosa* (Dalz.) Sant. & Mahcshw.	Therophyte	Herb

S.#	Family	Plant species	Life form	Habit
132.	Fabaceae	*Trifolium alexandrianum* L.	Therophyte	Herb
133.	Fabaceae	*Trifolium fragiferum* Linn	Therophyte	Herb
134.	Fabaceae	*Vigna trilobata* (L.) Verdc.	Therophyte	Herb
135.	Gentianaeae	*Enicostemma hyssopifolium* (Willd.) Verdoon	Hemicryptophyte	Herb
136.	Hydrocharitaceae	*Hydrilla verticillata* (L.f.) Royle	Hydrophyte	Herb
137.	Illecebraceae	*Cometes surattensis* L.	Therophyte	Herb
138.	Lamiaceae	*Salvia santolinifolia* Boiss.	Chamaephyte	Subshrub
139.	Malvaceae	*Abutilon bidentatum* A. Rich.	Phanerophyte	Subshrub
140.	Malvaceae	*Abutilon fruticosum* Guill.& Perr	Phanerophyte	Subshrub
141.	Malvaceae	*Abutilon indicum* (Linn.) Sweet	Phanerophyte	Subshrub
142.	Malvaceae	*Abutilon muticum* (Del.ex DC.) Sweet	Phanerophyte	Subshrub
143.	Malvaceae	*Hibiscus micranthus* L.f.	Chamaephyte	Subshrub
144.	Malvaceae	*Hibiscus scindicus* Stocks	Chaemaephyte	Subshrub
145.	Malvaceae	*Pavonia Arabica* Hochst. & Steud.	Chamaephyte	Subshrub
146.	Malvaceae	*Senra incana* Cav.	Phanerophyte	Subshrub
147.	Malvaceae	*Sida ovata* Forssk.	Phanerophyte	Subshrub
148.	Mimosaceae	*Acacia nilotica* (L.) Del. subsp. *Indica* (Benth.) Branan	Phanerophyte	Tree
149.	Mimosaceae	*Acacia senegal* (L.)Willd.	Phanerophyte	Tree
150.	Mimosaceae	*Prosopis cineraria* (Linn.) Druce.	Phanerophyte	Tree
151.	Mimosaceae	*Prosopis glandulosa* Torr.	Phanerophyte	Large Shrub
152.	Mimosaceae	*Prosopis juliflora* Swartz	Phanerophyte	Large Shrub
153.	Molluginaceae	*Corbichonia decumbens* (Forsk.) Exell	Therophyte	Herb
154.	Molluginaceae	*Gisekia Pharnaceodies* L.	Therophyte	Herb
155.	Molluginaceae	*Glinus lotoides* (L.) O.Kuntze.	Chamaephyte	Herb
156.	Molluginaceae	*Limeum indicum* Stocks ex. T. And.	Chamaephyte	Herb
157.	Najadaceae	*Najas minor* All.	Hydrophyte	Herb
158.	Nelumbonaceae	*Nelumbo nucifera* Gaertn.	Hydorphyte	Herb
159.	Nyctaginaceae	*Boerhavia procumbens* Banks ex Roxb.	Cryptophyte	Herb
160.	Nyctaginaceae	*Commicarpus boissieri* (Heimerl) Cufod.	Phanerophyte	Herb
161.	Nymphaeaceae	*Nymphaea lotus* Hook. f. & Thoms.	Hydrophyte	Herb
162.	Plumbaginaceae	*Limonium stocksii* (Boiss.) O.Kuntze	Chamaephyte	Subshrub
163.	Poaceae	*Aeluropus lagopoides* (L.) Trin. Ex Thw.	Cryptophyte	Grass
164.	Poaceae	*Aristida adscensionis* L.	Therophyte	Grass
165.	Poaceae	*Aristida funiculate* Trin. & Rupr.	Therophyte	Grass
166.	Poaceae	*Aristida mutabilis* Trin. & Rupr.	Therophyte	Grass
167.	Poaceae	*Brachiaria ovalis* (R. Br.) Stapf	Therophyte	Grass
168.	Poaceae	*Brachiaria ramose* (L.) Stapf	Therophyte	Grass
169.	Poaceae	*Brachiaria reptans* (L.) Gardner & Hubbard	Therophyte	Grass
170.	Poaceae	*Cenchrus ciliaris* L.	Hemicryptophyte	Grass
171.	Poaceae	*Cenchrus pennisetiformis* Hochst. & Steud. ex Steud	Hemicryptophyte	Grass
172.	Poaceae	*Cenchrus setigerus* Vahl.	Hemicryptophyte	Grass
173.	Poaceae	*Chloris barbata* Sw.	Haemicryptophyte	Grass
174.	Poaceae	*Chrysopogon aucheri* (Boiss.) Stapf.	Hemicryptophyte	Grass
175.	Poaceae	*Cymbopogon jwarancusa* (Jones) Schult.	Hemicryptophyte	Grass
176.	Poaceae	*Cynodon dactylon* (L.) Pers.	Hemicryptophyte	Grass

S.#	Family	Plant species	Life form	Habit
177.	Poaceae	*Dactyloctenium aegyptium* (L.) Willd	Therophyte	Grass
178.	Poaceae	*Dactyloctenium aristatum* Link	Therophyte	Grass
179.	Poaceae	*Dactyloctenium scindicum* Boiss.	Hemi cryptophyte	Grass
180.	Poaceae	*Desmostachya bipinnata* (L.) Stapf	Cryptophyte	Grass
181.	Poaceae	*Dichanthium annulatum* (Forsk.) Stapf	Hemicryptophyte	Grass
182.	Poaceae	*Dichanthium foveolatum* (Del.) Roberty	Hemicryptophyte	Grass
183.	Poaceae	*Diplachne fusca* (L.) P.Beauv. ex Roem & Schult.	Cryptophyte	Grass
184.	Poaceae	*Echinochloa colonum* (L.) Link	Therophyte	Grass
185.	Poaceae	*Eleusine indica* (Linn.) Gaertn.	Therophyte	Grass
186.	Poaceae	*Elionurus royleanus* Nees ex A.Rich.	Therophyte	Grass
187.	Poaceae	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard	Therophyte	Grass
188.	Poaceae	*Eragrostis ciliaris* (L.) R. Br.	Therophyte	Grass
189.	Poaceae	*Eragrostis japonica* (Thunb.) Trin.	Therophyte	Grass
190.	Poaceae	*Eragrostis minor* Host	Therophyte	Grass
191.	Poaceae	*Eragrostis pilosa* (L.) Beauv.	Therophyte	Grass
192.	Poaceae	*Eragrostis tenella* (L.) P. Beauv. ex Roem.	Therophyte	Grass
193.	Poaceae	*Eriochloa procera* (Retz.) C. E. Hubbard	Hemicryptophyte	Grass
194.	Poaceae	*Lasiurus scindicus* Henr.	Hemicryptophte	Large Grass
195.	Poaceae	*Leptothrium senegalensis* (Kunth) W.D. Clayton	Hemicryptophyte	Grass
196.	Poaceae	*Ochthochloa compressa* (Forsk.) Hilu	Therophyte	Grass
197.	Poaceae	*Panicum antidotale* Retz.	Hemicryptophyte	Grass
198.	Poaceae	*Panicum turgidum* Forsk.	Hemicryptophyte	Grass
199.	Poaceae	*Paspalidium flavidum* (Retz.) A. Camus	Hemicryphophyte	Grass
200.	Poaceae	*Paspalidium geminatum* (Forsk.) Stapf.	Hemicryptophyte	Grass
201.	Poaceae	*Paspalum vaginatum* Swartz.	Hemicryptophyte	Grass
202.	Poaceae	*Phragmites australis* (Cav.) Trin.	Cryptophyte	Large Grass
203.	Poaceae	*Phragmites karka* (Retz.) Trin. ex Steud.	Cryptophyte	Large Grass
204.	Poaceae	*Saccharum benghalense* Retz.	Hemicryptophyte	Large Grass
205.	Poaceae	*Saccharum griffithii* Munro ex Boiss.	Hemicryptophyte	Large Grass
206.	Poaceae	*Saccharum spontaneum* L.	Hemicryptophyte	Large Grass
207.	Poaceae	*Sporobolus helvolus* (Trin.) Dur. & Schinz	Hemicryptophyte	Grass
208.	Poaceae	*Sporobolus kentrophyllus* (K. Schum.) W.D. Clayton	Hemicryptophyte	Grass
209.	Poaceae	*Sporobolus nervosus* Hochst.	Hemicryptophyte	Grass
210.	Poaceae	*Sporobolus sp. nov.*	Hemicryptophyte	Grass
211.	Poaceae	*Tetrapogon tenellus* (Koen. Ex Roxb.) Chiov.	Therophyte	Grass
212.	Poaceae	*Tragus roxburgii* Panigrahi	Therophyte	Grass
213.	Poaceae	*Urochondra setulosa* (Trin.) C.E. Hubb.	Hemicryptophte	Grass
214.	Polygalaceae	*Polygala erioptera* DC.	Therophyte	Herb
215.	Polygalaceae	*Polygala irregularis* Boiss	Chamaephyte	Herb
216.	Polygonaceae	*Persicaria glabra* (Willd.) Gomes de la Maza	Phanerophyte	Herb
217.	Polygonaceae	*Polygonum effusum* Meisn	Chamaephyte	Herb
218.	Polygonaceae	*Polygonum plebejum* R. Br.	Chamaephyte	Herb
219.	Polygonaceae	*Rumex dentatus* L.	Thrrophyte	Herb

S.#	Family	Plant species	Life form	Habit
220.	Pontederiaceae	*Eichhornia crassipes* (Mart.) Solma	Hydrophyte	Herb
221.	Portulacaceae	*Portulaca oleracea* L.	Therophyte	Herb
222.	Potamogetonaceae	*Potamogeton lucens* L.	Hydrophyte	Herb
223.	Potamogetonaceae	*Potamogeton natans* L.	Hydrophyte	Herb
224.	Potamogetonaceae	*Potamogeton perfoliatus* L.	Hydrophyte	Herb
225.	Rhamnaceae	*Ziziphus nummularia* (Burm.f.) Wight & Arn.	Phanerophyte	Shrub
226.	Rubiaceae	*Kohautia retrorsa* (Boiss.) Bremek.	Phanerophyte	Subshrub
227.	Salicaceae	*Populus euphratica* Olivier	Phanerophyte	Tree
228.	Salvadoraceae	*Salvadora oleoides* Decne.	Phanerophyte	Tree
229.	Salvadoraceae	*Salvadora persica* L.	Phanerophyte	Tree
230.	Salviniaceae	*Salvinia molesta* Mitchelle	Hydrophyte Fern	Herb
231.	Scrophulariaceae	*Anticharis linearis* (Benth.) Hochst. ex Aschers.	Therophyte	Herb
232.	Scrophulariaceae	*Bacopa monnieri* (L.) Wettstein	Chamaephyte	Herb
233.	Scrophulariaceae	*Schweinfurthia papilionacea* (L.) Merrill	Chamaephyte	Herb
234.	Solanaceae	*Datura fastuosa* L.	Phanerophyte	Shrub
235.	Solanaceae	*Lycium edgeworthii* Dunal	Phanerophyte	Shrub
236.	Solanaceae	*Physalis divaricata* D. Don	Therophyte	Herb
237.	Solanaceae	*Physalis peruviana* L.	Therophyte	Herb
238.	Solanaceae	*Solanum cordatum* Forssk.	Phanerophyte	Straggling Shrub
239.	Solanaceae	*Solanum nigrum* L.	Therophyte	Herb
240.	Solanaceae	*Solanum surattense* Burm.f.	Chamaephyte	Herb
241.	Solanaceae	*Withania somnifera* (L.) Dunal	Phanerophyte	Subshrub
242.	Tamaricaceae	*Tamarix alii* Qaiser	Phanerophyte	Shrub
243.	Tamaricaceae	*Tamarix indica* L.	Phanerophyte	Shrub
244.	Tamaricaceae	*Tamarix pakistanica* Qaiser	Phanerophyte	Shrub
245.	Tamaricaceae	*Tamarix passernioides* Del. ex Desv.	Phanerophyte	Shrub
246.	Tamaricaceae	*Tamarix sarenensis* Qaiser	Phanerophyte	Shrub
247.	Tamaricaceae	*Tamarix sp. Nov.*	Phanerophyte	Shrub
248.	Tiliaceae	*Corchorus aestuans* L.	Chamaephyte	Subshrub
249.	Tiliaceae	*Corchorus depressus* (L.) Stocks	Therophyte	Herb
250.	Tiliaceae	*Corchorus tridens* L.	Therophyte	Herb
251.	Tiliaceae	*Corchorus trilocularis* L.	Therophyte	Herb
252.	Tiliaceae	*Grewia erythraea* Schweinf	Phanerophyte	Shrub
253.	Tiliaceae	*Grewia tenax* (Forssk.) A. & S.	Phanerophyte	Shrub
254.	Tiliaceae	*Grewia villosa* Willd.	Phanerophyte	Shrub
255.	Typhaceae	*Typha dominghensis* Pers.	Cryptophyte	Reed
256.	Verbenaceae	*Phyla nodiflora* (L.) Greene	Chamaephyte	Herb
257.	Violaceae	*Viola stocksii* Boiss.	Therophyte	Herb
258.	Zygophyllaceae	*Fagonia indica* Burm.f.	Chamaephyte	Herb
259.	Zygophyllaceae	*Tribulus longipetalus* Viv.	Therophyte	Herb
260.	Zygophyllaceae	*Tribulus ochroleucus* (Maire) Ozenda & Quezel	Therophyte	Herb
261.	Zygophyllaceae	*Tribulus terrestris* L.	Therophyte	Herb
262.	Zygophyllaceae	*Zygophyllum propinquum* Decne.	Chamaephyte	Subshrub
263.	Zygophyllaceae	*Zygophyllum simplex* L.	Therophyte	Herb

Comparison of plant families to overall flora of Keenjhar Lake is given in Annexure B – II.

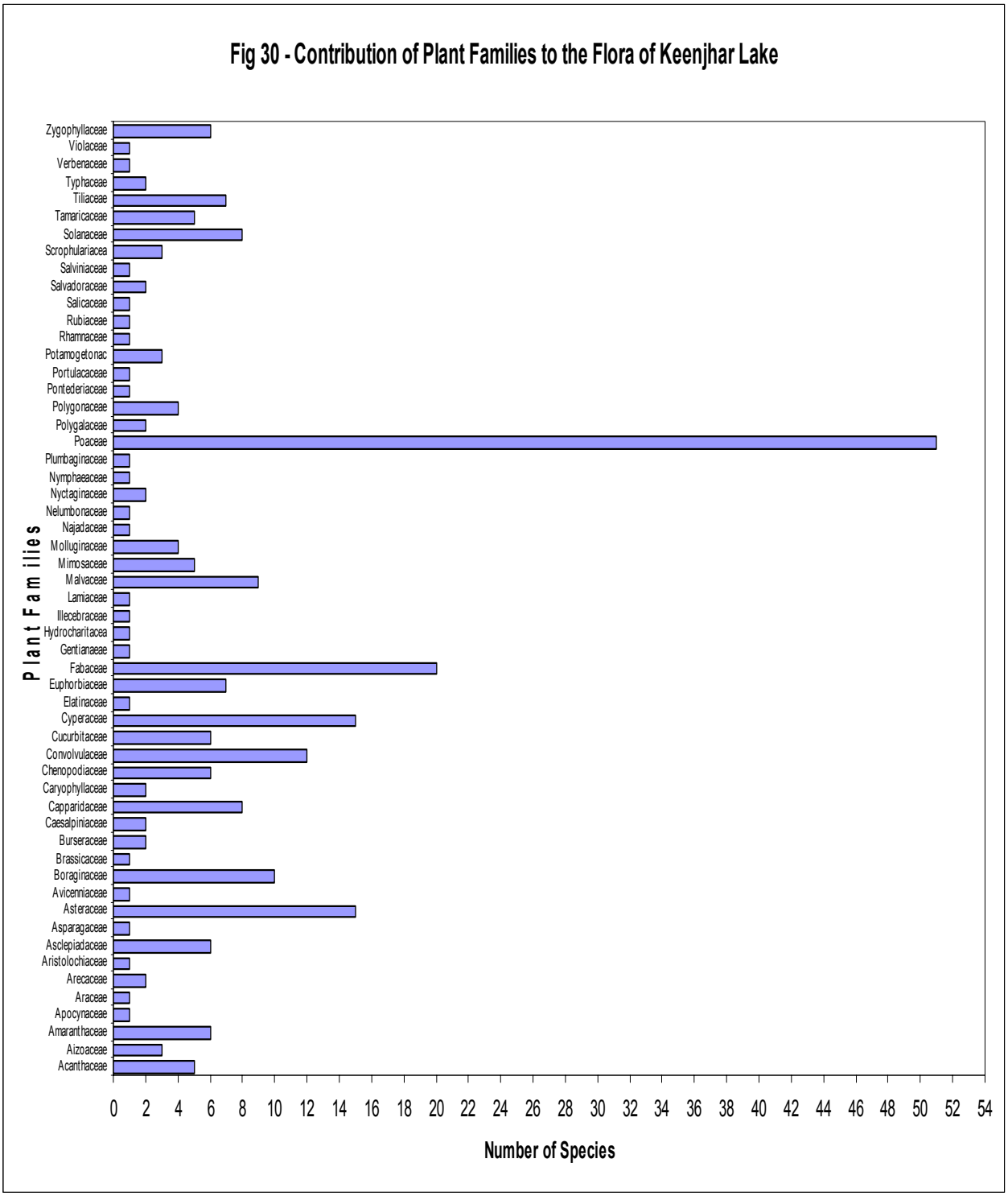


Fig 30 - Contribution of Plant Families to the Flora of Keenjhar Lake
Zygophyllaceae
Violaceae
Verbenaceae
Typhaceae
Tiliaceae
Tamaricaceae
Solanaceae
Scrophulariacea
Salviniaceae
Salvadoraceae
Salicaceae
Rubiaceae
Rhamnaceae
Potamogetonac
Portulacaceae
Pontederiaceae
Polygonaceae
Polygalaceae
Poaceae
Plumbaginaceae
Nymphaeaceae
Nyctaginaceae
Nelumbonaceae
Najadaceae
Molluginaceae
Mimosaceae
Malvaceae
Lamiaceae
Illecebraceae
Hydrocharitacea
Gentianaeae
Fabaceae
Euphorbiaceae
Elatinaceae
Cyperaceae
Cucurbitaceae
Convolvulaceae
Chenopodiaceae
Caryophyllaceae
Capparidaceae
Caesalpiniaceae
Burseraceae
Brassicaceae
Boraginaceae
Avicenniaceae
Asteraceae
Asparagaceae
Asclepiadaceae
Aristolochiaceae
Arecaceae
Araceae
Apocynaceae
Amaranthaceae
Aizoaceae
Acanthaceae
Plant Families
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Number of Species

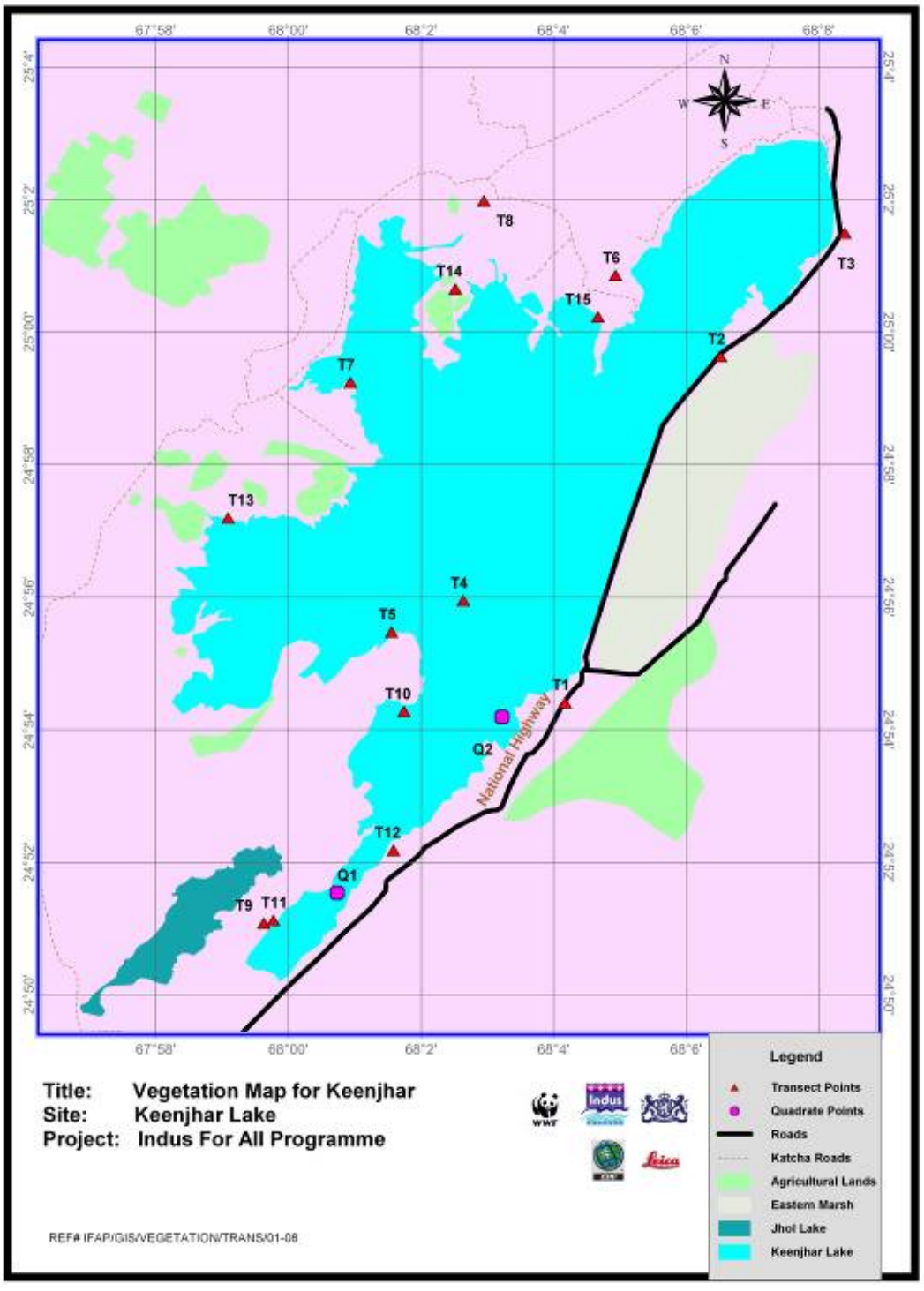


Figure - 31 Image showing location of sampling points in study area

3.4.2 Two Ways Indicator Species Analysis (TWINSPAN)

TWINSPAN analysis was used to delineate plant communities for each of the three years. A detailed account of this analysis is provided in Annexure B – III. The results are discussed in the following text.

3.4.2.1 *Cyperus – Cynodon – Phyllanthus* Plant Community (Fall 2006*)*

This plant community is representative of transects Nos. 3, 4 and 7. These sites were situated on relatively gravely grounds with lot of grasses and annuals. This plant community is highly relished by livestock; therefore, overgrazing was very common in places where this community was found. Associated flora over these sites included species like *Ipomoea (shrubs), P. juliflora, Cleome viscosa, Amaranthus sp., Corchorus trilocularis, Corchorus depressus, Indigofera hochstettri, Blepharis, Atriplex sp., Euphorbia granulata, Euphorbia caducifolia, Cynodon dactylon, Salvinia, Typha sp.,* and *Phragmites, Acacia nilotica, Salvadora persica, Phyllanthus, Rhynchosia minima, Heliotropium sp., Oxystelma, Pentatropis spiralis, Achyranthis sp., Senra incana, Phragmites karka, Ipomoea carnea, Corchorus trilocularis, Potamogeton, Salvinia sp., Persicaria glabra, Coccinia,* and *Launaea sp.* Forage production of this plant community varied from 51 Kg/ha to 203 Kg/Ha.

Figure 32 – *Sites occupied by Cyperus – Cynodon – Phyllanthus* Plant Community

3.4.2.2 *Zygophyllum – Grewia* Plant Community (Fall 2006)

This plant community was represented by Transect Nos. 2, 5, 6 and 9. which were situated either on raised grounds or on embankments and occupied by plant species like *Euphorbia caducifolia, Prosopis Juliflora, Launaea procumbens, Pentatropis spiralis, Polygala erioptera, Polycarpaea spicata, Hibiscus scindicus, Convolvulus glomeratus, Aristida sp., Eragrostis, Tetrapogon tenellus, Corchorus sp., Lycium sp. Solanum cordatum, Solanum suratense, Oxystelma, Asparagus, Launaea cordifolia, Phragmites karka, Saccharum munja, Heliotropium sp., Digera muricata, Senra incana, Grewia tenax, Heliotropium ophioglossum, Iphiona granitoides, Blepharis sindica, Maerua arenaria, Zygophyllum propinquum, Argyrolobium roseum, Tavernaria cuneifolia, Aerva javanica and, Commicarpus boissieri.* Forage production of the sites represented by this plant community varied from 93 Kg/Ha to 194 Kg/Ha.

Figure 33. Sites dominated by *Zygophyllum – Grewia* Plant Community

3.4.2.3 *Eragrostis – Cyperus – Zygophyllum* Plant Community (Fall 2006)

This plant community also represented the same sites as those in the *Zygophyllum – Grewia* plant community. The sites were dominated with annuals, grasses and shrubs and comprised of gravely well-drained soils. Mostly these sites were overgrazed. Forage production of this plant community varied from 51 to 195 Kg/Ha.

3.4.2.4 *Cynodon – Launaea* Plant Community (Summer 2007)

This community represented transects 1, 3, 4, 5, 6 and 7. The associated plant species of this community included *Prosopis glandulosa, P. juliflora, Indigofera cordifolia, I. hochstetteri, I. oblongifolia, Coldenia procumbens, Pentatropis nivalis, Senra incana, Euphorbia caducifolia, Digera muricata, Corchorus depressus, C. tridens, Heliotropium ovalifolium, Commicarpus boissieri, Zygophyllum propinquum, Z. simplex, Commicarpus boissieri, Senna holosericea, Tribulus terrestris, Phyla nodiflora, Bacopa monnieri, Taverniera cuneifolia, Suaeda fruticosa, Amaranthus graecizans, Ipomoea aquatica, Fagonia indica, Cleome scaposa, C. viscosa, Eclipta prostrata, Alternanthera sessilis, Eichhornia crassipes, Salvinia molesta, Parkinsonia aculeata, Cressa cretica* and *Salvadora persica.* In addition, the common grasses, reeds and sedges were consisted of species like *Aeluropus lagopoides, Aristida adscensionis, Brachiaria eruciformis, Cenchrus ciliaris, Cynodon dactylon, Dactyloctenium aegyptium, D. scindicum, Echinochloa colonna, Paspalum virginatum, Paspalidium germinatum, Eragrostis japonica, Phragmites karka, Typha* spp., *Cyperus laevigatus, C. longus* and *C. rotundus.* Forage production of these sites varied from 73 Kg/ha to 248 Kg/Ha showing overgrazing by livestock.

Figure 34 – Sites represented by *Cynodon – Launaea* Plant Community

3.4.2.5 *Oxystelma – Fagonia* Plant Community (Summer 2007)

Transects 2, 3, 4, 9, 11 and 12 represented this plant community. The associated plant species of these sites were represented by plants like *Prosopis juliflora, Euphrobia caducifolia, Acacia senegal, Lycium edgeworthii, Commiphora stocksiana, Grewia tenax* and *Iphiona grantioides.* The herbaceous cover was comprised of *Rhynchosia minima, Heliotropium ophioglossum, Euphorbia granulata, E. clarkeana, Blepharis sindica, Indigofera hochstetteri, Corchorus depressus, C. tridens, Seddera latifolia, Boerhavia procumbens, Polygala erioptera, P. irregularis, Senna holosericea, Pentatropis spiralis, Cleome scaposa, Corbichonia decumbens, Indigofera oblongifolia, Convolvulus glomeratus, Cucumis prophetarum, Zygophyllum propinquum* and *Z. simplex*. The sedges and grass group was comprised of *Cyperus bulbosus, C. rotundus, Aristida adscensionis, Eragrostis ciliaris, Ochthochloa compressa Tragus roxburghii, Dichanthium annulatum, D. foveolatum* and *Cenchrus ciliaris.* Forage production varied from 73 to 522 Kg/Ha.

Figure 35 – Sites occupied by *Oxystelma – Fagonia* Plant Community

3.4.2.6 *Prosopis juliflora – Fagonia indica - Aristida adscensionis* Plant Community (Spring 2008)

This plant community was represented by transects 1, 3, 5, 6, 8, 10, 11, 13 and 14. Mostly hard ground dominated by gravels occupied these sites *Cyperus alopecuroides, Polygonum effusum, Alhagi maurorum, Cressa cretica, Zygophyllum simplex, Heliotropium curassavicum, Prosopis glandulosa* and *Tamarix alii.* The forage production of this plant community ranged from 216 to 612 Kg/Ha.

Figure 36 – Sites dominated by *Prosopis juliflora – Fagonia indica – Aristida adscensionis* Plant Community

3.4.2.7 *Cynodon dactylon – Phyla nodiflora* Plant Community (Spring 2008)

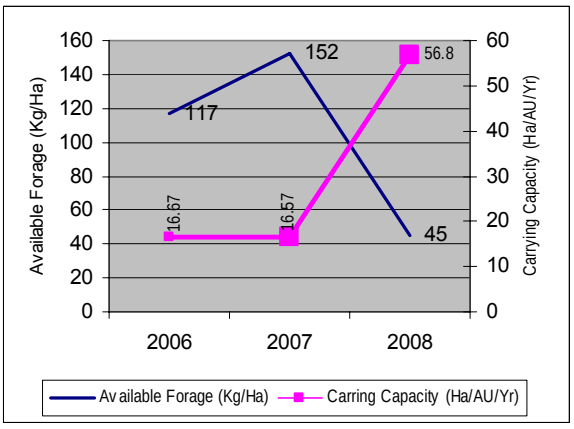
This community represented sites which were occupied mainly grasses and annuals. Although shrubs also dominated the sites yet dominant flora was comprised of species like *Phyllanthus maderaspatensis, Prosopis cineraria, Salvadora persica, Persicaria glabra, Launaea procumbens, Sida ovata, Indigofera cordifolia,* and *Prosopis juliflora, Tamarix sp, Bulboschoenus affinis, Schoenoplectus litoralis, Heliotropium ovalifoilum, Rhynchosia minima, Cynodon dactylon,* associated species are *Cyperus articulatus, Paspalidium gemimatum, Persicaria glabra, Cyperus alopecuroides, Bacopa monnieri, Cyperus exaltatus, Alternenthera sessilis, Alhagi maurorum* and *Panicum turgidum.* Forage production varied from 420 to 612 Kg/Ha.

Figure 37 – Sites represented by *Cynodon dactylon – Phyla nodiflora* Plant Community

3.4.3 Carrying Capacity

Carrying Capacity (CC) of Keenjhar Lake was determined in terms of hectares per animal unit per year. This important factor was determined for each of the study years *i.e.,* 2006, 2007 and 2008. The overall CC of this site has dropped from 2006 to 2008 and same is the case with carrying capacity (Figure 38) The drop in forage production and associated carrying capacity depicts two major reasons (i) there is high grazing pressure including stone mining contributing in the deterioration of natural vegetation of the Keenjhar Lake area. It has been observed that due to reduced fish catches the inhabitants of the area are shifting their livelihood towards livestock rearing, stone mining and mat making (through *Typha* species). The stone mining in the area is severely damaging flora and fauna of Keenjhar Lake. (ii) There is no monitoring of these pastures and so is the case with absence of range management. Sindh Forest Department has no stake in the pastures around this water body. Yearwise comparison of the forage production and the carrying capacity is given in Annexure B – IV.

Figure 38 – Carrying Capacity of Pastures of Keenjhar Lake over three Different Years



3.4.4 Biodiversity Index & species Richness:

3.4.4.1 α- Diversity (*i.e.,* the species richness and species diversity within each locality). With reference to species richness, Keenjhar Lake surroundings have shown the highest α – diversity with a total of 55 plant families, 165 genera and 263 species.

The largest genera was *Cyperus* with 12 species, followed by *Tamarix* (10 species), *Euphorbia* and *Heliotropium,* (7 species each) and, *Eragrostis* and *Indigofera* (6 species each). Gramineae (Poaceae) was the largest family with 67 species, followed by Fabaceae (27 species), and Cyperaceae (22 species) and Asteraceae (17 species). A summary showing comparison of plant communities, associated species and the forage production is give in Annexure B – V.

3.4.4.2 β -Diversity (*i.e.,* the species turnover from one locality to other locality or diversity between localities). Localities were compared in pairs with every possible combination. The highest number of species was shared by Keenjhar and Chotiari, *i.e.,* these two localities had 162 species in common, followed by Keti & Keenjhar with 96 species, Keenjhar & Pai with 94 species.

These localities pairs showed are given in Table 16 below.

Table 16 - Similarity Index and β -Diversity of study sites

S. No	Locality pairs	2006			2007			2008		
		Shared species	CC	BD	Shared species	CC	BD	Shared species	CC	BD
1	Keti - Keenjhar	27	0.30	1.691	82	0.46	1.54	96	0.51	1.49
4	Keenjhar - Chotiari	57	0.45	1.548	145	0.65	1.35	162	0.68	1.32
5	Keenjhar - Pai	30	0.3	1.7	80	0.44	1.56	94	0.5	1.5

3.4.5 Significant findings

Luffa echinata: According to Flora of Pakistan records, it was considered a rare species recorded only form Chitral, Swat and Tharparkar. However, this study revealed it to be abundantly present in Keenjhar (particularly in the part of Lake towards Chilliya bund) and Chotiari reservoir where this species is very commonly found.

Populus euphratica: This species is also recorded for the fist time form Keenjhar Lake where it was found to be abundantly present on small islands towards Chilliya bund, Soneri and Amir Pir areas.

Avicennia marina*:* Also recorded from the vicinity of Keenjhar Lake

Sporobolus sp: This will be a new species for the plant world.

Tamarix sarenensis: It is an endemic species for Sindh recorded form Keenjhar Lake.

3.5 Discussion

This site presents a rich diversity of habitats due to the presence of a large freshwater Lake and its surrounding sandy, rocky and hilly areas. The small hills in the vicinity of Lake present an entirely different flora compared to that found in the low lying areas near water margins. In spite of being a freshwater Lake, patches of saline land are present at various points of its periphery that add to habitat diversity. This is why a rich floristic diversity is recorded from this site totalling 263 species from 2006 to 2008. This number may increase after regular monitoring over next few years in different seasons. Out of 263 species, 56 can be recognized as aquatic and wetland species collected from water and surrounding moist soils. Rest of the species are dry land species collected from dry areas away from water margins. About 14 species are rare species which may become locally endangered in near future, particularly *Barleria hochstetteri, Barleria prionitis, Farsetia hamiltonii, Pycreus dwarkensis, Elionurus royleanus, Leptothrium senegalensis,* and *Anticharis linearis.* Among various families, Poaceae have shown the highest diversity which is in conformity with the typical pattern of arid lands. One of the very distinctive features of this site is the presence of an *Avicennia marina* stand on its eastern margin just near the entrance to the picnic point. The inland occurrence of this mangrove species is a rare and unique phenomenon. The islands in the Lake have their own floristic diversity. One comparatively large island near to the picnic point is somewhat rocky with calcareous hillocks bear dry land species like *Salvadore oleoides, Euphorbia caducifolia, Cadaba fruticosa, Hibiscus micranthus, Abutilon fruticosum, Barleria prionitis, Chrysopogon aucheri,* etc. In addition to these a number of annual species appear after summer rains. On periphery of the island, however, wetland species like *Oxystelma esculentum, Phragmites karka, Ipomoea carnea, Merremia hederacea, Phyllanthus maderaspatensis etc.* are present. Other islands, particularly those towards Chillia are occupied mostly by wetland species like *Typha dominghensis, Phragmites karka, Phyllanthus reticulatus, Cyperus articulatus, Merremia hederacea, Populus euphratica, Tamarix spp.* along with *Acacia nilotica. Typha and Phragmites* frequently form dense thickets which provide sheltered nesting place for a number of birds species.

Annual species *Luffa echinata* is particularly prominent in the post-monsoon season. It is an extensive climber which spreads upon other larger plants. Among plants with floating leaves *Nelumbo nucifera* is the most prominent; its seeds and rhizomes are edible, the latter used as vegetable. Among submerged plants *Potamogeton pectinatus* is the most abundant. The alien invasive species *Salvinia molesta* and *Eichhornia crassipes* are quite frequent, particularly the former.

In the phytosociological analysis, *Prosopis juliflora and Aristida adscensionis* were found to be dominant or co dominant in five transects out of a total of 14 transects according to their IVI value, followed by *Cynodon* (3 transects), *Phyla nodiflora, Ochthochloa compressa*, and *Aeluropus lagopoides* (2 transects each). The TWINSPAN recognized two communities, one *Prosopis juliflora-Fagonia indica-Aristida adscensionis,* and the other *Cynodon dactylon-Phyla nodiflora.* This indicates that the alien invasive species *Prosopis juliflora* is badly affecting this ecosystem and it has already replaced much of the native flora.

The primary productivity (DMY) varied from 21.6 Kg/Ha/Yr to 61.2 Kg/Ha/Yr between different transects (Table 16) with a mean of 45.0 Kg/Ha/Yr in 2008. The mean carrying capacity was found to be 16.67 Ha/AU/Yr in 2006, 16.57 Ha/AU/Yr in 2007 and 56.8

H/AU/Yr in 2008. It means that the carrying capacity is particularly low in winter, and it is not high in summer either. Thus the ecosystem can not support any large number of livestock. Any increase in the livestock population would lead to unsustainable grazing and ultimately desertification.

The local people depend upon the natural vegetation in various ways besides livestock grazing. *Typha and Phragmites* is used for making mats and rugs; and these along with *Saccharum and Tamarix spp.* are extensively used for thatching and hut-making. *Tamarix spp.* is also used as fuel. *Acacia nilotica and Populus euphratica* are valuable timber species. Rhizomes and petioles of *Nelumbo nucifera* are used as vegetable.

3.5.1 Problems and Threats:

The Lake, although managed by the Sindh Irrigation department and to some extent by local fisherman, still has the following threats:

3.5.1.1 Deforestation: Heavy woodcutting and deforestation was found on the eastern bank of the lake mainly by the local people for fuel and fodder. The whole ecosystem of the area is disturbed by these activities. The presence of vegetation is important as it checks siltation; provides food, shelter and breeding place to fauna. Now there is very sparse vegetation in the vicinity of Keenjhar Lake. The contributing factors are illegal wood cutting, stone mining, clearing of land for agriculture, poultry farming and overgrazing.

3.5.1.2 Illegal hunting & shooting: Illegal hunting and shooting of the resident and migratory birds by locals as well as visitors mostly for meat, feathers and fun in the Lake is a continuous practice, disturbing the web of life and destroying the prevailing ecosystem.

3.5.1.3 Excessive Grazing: The catchments area of Lake was already under grazing pressure and this pressure is increasing day by day due to shift in source of livelihood other than the fishing from Lake. Local communities are adopting livestock rearing activity as an alternate source of income.

3.5.1.4 Stone Mining: The fishermen community is adopting stone mining activity at high rate as an alternate source of household earning in the Lake area. This activity is leading to increased soil erosion, siltation, destruction of natural flora and damage to habitat of local as well as migratory fauna. In fact it is deteriorating environment of the Lake ecosystem. The stone mining is not under legal coverage. The buyers pay very nominal amount per truck (Rs. 600/ truck of 450 cft) including loading. While one individual/family mine one truck load stone within 4-5 days.

3.5.1.5 Introduction of Exotic Species: There is hardly any possibility of fish seed for the Keenjhar Lake from the River Indus because of water pollution in upland areas and check on fish seed at the KB feeder canal head to replenish the fingerlings. Moreover, introduction of exotic fish species *Tilapia spp (*locally called as Daiyo) which is smaller in size but highly vegetarian has posed a severe problem to local species. Due to introduction of this exotic species native bed reeds vegetation in the shallow western and northern waters of the Lake has been disappearing gradually, which may affect the originality of the prevailing ecosystem in the long run. Likewise, *Salvinia molesta* and *Eichhornia crassipis* are floating plants that damage the hydrophytic monocotyledonous

species. It might be due to allelopathic effects on submerged plants by these two species. The species like *Hydrilla verticillata* and *Potamogeton* spp. are favourite feed of fishes. The decreasing population of aforesaid species is one of the causes for declining fish population.

3.5.1.6 Mismanagement: Not much attention has so far been paid by the concerned government agencies for the conservation and management of fish resources of the Lake. Due to this negligence and inadequate care of the Lake, fish stock is depleting gradually. On the other hand, the fishermen community are not having appropriate market for selling the catch on daily basis. The fishermen are forced to sell their catches to the local middle men at very low rates because there exists no other options of sale at an appropriate market. This way of marketing to get more money compels the fishermen to catch as many as they can. This unsustainable practice of fishing is deteriorating the fish population at very high pace which is clear from the fact that fishermen community is diverting their livelihood earning towards livestock rearing and stone mining.

3.5.1.7 Fresh Water Scarcity & Contamination: Both quality and quantity of freshwater in the Lake is decreasing slowly, might be due to construction of the link canal at eastern side, diverting water away from the Lake during normal season and to the Lake during monsoon only. Such a shortage of freshwater in the Lake will obviously affect the ecology of the Lake. Moreover, the ever increasing soil erosion in catchments, resulting in excessive deposition of silt into the Lake is another cause of water scarcity. Water carrying effluents from the tanneries at Hyderabad is continuously being drained into the Lake for the last ten years is not only deteriorating the quality of water, but also posing serious threats to the precious biota of the freshwater Lake. A lot of poultry farms and livestock farms also exist on eastern side of the Lake that are also a major source of pollution. The picnickers also frequently wash their vehicles in the Lake and deposit garbage at the edge on southern side that ultimately goes into the Lake. Due to continuous use of boats for picnic and fish catching is also adding to pollution of Lake water. An other important factor of pollution is agrochemicals used to protect arable crops in the vicinity of this water body.

3.5.2 Improvements Required:

Although problems are numerous and require holistic approach for their remedial measures, yet these require prioritization for setting the direction to overcome within limited time frame. One should realize that there are three main areas for which Keenjhar Lake is potentially utilized; Fisheries, water and tourism. Apart from these uses surrounding communities also earn their livelihood through livestock rearing in the buffer zone of the Lake.

3.5.2.1 Management Plan: There is a dire need that a Management Plan of this important water body is developed considering its economic, ecological and social significance. This plan should be developed in consultation with all concerned stakeholders including representatives from local communities. An action plan then should emerge from the Management Plan clearly identifying roles and responsibilities of each of the stakeholder. Before this lake turns to an irreversible state, such plan is needed to maintain this Lake in healthy and productive state.

3.5.2.2 Fisheries Resource: Involvement of Provincial Fisheries Department and the local fishermen communities to manage and release of fish seed of native species is

urgently required. This practice will not only improve the fish resource of the Lake but also the livelihood conditions of the fishermen communities. Moreover, introduction of exotic fish species like *Tilapia* sp. should be banned in future.

- Women technical skills should be enhanced through training for the development of cottage industry.

- Stone mining should be regulated through Mining Department to eliminate the middle man's role. This will not only help improve the economic conditions of the local poor but also result in restoration of degrading ecosystem.

- Awareness campaign should be launched within the community regarding the conservation of natural resources.

- There is an immediate need to put nets in and outside to prevent the escape of fish seeds and juveniles fish into the canal.

3.5.2.3 Tourism: This Lake being in the vicinity to Thatta and Karachi is frequently visited by large number of tourists year-round. There are no facilities available for the tourists regarding know-how about the Lake. There is serious need to provide quality facilities for the incoming tourists according to their age profile. This requires setting up a Visitors Centre containing good quality souvenirs and brochures. Visitor's Centre should also get the feedback from the tourists about facilities they require for enhancing the quality of the tourist facilities.

- In the past some fatal accidents have occurred in the Lake due to poor quality boats and increased load on such boats. Sindh Tourism Development Corporation (STDC) should take a lead to ensure the safety of tourists by strict law and order enforcement. Boatmen should not allow visitors on their boats beyond permissible limit. Moreover, STDC should also arrange small credit facilities for purchase of speed boats, life jackets and other paraphernalia. All the boats used for tourists should be properly registered and regularly visited by STDC to ensure safety measures.

- The STDC collects fee from the tourists but does not recycle it for maintenance of the picnic spot. This is causing unhygienic conditions at picnic spot which is ultimately deteriorating the environment of the Lake. The STDC should make arrangement for recycling of the Lake's income for improvements and maintenance of the picnic spot.

- Currently, the Lake water is used for washing commercial and domestic vehicles which not only add contamination to the water but also invite different hazards. Keenjhar Lake is used for providing drinking water to Karachi city and the surrounding communities and houses rich aquatic life. Oil coming out of vehicles and boats can severely damage both human as well as other aquatic life. It is recommended that vehicles parking should be at a distance from the picnic spot.

- Presently, STDC has a nice facility of boarding and lodging for tourists at the Lake. However, this facility is deteriorating due to negligence on the part of senior officials. The quality of beds, wash rooms and furniture is absolutely unbearable. Probably,

senior officials either do not visit these cottages or they are well taken care off by the keepers and hence do not bother about the tourists.

3.5.2.4 Water: As mentioned in the preceding paragraphs, Keenjhar is an important source of drinking water for the people of Karachi and neighbouring villages. Moreover, it is also important abode for a variety of fishes on which livelihood of a large population of fishermen communities and migratory birds is dependent. Being Ramsar site and a Wildlife Sanctuary, the waters of this Lake are important for harbouring thousands of migratory waterfowls during winter. For the care of such important aspects, it becomes increasingly important that both quality and quantity of water should regularly be monitored. To ensure that such monitoring is in place, now and in future, an Executive Body comprising senior members from all concerned government departments, non-government agencies, local body institutions and the local communities should be notified by the provincial government. This body should be vested with certain legal and regulatory powers for taking corrective measure without seeking permission from elsewhere.

- Effluents from the agricultural fields and tanneries should be controlled and stopped immediately. Ban on washing vehicles in Lake water and other sources of contaminants should be imposed immediately.

- There are a number of poultry farms and livestock farms on the bank of Keenjhar Lake on eastern side. These farms are not only a regular source of contamination of Lake water but also increasing eutrophication in the water body which is severely hampering the aquatic life.

3.5.2.5 Pastures & Livestock: Peripheral areas of Keenjhar Lake are used as grazing grounds for the livestock of neighbouring villages. The livestock includes small and large ruminants. Overgrazing of surrounding pastures trigger soil erosion thus silting of water body. Animal dung is also a source of contamination. To regulate such grazing, there is a need that local population is provided inputs for raising improved fodder crops on agricultural fields.

- Neighbouring grounds are also infested with Mesquite (*Prosopis juliflora*) and other exotic plants such as *Eucalyptus camaldulensis*, Mesquite itself is a big threat to the local ecosystem as it is out competing the local flora and bringing disruption in the local ecosystem. There is a serious need to check such alien species on regular grounds.

- Islands inside Lake possess pristine flora that provides unique opportunity to the researchers and students for studying plant wealth of this region. These islands should immediately be protected from wood cutting and other interventions that may alter the plant composition.

- There is a unique inland stand of *Avicennia marina* present in close vicinity of Keenjhar Lake that needs protection through fencing.

3.6 Conclusions

This Lake is in the process of deterioration at very fast pace. Although this ecosystem is rich in floral diversity with respect to number of species recorded (263 species) yet out of

87 species recorded in transects, there were 34 species in the category of rare and 35 species rated as vulnerable. Similarly, carrying capacity is also very poor and deteriorating gradually. This is indicative of the fact that this fresh water wetland ecosystem is loosing its productive potential. Immediate rehabilitation measures like restoration of local fish species control on overgrazing, over fishing, replacement of exotic species of fish with local ones and discouragement of alien plant species like *Eucalyptus* and mesquite etc. The planting of fodder tree species and reseeding of palatable grasses be promoted through community participation in the area to overcome the grazing pressure.

4 - Chotiari Wetland Complex (A Blend of Wetland & Desert Ecosystems)

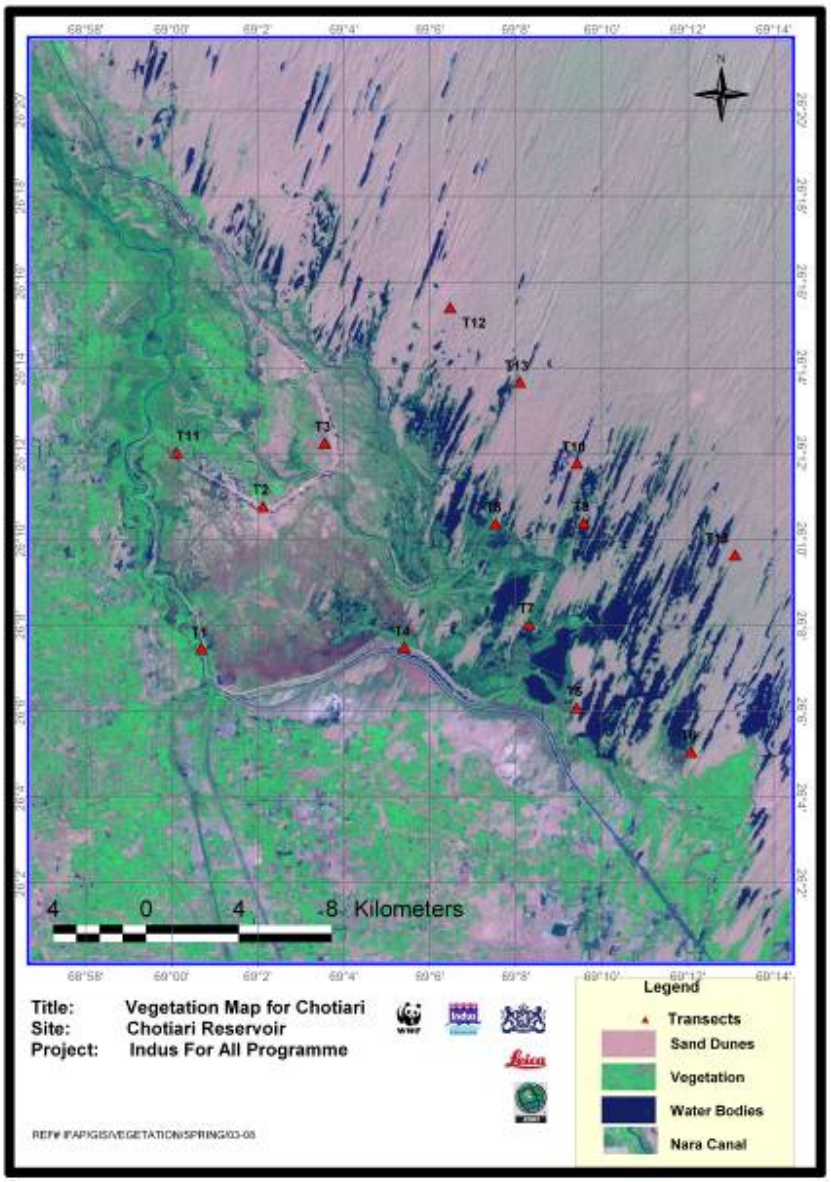


Figure 39 – Satellite Image of Chotiari Wetland Complex

4.1 Brief History of Chotiari Wetland Complex

Chotiari reservoir lies in the province of Sindh, on western flanks of Achro Thar desert (white sandy desert) at about 30 - 35 km northeast of Sanghar City. The Reservoir occupies an area of about 18,000 hectares and has water storage capacity of 0.75 Million Acre Feet (MAF) flooding an area of approximately 160 km^2.

Chotiari reservoir is created in a natural depression that exists along the left bank of the Nara canal. The depression area is bounded by sand hills towards north, east and south-east, while towards the west and south lies the Nara canal.

This reservoir is established to improve the irrigation supplies during lean months when Indus flows are at minimum. It is an off canal storage reservoir retaining Indus flood water collected during the peak flow period (June to September) and releasing it for use during the dry season (mid October to mid April). This reservoir will be filled from the Nara canal through a 6,500-cusec capacity channel, the Ranto Canal, off-taking from the Nara Canal at Jamrao Head.

The reservoir land area lies within seven dehs (cluster of villages) viz. Makhi, Haranthari, Bakar, Akanvari, Khadvari and Phuleli. The aquatic features of the reservoir area comprise diversity of small and large size freshwater and brackish Lakes, smallest being of 1 Hectare area and largest of about 200 Hectares which occupy about 30% of the total reservoir area. These Lakes are a source of subsistence and commercial fisheries for the local people.

The area has a hot arid climate. The hottest months are May and June when average maximum daily temperature exceeds 40°C. The coolest months are December to February, when the maximum daily temperatures range from 25 to 30°C. Rainfall is sparse and erratic and is most frequent between July and August when it averages 40 mm monthly. Annual average rainfall is about 125 mm. Floods are common in monsoon season. Evaporation averages 11 mm per day in summer, falling to 2.5 mm per day in winter. Annual average evaporation is about 2250 mm. The local population is engaged in fishing, agriculture, jobs in different sectors and livestock rearing. A large area is being used for livestock grazing, which is a major occupation for the local communities. According to one estimate, nearly 400 families are associated with livestock rearing in the reservoir area. The majority of livestock includes, buffalo, cattle, goat, sheep and camel. A variety of non-timber forest produce that grow naturally in the reservoir area are used by local people for hut making, mat making, sweep sticks, roof thatching, medicinal and food purposes. Women living in those areas where reeds are abundant are associated with mat making as a source of their livelihood.

Socio-economic assessment study conducted by Indus for All programme revealed that varying proportions of households of Chotiari Wetland Complex have access to different natural resources such as irrigation water (35%), drinking water (66%), fish (56%), fuel wood (70%) and grazing of livestock (36%). It was also found that on an overall basis, 48% of respondents agreed that irrigation water resources have depleted during the last five years. Over 70% of respondents agreed that the fisheries have declined, while 64% agreed that forest resources have sharply depleted during the last 5 years. A summary of the socio-economic profile of the communities of Chotirai Wetland Complex are provided in Annexures C – VI to C - XIV.

4.2 State of Biodiversity:

Chotiari is a rich ecological site and a unique habitat consisting of wetland, riverine forest, desert scrub and sand dunes. This area is formed from several small natural Lakes (dhands) and inter-dunal depressions that protrude finger-like into the western margins of the Thar Desert. Depth of water in the Lakes ranges from shallow (less than 6 feet) to deep (30 to 45 feet). The edges of the Lakes present a mosaic of reed beds, which lie alongside alluvial fans, irrigation channels, riverine forests, desert dunes, swamps and agricultural land. Historically, the Chotiari Wetland Complex was flanked by "Makhi forest" famous for rich reserves of quality honey. Most of this forest was cleared and converted into agriculture fields in the British era in the backdrop of "Hur Revolt".

4.2.1 FLORA: Aquatic vegetation includes *Typha latifolia, Typha dominghensis, Phragmites karka, Ipomoea aquatica, Nymphaea lotus, Nelumbo nucifera, Polygonum* spp. The Riverine Forest has canopy of *Populus euphratica, Dalbergia sissoo, Prosopis cineraria, Acacia nilotica* and *Ziziphus mauritiana* etc. Leghari *et al.* (1999) reported 41 aquatic plants including two bryophytes (*Riccia spp.*), Four Pteridophytes and 35 Angiosperms. They also reported 157 species of algae.

Cultivated crops are generally cotton (Kharif season) and wheat (Rabi season), augmented with rice, sugar cane, animal fodder and vegetables. A further detail of cultivated herbs and shrubs on agricultural lands and in habitations could be seen from Table 16 below.

Table 17 - Cultivated plant species recorded at Chotiari

Sr :	Family	Plant species	Life form	Habit
1	Anacardiaceae	*Mangifera indica* L.	Phanerophyte	Tree
2	Boraginaceae	*Cordia myxa* L.	Phanerophyte	Tree
3	Caesalpinaceae	*Parkinsonia aculeata* L.	Phanerophyte	Tree
4	Caesalpiniaceae	*Tamarindus indica* L.	Phanerophyte	Tree
5	Euphorbiaceae	*Ricinus communis* L.	Phanerophyte	Small tree
6	Fabaceae	*Cyamopsis tetragonoloba* (L.) Taub.	Therophyte	Herb
7	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Chamaephyte	Subshrub
8	Lythraceae	*Lawsonia inermis* L.	Phanerophyte	Shrub
9	Meliaceae	*Azadirachta indica* A.Juss.	Phanerophyte	Tree
10	Mimosaceae	*Albizzia lebbeck* (L.) Benth.	Phnerophyte	Tree
11	Mimosaceae	*Pithecellobium dulce* (Willd.)Benth.	Phanerophyte	Tree
12	Moraceae	*Ficus religiosa* L.	Phanerophyte	Tree
13	Myrtaceae	*Conocarpus erectus*	Phanerophyte	Tree
14	Myrtaceae	*Eucalyptus camaldulensis*	Phanerophyte	Tree
15	Papilionaceae	*Dalbergia sissoo* Roxb.	Phanerophyte	Tree
16	Pedaliaceae	*Sesamum indicum* L.	Therophyte	Herb

4.2.2 FAUNA: The open wetlands and terrestrial areas are habitats for variety of fish, mammals, birds and reptiles.

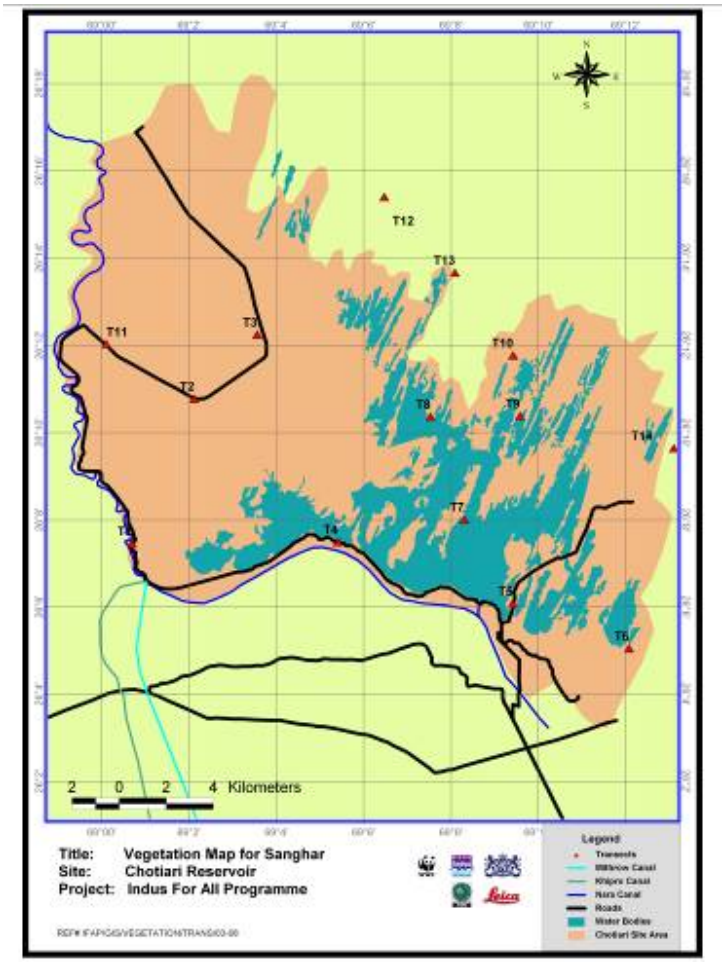
- **Fish:** Chotiari is now producing fish weighing about 525 tonnes per year. In 1997 Sindh University conducted a study of fish fauna and recorded 31 fresh water species.

- **Mammals:** Hog Deer, Chinkara, Jungle Cat, Fishing Cat, Caracal, Smooth coated Otter, Wild boar, Mongoose, Desert hare and Squirrels are reported in the area. A survey of Hog deer during the period May – October 1997 estimated that about 90 animals live along the western side of reservoir from Makhi Weir to Akanwari Deh. The gradual decline in vegetative cover has resulted in degradation of natural habitat of the Hog Deer whose wild population has declined severely.

- **Birds:** Chotiari Lakes are important habitat for a variety of bird species. As many as 107 species of birds have been recorded from the area. Two species of birds found in the area are worth mentioning. The Marbled Teal is globally threatened but significant population has been reported to winter and breed here. Sindh Warbler is a rare species that have been reported from this area. The area was significant for migratory water birds. In a survey in 1993, 40,000 birds were observed in this area.

- **Reptiles:** About 50 marsh crocodiles were recorded in Makhi area in 1997. Python, a vulnerable species is also known to occur in the area but its present status is unknown. Varieties of snakes and lizards are found here.

Figure 40 – Image showing location of transects in Chotiari Wetland Complex



4.3 Results

4.3.1 Floristic analysis:

Vegetation assessment of Chotiari Reservoir was carried out over three years and three different seasons (Fall 2006, Summer 2007 and Spring 2008). Transect-wise phytosociological account of the flora of Chotiari Wetland Complex is provided in Annexure C – I. These assessments revealed a total number of 211 species in 123 genera and 49 families. Of these, Pteridophytes are represented by 3 species in 3 genera and 3 families, Gymnosperms by one species in one genus and one family, Dicotyledonous Angiosperms by 144 species in 86 genera and 39 families and mocotyledenous Angiosperms by 63 species in 33 genera and 6 families. Over all 41 species are recognized as aquatic and wetland species occurring in and around water of the main reservoir or various channels/canals in the area, while 170 are dry land species occurring in the surroundings of reservoir away from water margins. Poaceae comes out as the largest family with 41 species, followed by Cyperaceae and Fabaceae with 18 species each and Solanaceae with 10 species. *Cyperus* with 9 species is the largest genus followed by *Tamarix 6 species and Eragrostis* with 5 species (Annexure C - II). The alphabetical checklist of species along their family and life form/habit is provided in Table 18. In addition to the natural flora, 16 cultivated species were also recorded from the area given in Table 17. The year-wise comparison of the families is given in Annexure F - I. The contributions of plant families in the vegetation of programme area are also summarized in Figure 41.

Table 18: List of plant species along with their families and life form of Chotiari Wetland Complex.

Sr #	Family	Plant species	Life form	Habit
1.	Acanthaceae	*Blepharis sindica* Stocks ex. T. Anders.	Therophyte	Shrub
2.	Aizoaceae	*Sesuvium sesuvioides* (Fens) Verdi.	Therophyte	Herb
3.	Aizoaceae	*Trianthema portulacastrum* L.	Therophyte	Herb
4.	Aizoaceae	*Trianthema triquetra* Rottl. and Willd.	Therophyte	Herb
5.	Aizoaceae	*Zaleya pentandra* (L.) Jeffrey.	Chamaephyte	Herb
6.	Amaranthaceae	*Achyranthus aspera* L.	Phanerophyte	Robust herb
7.	Amaranthaceae	*Aerva javanica* (Burm.f.)Juss.	Phanerophyte	Robust herb
8.	Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Chamaephyte	Herb
9.	Amaranthaceae	*Amaranthus graecizans* L.	Therophyte	Herb
10.	Amaranthaceae	*Amaranthus viridis* L.	Therophyte	Herb
11.	Amaranthaceae	*Digera muricata* (L.) Mart.	Therophyte	Herb
12.	Arecaceae	*Phoenix sylvestris* Roxb.	Phanerophyte	Tree
13.	Asclepiadaceae	*Calotropis procera* (Ait.) Ait.f.	Phanerophyte	Shrub
14.	Asclepiadaceae	*Leptadenia pyrotechnica* (Forsk.) Dcne.	Phanerophyte	Shrub
15.	Asclepiadaceae	*Oxystelma esculentum* (L.f) R.Br.	Cryptophyte	Climber
16.	Asclepiadaceae	*Pentatropis nivalis* (J.F.Gmel.) Field & J.R.I.Wood	Phanerophyte	Climber
17.	Asphodelaceae	*Asphodelus tenuifolius* Cav.	Therophyte	Herb
18.	Asteraceae	*Conyza aegyptiaca* Ait.	Chamaephyte	Herb
19.	Asteraceae	*Eclipta prostrata* (L.) L.	Chamaephyte	Herb
20.	Asteraceae	*Launaea procumbens* (Roxb.) Amin.	Chamaephyte	Herb
21.	Asteraceae	*Pluchea arguta* Boiss.	Chamaephyte	Shrub

Sr #	Family	Plant species	Life form	Habit
22.	Asteraceae	*Pluchea lanceolata* (DC.) C.B. Clarke	Phanerophyte	Shrub
23.	Asteraceae	*Pluchea wallichiana* DC	Phanerophyte	Shrub
24.	Asteraceae	*Sonchus oleraceus* L.	Therophyte	Herb
25.	Asteraceae	*Xanthium strumarium* L.	Phanerophyte	Shrub
26.	Boraginaceae	*Cordia dichotoma* Forster	Phanerophyte	Tree
27.	Boraginaceae	*Cordia gharaf* (Forsk.) Ehren. ex Asch.	phanerophyte	Tree
28.	Boraginaceae	*Heliotropium crispum* Desf.	Chamaephyte	Shrub
29.	Brassicaceae	*Farsetia hamiltonii* Royle	Therophyte	Herb
30.	Burseraceae	*Commiphora stocksiana (*Engl.*)*Engl.	Phanerophyte	Shrub
31.	Burseraceae	*Commiphora wightii* (Arn.) Bhandari	Phanerophyte	Shrub
32.	Caesalpiniaceae	*Senna holosericea* (Fresen) Greuter	Chamaephyte	Shrub
33.	Caesalpiniaceae	*Senna italica* Mill.	Chamaephyte	Shrub
34.	Capparidaceae	*Capparis decidua* (Forsk.) Edgew.	Phanerophyte	Shrub
35.	Capparidaceae	*Capparis spinosa* L.	Phanerophyte	Sub-shrub
36.	Capparidaceae	*Cleome brachycarpa* Vahl ex DC.	Chamaephyte	Herb
37.	Capparidaceae	*Cleome scaposa* DC.	Therophyte	Herb
38.	Capparidaceae	*Cleome viscosa* L.	Therophyte	Herb
39.	Capparidaceae	*Dipterygium glaucum* Decne.	Phanerophyte	Sub-shrub
40.	Capparidaceae	*Gynandropsis gynandra* (L.) Briq.	Therophyte	Herb
41.	Caryophyllaceae	*Spergularia marina* (L.) Griseb.	Therophyte	Herb
42.	Chenopodiaceae	*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.	Phanerophyte	Shrub
43.	Chenopodiaceae	*Salsola imbricata* Forsk.	Phanerophyte	Shrub
44.	Chenopodiaceae	*Suaeda fruticosa* Forsk. ex J.F.Gmelin	Phanerophyte	Shrub
45.	Convolvulaceae	*Convolvulus arvensis* L.	Therophyte	Climber
46.	Convolvulaceae	*Convolvulus glomeratus* Choisy.	Chamaephyte	Climber
47.	Convolvulaceae	*Convolvulus prostratus* Forssk.	Therophyte	Herb
48.	Convolvulaceae	*Cressa cretica* L.	Therophyte	Herb
49.	Convolvulaceae	*Ipomoea aquatica* Forsk.	Hydrophyte	Herb
50.	Convolvulaceae	*Ipomoea carnea* Jacq.	Phanerophyte	Shrub
51.	Convolvulaceae	*Merremia aegyptia* (L.) Urban	Therophyte	Climber
52.	Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Chamaephyte	Climber
53.	Cucurbitaceae	*Cucumis melo* var. *agrestis* Naud.	Chamaephyte	Climber
54.	Cucurbitaceae	*Luffa echinata* Roxb.	Chamaephyte	Climber
55.	Cucurbitaceae	*Mukia maderaspatana* (L.) M.J. Roem.	Chamaephyte	Climber
56.	Cuscutaceae	*Cuscuta hyaline* Roth	Chamaephyte	Parasite
57.	Cyperaceae	*Bolboschoenus affinis* (Roth) Drobov	Cryptophyte	Sedge
58.	Cyperaceae	*Bolboschoenus glaucus* (L.) S.G. Smith	Cryptophyte	Sedge
59.	Cyperaceae	*Cyperus articulatus* L.	Cryptophyte	Sedge
60.	Cyperaceae	*Cyperus aucheri* Jaub. & Spach	Cryptophyte	Sedge
61.	Cyperaceae	*Cyperus bulbosus* Vahl.	Cryptophyte	Sedge
62.	Cyperaceae	*Cyperus difformis* L.	Hemiryptophyte	Sedge
63.	Cyperaceae	*Cyperus laevigatus* L.	Cryptophyte	Sedge
64.	Cyperaceae	*Cyperus longus* L.	Hemicryptophyte	Sedge
65.	Cyperaceae	*Cyperus pangorei* Rottb.	Hemicryptophyte	Sedge

Sr #	Family	Plant species	Life form	Habit
66.	Cyperaceae	*Cyperus pygmaeus* Rottb.	Hemicryptophyte	Sedge
67.	Cyperaceae	*Cyperus rotundus* L.	Hemicryptophyte	Sedge
68.	Cyperaceae	*Eleocahris atropurpurea* (Retz.) Prest.	Hemicryptophyte	Sedge
69.	Cyperuaceae	*Eleocharis geniculata* (L.) Roem. et Schultz.	Hemicryptophyte	Sedge
70.	Cyperaceae	*Fimbristylis bisumbellata* (Forssk.) Bubani	Hemicryptophyte	Sedge
71.	Cyperaceae	*Fimbristylis cymosa* (L.) Vahl.	Hemicryptophyte	Sedge
72.	Cyperaceae	*Fimbristylis turkestanica* (Regel) B. Fedsch.	Hemicryptophyte	Sedge
73.	Cyperaceae	*Fimbristylis sp. nov.*	Hemicryptophyte	Sedge
74.	Cyperaceae	*Schoenoplectus litoralis* subsp *thermalis* (Trabut) S.Hooper	Crytophyte	Sedge
75.	Ephedraceae	*Ephedra ciliata* Fisch. & Mey. Ex C.A.Meyer.	Gymnosperm	Shrub
76.	Equisetaceae	*Equisetum debile* Roxb ex Vaucher	Pteridophyte	Herb
77.	Euphorbiaceae	*Euphorbia caducifolia* Haines	Phanerophyte	Shrub
78.	Euphorbiaceae	*Euphorbia clarkeana* Hk.f.	Therophyte	Herb
79.	Euphorbiaceae	*Euphorbia hirta* L.	Hemicryptophyte	Herb
80.	Euphorbiaceae	*Euphorbia serpens* Kunth	Therophyte	Herb
81.	Euphorbiaceae	*Phyllanthus maderaspatensis* L.	Therophyte	Herb
82.	Euphorbiaceae	*Phyllanthus reticulatus* Poir.	Phanerophyte	Shrub
83.	Fabaceae	*Alhagi maurorum* Medic.	Phanerophyte	Subshrub
84.	Fabaceae	*Alysicarpus ovalifolius* (Schumach.) J. Leonard	Therophyte	Herb
85.	Fabaceae	*Crotalaria burhia* Ham. Ex Bth.	Phanerophyte	Shrub
86.	Fabaceae	*Crotalaria medicaginea* Lamk.	Therophyte	Herb
87.	Fabaceae	*Indigofera argentea* Burm.f.	Chamaephyte	Herb
88.	Fabaceae	*Indigofera cordifolia* Heyne ex Roth	Therophyte	Herb
89.	Fabaceae	*Indigofera hochstetteri* Baker	Therophyte	Herb
90.	Fabaceae	*Indigofera linifolia* (L.f.) Retz.	Therophyte	Herb
91.	Fabaceae	*Indigofera sessiliflora* DC.	Therophyte	Herb
92.	Fabaceae	*Melilotus alba* Desr.	Therophyte	Herb
93.	Fabaceae	*Melilotus indica* (L.) All.	Therophyte	Herb
94.	Fabaceae	*Rhynchosia capitata* (Heyne ex Roth) DC.	Therophyte	Climber
95.	Fabaceae	*Rhynchosia minima* (L.) DC.	Chamaephyte	Climber
96.	Fabaceae	*Rhynchosia schimperi* Hochst. ex Boiss.	Chamaephyte	Subshrub
97.	Fabaceae	*Tephrosia purpurea* (L.) Pers.	Chamaephyte	Subshrub
98.	Fabaceae	*Tephrosia strigosa* (Dalz.) Sant. & Mahcshw.	Therophyte	Herb
99.	Fabaceae	*Tephrosia uniflora* Pers.	Chamaephyte	Subshrub
100.	Fabaceae	*Tephrosia villosa* (L.) Pers.	Chamaephyte	Subshrub
101.	Malvaceae	*Abutilon bidentatum* A. Rich.	Phanerophyte	Subshrub
102.	Malvaceae	*Abutilon fruticosum* Guill.& Perr	Phanerophyte	Subshrub
103.	Malvaceae	*Abutilon indicum* (Linn.) Sweet	Phanerophyte	Subshrub
104.	Malvaceae	*Abutilon muticum* (Del.ex DC.) Sweet	Phanerophyte	Subshrub
105.	Malvaceae	*Sida ovata* Forssk	Phanerophyte	Subshrub
106.	Marsiliaceae	*Marsilia minuta* L.	Pteridophyte	Herb
107.	Menispermaceae	*Cocculus hirsutus* (L.) Diels	Phanerophyte	Vine

Sr #	Family	Plant species	Life form	Habit
108.	Menyanthaceae	*Nymphoides cirstata* (Roxb.) O.Ktze	Hydrophyte	Herb
109.	Mimosaceae	*Acacia jacquemontii* Benth.	Phanerophyte	Shrub
110.	Mimosaceae	*Acacia nilotica* (L.) Del. subsp *indica* (Benth.) Brenan	Phanerophyte	Tree
111.	Mimosaceae	*Acacia nilotica* subsp *cupressiformis* (T.L. Stewart) Ali	Phanerophyte	Tree
112.	Mimosaceae	*Acacia senegal* (L.)Willd.	Phanerophyte	Tree
113.	Mimosaceae	*Prosopis cineraria* (Linn.) Druce.	Phanerophyte	Tree
114.	Mimosaceae	*Prosopis glandulosa* Torr.	Phanerophyte	Shrub
115.	Mimosaceae	*Prosopis juliflora* Swartz	Phanerophyte	Shrub
116.	Molluginaceae	*Gisekia pharnaceoides* L.	Therophyte	Herb
117.	Molluginaceae	*Glinus lotoides* L.	Therophyte	Herb
118.	Molluginaceae	*Limeum indicum* Stocks ex. T. And.	Therophyte	Herb
119.	Molluginaceae	*Mollugo cerviana* (Linn.) Ser.	Therophyte	Herb
120.	Nelumbonaceae	*Nelumbo nucifera* Gaertn.	Hydrophyte	Herb
121.	Neuradaceae	*Neurada procumbens* L.	Therophyte	Herb
122.	Nyctaginaceae	*Boerhavia diandra* L.	Therophyte	Herb
123.	Nyctaginaceae	*Boerhavia diffusa* L.	Chamaephyte	Herb
124.	Nyctaginaceae	*Boerhavia procumbens* Banks ex Roxb.	Cryptophyte	Herb
125.	Nyctaginaceae	*Commicarpus boissieri* (Heimerl) Cufod.	Phanerophyte	Herb
126.	Poaceae	*Aeluropus lagopoides* (L.) Trin. ex Thw.	Cryptophyte	Grass
127.	Poaceae	*Aristida adscensionis* L.	Therophyte	Grass
128.	Poaceae	*Aristida funiculata* Trin. & Rupr.	Therophyte	Grass
129.	Poaceae	*Aristida mutabilis* Trin. & Rupr.	Therophyte	Grass
130.	Poaceae	*Brachiaria ovalis* (R. Br.) Stapf	Therophyte	Grass
131.	Poaceae	*Brachiaria ramosa* (L.) Stapf	Therophyte	Grass
132.	Poaceae	*Cenchrus biflorus* Roxb.	Therophyte	Grass
133.	Poaceae	*Cenchrus pennisetiformis* Hochst. & Steud. ex Steud.	Hemicryptophyte	Grass
134.	Poaceae	*Cenchrus prieurii* (Kunth) AMaire	Hemicryptophyte	Grass
135.	Poaceae	*Cenchrus setigerus* Vahl.	Hemicryptophyte	Grass
136.	Poaceae	*Cynodon dactylon* (L.) Pers.	Hemicryptophyte	Grass
137.	Poaceae	*Dactyloctenium aegyptium* (L.) Willd.	Therophyte	Grass
138.	Poaceae	*Dactyloctenium aristatum* Link	Therophyte	Grass
139.	Poaceae	*Dactyloctenium scindicum* Boiss.	Hemicryptophyte	Grass
140.	Poaceae	*Desmostachya bipinnata* (L.) Stapf	Cryptophyte	Grass
141.	Poaceae	*Dichanthium annulatum* (Forsk.) Stapf	Hemicryptophyte	Grass
142.	Poaceae	*Digitaria bicornis* (Lam.) Loud.	Therophyte	Grass
143.	Poaceae	*Diplachne fusca* (L.) P.Beauv. ex Roem. & Shult.	Therophyte	Grass
144.	Poaceae	*Echinochloa colonum* (L.) Link	Therophyte	Grass
145.	Poaceae	*Eleusine indica* (Linn.) Gaertn.	Therophyte	Grass
146.	Poaceae	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard	Therophyte	Grass
147.	Poaceae	*Eragrostis ciliaris* (L.) R. Br.	Therophyte	Grass
148.	Poaceae	*Eragrostis minor* Host.	Therophyte	Grass
149.	Poaceae	*Eragrostis tenella* (L.) P. Beauv. ex Roem.	Therophyte	Grass

Sr #	Family	Plant species	Life form	Habit
150.	Poaceae	*Eragrostis viscose* (Retz.) Trin.	Therophyte	Grass
151.	Poaceae	*Eriochloa procera* (Retz.) C. E. Hubbard	Therophyte	Grass
152.	Poaceae	*Imperata cylindrical* (L.) P.Beauv.	Therophyte	Grass
153.	Poaceae	*Leptothrium senegalensis* (Kunth) W.D. Clayton	Therophyte	Grass
154.	Poaceae	*Ochthochloa compressa* (Forsk.) Hilu	Therophyte	Grass
155.	Poaceae	*Panicum antidotale* Retz.	Hemicryptophyte	Grass
156.	Poaceae	*Panicum turgidum* Forsk.	Hemicryptophyte	Grass
157.	Poaceae	*Paspalidium geminatum* (Forsk.) Stapf.	Therophyte	Grass
158.	Poaceae	*Paspalum scrobiculatum* L.	Therophyte	Grass
159.	Poaceae	*Paspalum vaginatum* Swartz.	Hemicryptophyte	Grass
160.	Poaceae	*Phragmites australis* (Cav.) Trin.	Cryptophyte	Large Grass
161.	Poaceae	*Phragmites karka* (Retz.) Trin.	Cryptophyte	Tall grass
162.	Poaceae	*Saccharum benghalense* Retz.	Hemicryptophyte	Tall grass
163.	Poaceae	*Saccharum griffithii* Munro ex Boiss.	Hemicryptophyte	Tall grass
164.	Poaceae	*Saccharum ravennae* (Linn.) Murr.,	Hemicryptophyte	Tall grass
165.	Poaceae	*Saccharum spontaneum* Linn.	Hemicryptophyte	Tall grass
166.	Poaceae	*Sporobolus nervosus* Hochst.	Hemicryptophte	Grass
167.	Polygalaceae	*Polygala erioptera* DC.	Chamaephyte	Herb
168.	Polygalaceae	*Polygala irregularis* Boiss	Chamaephyte	Herb
169.	Polygonaceae	*Calligonum polygonoides* L.	Phanerophyte	Shrub
170.	Polygonaceae	*Persicaria barbata* (L.) Hara	Chamaephyte	Herb
171.	Polygonaceae	*Persicaria glabra* (Willd.) Gomes	Chamaephyte	Herb
172.	Pontederiaceae	*Eichhornia crassipes* (Mart.) Solma	Hydrophyte	Herb
173.	Portulacaceae	*Portulaca oleracea* L.	Therophyte	Herb
174.	Primulaceae	*Anagallis arvensis var coerulea* (L.) Gonan.	Therophyte	Herb
175.	Rhamnaceae	*Ziziphus nummularia* (Burm.f.) Wight & Arn.	Phanerophytes	Shrub
176.	Salicaceae	*Populus euphratica* Olivier	Phanerophyte	Tree
177.	Salvadoraceae	*Salvadora oleoides* Decne.	Phanerophyte	Tree
178.	Salvadoraceae	*Salvadora persica* L.	Phanerophyte	Tree
179.	Salviniaceae	*Salvinia molesta* Mitchelle	Hydrophyte Fern	Herb
180.	Scrophulariaceae	*Bacopa monnieri* (L.) Wettstein	Chamaephyte	Herb
181.	Solanaceae	*Datura fastuosa* L.	Phanerophyte	Shrub
182.	Solanaceae	*Datura suaveolens* Humb. & Bonpland ex Willd.	Phanerophyte	Large shrub
183.	Solanaceae	*Lycium edgeworthii* Dunal	Phanerophyte	Shrub
184.	Solanaceae	*Lycium ruthenicum* Murray	Phanerophyte	Shrub
185.	Solanaceae	*Physalis divaricata* D. Don	Therophyte	Herb
186.	Solanaceae	*Physalis peruviana* L.	Therophyte	Herb
187.	Solanaceae	*Solanum nigrum* L.	Therophyte	Herb
188.	Solanaceae	*Solanum surattense* Burm.f.	Therophyte	Herb
189.	Solanaceae	*Withania coagulans* (Stocks) Dunal	Phanerophyte	Shrub
190.	Solanaceae	*Withania somnifera* (L.) Dunal	Phanerophyte	Shrub
191.	Sterculiaceae	*Melhania denhamii* R. Br.	Chamaephyte	Under shrub
192.	Tamaricaceae	*Tamarix aphylla* (L.) H. Karst.	Phanerophyte	Tree
193.	Tamaricaceae	*Tamarix dioica* Roxb.	Phanerophyte	Tree

Sr #	Family	Plant species	Life form	Habit
194.	Tamaricaceae	*Tamarix indica* Willd.	Phanerophyte	Shrub
195.	Tamaricaceae	*Tamarix pakistanica* Qaiser	Phanerophyte	Shrub
196.	Tamaricaceae	*Tamarix szovitsina* Bunge	Phanerophyte	Shrub
197.	Tamaricaceae	*Tamarix sp. Nov.*	Phanerophyte	Shrub
198.	Tiliaceae	*Corchorus aestuans* L.	Therophyte	Herb
199.	Tiliaceae	*Corchorus depressus* (L.) Stocks	Therophyte	Herb
200.	Tiliaceae	*Corchorus tridens* L.	Therophyte	Herb
201.	Tiliaceae	*Corchorus trilocularis* L.	Therophyte	Herb
202.	Tiliaceae	*Grewia tenax* (Forssk.) A. & S.	Phanerophyte	Shrub
203.	Typhaceae	*Typha dominghensis* Pers.	Hemicryptophyte	Tall reed
204.	Verbenaceae	*Clerodendrum phlomidis* L.	Phanerophyte	Shrub
205.	Verbenaceae	*Phyla nodiflora* (L.) Greene	Chamaephyte	Herb
206.	Zygophyllaceae	*Fagonia indica* Burm.f.	Chamaephyte	Herb/subshrub
207.	Zygophyllaceae	*Fagonia indica* var. *schweinfurthii* Hadidi	Chamaephyte	Herb/subshrub
208.	Zygophyllaceae	*Tribulus longipetalus* Viv.	Therophyte	Herb
209.	Zygophyllaceae	*Tribulus ochroleucus* (Maire) Ozenda & Quezel	Therophyte	Herb
210.	Zygophyllaceae	*Tribulus terrestris* L.	Therophyte	Herb
211.	Zygophyllaceae	*Zygophyllum simplex* L.	Therophyte	Herb

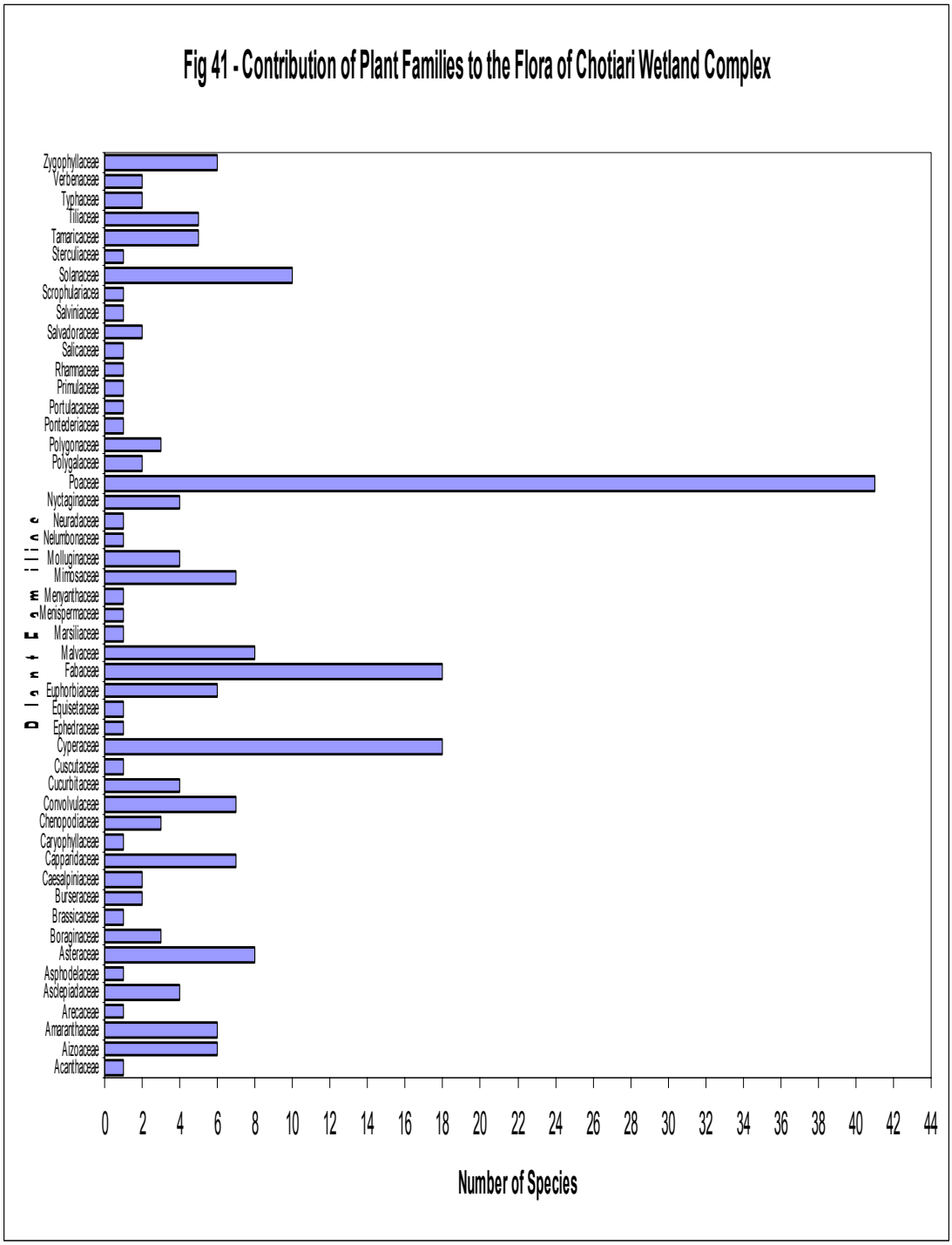


Fig 41 - Contribution of Plant Families to the Flora of Chotiari Wetland Complex
Plant Families
Zygophyllaceae
Verbenaceae
Typhaceae
Tiliaceae
Tamaricaceae
Sterculiaceae
Solanaceae
Scrophulariaceae
Salviniaceae
Salvadoraceae
Salicaceae
Rhamnaceae
Primulaceae
Portulacaceae
Pontederiaceae
Polygonaceae
Polygalaceae
Poaceae
Nyctaginaceae
Neuradaceae
Nelumbonaceae
Molluginaceae
Mimosaceae
Menyanthaceae
Menispermaceae
Marsiliaceae
Malvaceae
Fabaceae
Euphorbiaceae
Equisetaceae
Ephedraceae
Cyperaceae
Cuscutaceae
Cucurbitaceae
Convolvulaceae
Chenopodiaceae
Caryophyllaceae
Capparidaceae
Caesalpiniaceae
Burseraceae
Brassicaceae
Boraginaceae
Asteraceae
Asphodelaceae
Asclepiadaceae
Arecaceae
Amaranthaceae
Aizoaceae
Acanthaceae
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Number of Species

Year-wise comparson of the plant families at Chotiari to overall flora is provided in Annexure C – II.

4. 3.2 Phytosociological Aspects

The flora of Chotiari was surveyed consectively over three years starting from 2006 to 2008 over different seasons. TWINSPAN Analysis was used considering plant cover of each species and different plant communities were observed over different seasons in three years which are briefly described as under. A further detail of the analysis could be revealed from Annexure C – III.

4.3.2.1 *Indigofera argentea – Indigofera linifolia – Gynandropsis* Plant Community (2006)

This community was found on Transects 1, 6, 8, 9 and 10. Transect 1 was situated on the side of main embankment where there was a lot of grazing and soil was deep. The community is represented by families Fabaceae (*Indigofera argentea - Indigofera linifolia)* and Capparidaceae (*Gynandropsis gynandra).* Although there were a lot of other plant species present at these points, yet community was formed by these species. Dry Matter forage production of the sites represented by this plant community varied from 150 to 552 Kg/Ha.

Figure 42 – Sites possessed by *Indigofera argentea – Indigofera linifolia – Gynandropsis* Plant Community (2006)

4.3.2.2 *Octhochloa – Pluchea – Salvadora* Plant Community (2006)

This plant community was represented by Transects 2, 3, 5, 7 and 4. All these points were on sand dunes situated in vicinity of wetlands. The plant species comprising this community included *Ochthochloa compressa* (family Poaceae) with a life form of Hemicryptophte, *Pluchea lanceolata (*family Asteraceae) and life form of Phanerophyte and *Salvadora oleoides* (family Salvadoraceae) and having life form of Phanerophyte.Dry matter forage yield fluctuated between 66 and 483 Kg/Ha.

Figure 43 – Sites represented by *Octhochloa – Pluchea – Salvadora* Plant Community (2006)

4.3.2.3 Calligonum - *Indigofera – Ochthochloa* Plant Community (2007)

This community was found on Transects No. 1, 2, 3, 4, 6, 7, 8 and 9. Families Polygonaceae, Fabaceae and Poaceae represented the community. *Calligonum polygonoides* and *Indigofera argentea were* found in 7 transects followed by *Ochthochloa compressa* in 4 transects. Dry matter forage production varied from 66 to 553 Kg/Ha.

Figure 44 – Sites represented by *Calligonum - Indigofera – Ochthochloa* Plant Community (2007)

4.3.2.4 *Indigofera – Dactyloctenium – Salvadora* Plant Community (2007)

This plant community was represented by Transects 3, 5, 6, 7, 8, and 9. All these points were on sand dunes situated in vicinity of wetlands. The community was comprised of species like *Indigofera argentea* (Fabaceae)*, Dactyloctenium scindicum* ({Poaceae) and *Salvadora oleoides* (Salvadoraceae). Dry matter forage production of this community varied from 199 to 694 Kg/Ha thus exhibiting a potential rangeland in summer (post-monsoon) season

Figure 45 – Sites represented by *Indigofera – Dactyloctenium – Salvadora* Plant Community (2007)

4.3.2.5 *Calligonum polygonoides – Panicum turgidum – Crotalaria burhia* Plant Community (2008)

This plant community was represented by transects 5, 7, 8, 10, 12, 13 and 14 where *Calligonum polygonoides* followed by co-dominant species of *Panicum turgidum* and associated species of *Crotalaria burhia.* It is a typical desert community represented by xerophytes that exist either on sand dunes or in sandy desert lands. Chotiari reservoir is occupied by a number of sand dunes which are used as grazing grounds for the livestock of local communities. Other plant species found in this community were *Lycium*

edgeworthii, Calotropis procera, Phragmites karka, Salvadora oleoides, Prosopis cineraria, Luffa echinata, Indigofera argentea, Indigofera cordifolia, Phyla nodiflora, Panicum turgidum, Corchorus depressus, Cistanche tubulosa and *Ephedra ciliata.* Forage production of these sites varied from 54 to 102 Kg/Ha. These island communities occupying sand dunes are heavily grazed year-round.

Figure 46 – Sites represented by *Calligonum polygonoides – Panicum turgidum – Crotolaria burhia* Plant Community (2008)

4.3.2.6 *Calotropis procera – Acacia nilotica - Suaeda fruticosa – Desmostachya bipinnata* Plant Community (2008)

This community was present in transects 2, 3, 4 and 11 showing relatively degraded and overgrazed sites. Other species of the area were *Leptadenia pyrotechnica, Salsola imbricata, Gynandropsis gynandra, Phragmites karka, Typha elephantiana, Cyperus rotundus, Cyperus bulbosus, Phyla nodiflora, Bacopa monnieri, Ochthochloa compressa* and *Pluchea lanceolata.* Forage production of these sites varied from 60 to 154 Kg/Ha showing intensive overgrazing.

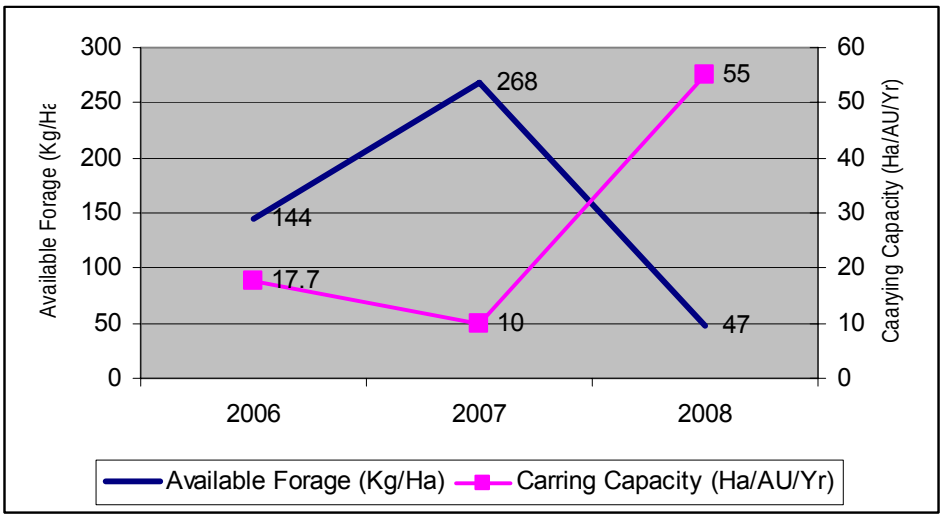
Figure 47 – Sites represented by *Calotropis procera – Acacia nilotica - Suaeda fruticosa – Desmostachya bipinnata* Plant Community (2008)

4.3.3 Carrying Capacity

Carrying Capacity of Chotiari Wetland Complex was determined in terms of hectares per animal unit per year over three consecutive years (Figure 48 and Annex C - IV). Both forage production and carrying capacity showed a downward trend from 2007 to 2008. Maximum values of these parameters were found in 2007. Such downward trend could be result of (i) the seasons as both in 2006 and 2008 surveys were conducted in fall and early spring seasons while in 2007 it was conducted right after monsoon rains in summer or (ii) with the increasing level of water in the reservoir many productive

pastures have submerged. The study also revealed that there is grazing pressure, wood cutting and lopping which is contributing in the deterioration of natural vegetation of the study area. It has been observed that the inhabitants around the reservoir are mainly engaged in agriculture and livestock rearing and in the absence of any grazing system (either conventional one) rangelands get no relief and productivity is declining.

Figure 48 – Forage Production and Carrying Capacity of Pastures of Chotiari Wetland Complex Over Three Different Years



4.3.4 Biodiversity Index & species Richness:

4.3.4.1 α- Diversity (*i.e.,* the species richness and species diversity within each locality). With reference to species richness Chotiari Wetland Complex showed second highest value of α- Diversity across all the sites except Keenjhar Lake with 49 families, 125 genera and 213 species. A summary of the plant communities, associated species and the forage production is provided in Annexure C – V.

Among various families, Poaceae exhibited the highest species richness in all sites. At Chotiari Wetland Complex the highest number of species recorded belonging to the family Poaceae (41 species) followed by Cyperaceae, Fabaceae (18 species, each), Solanaceae (10 species), Asteraceae, Malvaceae (8 species each), Capparidaceae, Convolvulaceae, Mimosaceae (7 species each) and other families having less then seven species.

4.3.4.2 β -Diversity (*i.e.,* the species turnover from one locality to other locality or diversity between localities)
Localities were compared in pairs with every possible combination. The highest number of species was shared by Keenjhar and Chotiari, *i.e.,* these two localities had 162 species in common, Chotiari & Pai with 88 species and, Keti & Chotiari 78 species in common.

These localities pairs are shown in Table 19 below.

Table - 19 Similarity Index and β -Diversity of study sites

S. No	Locality pairs	2006			2007			2008		
		Shared species	CC	BD	Shared species	CC	BD	Shared species	CC	BD
2	Keti – Chotiari	13	0.16	1.832	68	0.45	1.55	78	0.48	1.52
4	Keenjhar - Chotiari	57	0.45	1.548	145	0.65	1.35	162	0.68	1.32
6	Chotiari – Pai	30	0.33	1.667	78	0.51	1.49	88	0.53	1.47

4.3.5 Significant findings

Luffa echinata: According to Flora of Pakistan records, it was considered a rare species earlier recorded only form Chitral, Swat and Tharparkar. However, this was found to be abundantly in Chotiari reservoir area.

Fimbristylis* sp *& Tamarix* sp*: These are newly discovered species and would be described later.

Tamarix szovitsiana: This species was first time recorded form Sindh province.

4.4 Discussion

Being an arid area with a landscape mainly consisting of undulating sand dunes, the vegetation of this site is xerophytic in general, dominated by tough xerophytes like *Calligonum polygonoides, Panicum turgidum, Crotolaria burhia, Capparis decidua, etc.* Floristically Poaceae is the largest family with 41 species. The high diversity of grasses is another characteristic feature of arid lands. However, the presence of various Lakes (which are bound to become one large Lake after the complete filling of reservoir) provides different kinds of microhabitat due to which the over all diversity of the site is fairly high with a total of 211 species. The water margins are inhabited by a number of wetland species like *Phyla nodiflora, Bacopa monnieri, Oxystelma esculentum, Ipomoea carnea, Ipomoea aquatica, Persicaria glabra, Alternanthera sessilis* and*, Glinus lotoides,* etc. However, the truly aquatic plants were much fewer as compared to those reported by Leghari *et al.* (1999). They reported a total of 41 aquatic species including floating, emergent and submerged plants, out of which this study revealed only 9 species such as *Equisetum debile, Marsilia minuta, Salvinia molesta, Persicaria barbata, Typha dominghensis, Cyperus longus, Cyperus rotundus, Nelumbo nucifera and Ipomoea aquatica.* The most probable reason for this difference is that Leghari *et al.* (1999) studied this wetland complex before filling of the reservoir was started. On the other hand, at the time of this study the reservoir had filled to a considerable extent, submerging a large amount of vegetation including trees and shrubs. As a result, most of the hydrophytes previously present in the smaller natural Lakes must have died for two reasons, firstly due to change in water level, and secondly the decomposition of submerged vegetation must have resulted in lowered level of dissolved oxygen and

change in pH. The submerged vegetation at deeper depths inside water decomposes anaerobically, releasing methane. All these factors seem to have negatively affected the diversity of aquatic plants.

The islands in the reservoir present quite interesting vegetation. Many of them have considerably high land in their middle part, inhabited by xerophhytic species like *Euphorbia caducifolia and Salvadora oleoides,* but at their margins wetland species like *Phyla nodiflora, Bacopa monnieri, Fimbristylis bisumbellata, Cyperus pygmaeus, Typha dominghensis, Phragmites karka, Oxystelma esculentum, Luffa echinata, etc.* are present. The latter (*Luffa echinata*) is particularly common on the islands. It is an extensive annual climber growing after monsoon and it totally covers its surrounding shrubs and trees. After flowering in September – October and subsequently fruiting, it dries up in the winter.

Among woody species *Acacia nilotica, Prosopis cineraria, Acacia senegal, Salvadora oleoides* are found in dry places and *Populus euphratica* and *Tamarix spp.* Are prominent in semi aquatic and wet habitats. *Tamarix* is in fact the largest woody genus with 6 species, mainly distributed along water margins, water logged lands and periphery of cultivated fields where soil is more or less saturated with water. The local people depend upon the natural vegetation in different ways besides livestock grazing. *Typha, Saccharum, Phragmites,* and fine twigs of *Tamarix spp.* are extensively used for thatching and for making mats. Thicker stems of *Tamarix* are used in making huts and also as fire wood. Petioles and rhizomes of *Nelumbo nucifera* and inflorescence of *Calligonum* are used as vegetable.

Like other arid areas, the primary productivity (DMY) and carrying capacity in 2008 are low, the mean values being 267.7 and 54.9 Ha/AU/Yr, respectively, which are much lower than that found in survey of 2007 which was conducted during monsoon season. It is obvious that in winter the carrying capacity is particularly low. The main livelihood of local people is pastoralism; therefore, there is an immense pressure on the meagre resources of the ecosystem with signs of overgrazing and desertification. It is learnt that about 400 families around the reservoir are engaged in livestock rearing, who also depend upon ecosystem resources for firewood and hut making materials. This is why wood cutting and lopping activities are also rampant in the area.

4.4.1 Problems and Threats:

The main functions of Chotiari reservoir are sustained supply of water for agriculture, support fish population and provide healthy habitat to local as well as migratory bird fauna. It has lot of importance for people inhabiting in and around the reservoir. Local communities use Lake waters for human and livestock drinking and for irrigation. In spite of the cancellation of contractual arrangements for fish, the contractors are still present and forcing the local communities to sell their stock to them. The local economy of the area relies largely on agriculture, livestock and fishing. By virtue of being located at the edge of desert the poverty among the local communities is more common and the resource degradation is more rampant. Chotiari reservoir is facing a number of threats which are summarized below:

4.4.1.1 Water logging and Salinity: The widening of the reservoir and consequently increase in the incoming water has adversely affected the agriculture and livestock practices of the surrounding areas, especially on western and southern sides of the

reservoir. Vast chunks of agricultural lands are being water logged due to seepage from reservoir and Nara canal. Water table is at rise in adjoining areas which will subject more areas to this menace in addition to the gift of salinity. It is expected that water level of the reservoir will rise up to 7 feet so one can well imagine how much productive agricultural area in vicinity of Nara desert will be affected by water logging and salinity and resultantly how many agrarian families will suffer economic losses. According to one estimate, nearly 400 families are associated with livestock rearing in the reservoir area. Ultimately the shifting of both human and livestock populations to adjoining areas will pose serious environmental impacts both on flora and fauna of already degraded desert ecosystem.

4.4.1.2 Loss of Trees Wealth in the Area: In the process of increasing water in the reservoir, Makki forest that was very famous for luxuriant natural vegetation has gone completely under water. Large trees of *Prosopis cineraria* and *Acacia nilotica* have completely drowned inside water. The submersion of forest has not only heavily altered the ecosystem but also posed new threats. The woody vegetation inside water will ultimately die and decompose and consequently giving rise to eutrophication. Moreover, because of conversion of existing mosaic of desert and wetland ecosystems into aquatic ecosystem, grasses, shrubs and trees which were being used as fodder for range and domestic livestock and medicinal flora will vanish and so will the habitats of associated fauna. Due to seepage from Nara canal, the highly fertile agricultural lands in the vicinity are being destroyed; farming families are forced to raise livestock to earn their livelihoods which will ultimately increase grazing pressure on already deteriorating rangelands of the area. Unfortunately, except Sindh Irrigation and Drainage Authority (SIDA), no other government department like Forests, Wildlife or Fisheries is present at Chotiari. Presently forests and rangelands in and around Chotiari do not carry any legal title. Consequently, people cut healthy trees without any check. Even people from Sanghar city take away wood for commercial purposes. Under such deforestation, there will be little refuge for the wild animals in the area.

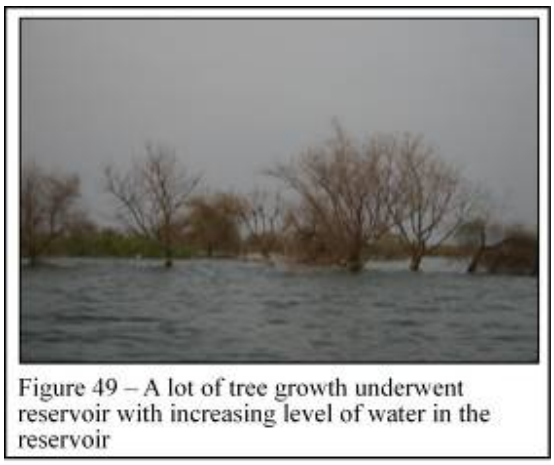


Figure 49 – A lot of tree growth underwent reservoir with increasing level of water in the reservoir

4.4.1.3 Shifting Populations: The large number of human and livestock populations is continuously shifting from seepage affected areas to adjoining areas. This is causing greater pressure on natural vegetation for timber, fuel wood, medicinal plants, rangelands, housing and agriculture. This is putting greater economic stress on already poor rural communities.

4.4.1.4 Over Exploitation of Fishes: It has been learnt during vegetation surveys that fish yield has increased 2-3 times compared to the past. For example, if the Chotiari Lake first used to yield one truck load/day, now it is yielding 2-3 truck loads/day. In fact increased fish catches are not due to increase in fish population, rather it is due to entry of more people into the fishing business on account of unemployment of local people thus putting more economic stress on already poor livelihood conditions. Due to over fishing there will be drastic decline in fish population of Chotiari Lake. Furthermore, no efforts by the fisheries department are visible to improve the condition

by adding fish seed or fingerlings into the Lake to replenish the decreasing fish stock. Another important contributing factor is the use of unsustainable fishing practices by the fishing contractors which is undermining long-term sustainability of fisheries in this complex. These include, use of small size fishing nets, use of poison and chemicals. Degradation of fisheries poses a potential threat to the livelihood of local fishing communities.

4.4.1.5 Illegal Hunting & Shooting: Generally hunting and shooting is done by elites of the area. Due to unchecked hunting population of important large animals like Hog deer and Chinkara has drastically declined while bird population is also decreasing due to constant disturbance thus forcing these birds to migrate to undisturbed grounds elsewhere.

4.4.1.6 Lack of social services: The social problems faced by the area include lack of safe drinking water, schools, health facilities, unemployment and dominance of influential local interest groups.

4.4.2 Improvements Required:

4.4.2.1 Conservation of Vegetation

- **Tree Plantation:** Chotiari reservoir is a unique landscape that contains water bodies and the desert ecosystem simultaneously. Such merger of different ecosystems within the same area presents a wealth of flora and fauna. The flora of the reservoir has suffered badly due to increase in the water level. It is suggested that along the banks of the reservoir and along the Nara Canal extensive planting of water loving trees be done at least in one kilometre radius to control the spread of seepage, water logging and salinity. The plant species suggested are *Eucalyptus camaldulensis, Syzygium cumini, Populus euphratica* and *Tamarix passernioides, etc*. This will help improve not only the soil conditions for cultivation but also improve the economic conditions of the land owners.
- **Alternate Use of Submerged Agriculture Lands:** The agriculture fields in the depressions should be used for aquaculture such as cultivation of Singhara (*Trapa bispinosa* (Family Onagraceae). The farmers should also be encouraged to use such type of lands for fish hatcheries. Cultivation of aquatic flora, like Nilofer (*Nelumbo nucifera*), *Nymphaea lotus,* etc. need to be encouraged to promote livelihood opportunities for the communities. This will help the communities to use their lands for productive purposes and they can get diversified income from their lands. To overcome the fodder shortage in the area and reduce grazing pressure on rangelands, it is suggested that Kallar grass (*Diplachne fusca*) may also be introduced on salt affected soils.
- **Livestock and Pasture:**
  - **Germplasm Conservation:** The study revealed that local communities depend heavily on livestock rearing for their sustenance. Livestock includes both small and large ruminants of varying numbers. Livestock such as cows and buffaloes were seen grazing even on distantly located islands where such animals can only approach through transportation by boats. There is a large variety of grasses, forbs and shrubs that provide nutrient rich forage for all kinds of livestock. Potential for carrying capacity of these grazing grounds is very high and it is suggested that these islands be protected from grazing as seed banks for the

conservation of germplasm. Moreover, a few number of vegetation exclosures need to be established to demonstrate the effect of protection on the recovery and multiplication of natural vegetation.

- **Livestock Management:** Local communities in desert areas largely believe in having more numbers of domestic animals than considering their quality. The reason for such attitude is largely attributed to the low costs associated with grazing and also to economic instability. It requires continuous awareness raising among agro-pastoral families besides regular monitoring of carrying capacity of important pastures to suggest the proper kind and number of livestock in a manner where competition among wild herbivores and domestic livestock for food is minimised. There is a need that local communities should be trained on range-livestock interaction and the ways to improve the pastures through community actions. Moreover, regular trainings on livestock health care are also required.
- **Pasture development through Latest Technologies:** The pastures should be developed using sprinkler irrigation systems on modern lines using lift irrigation from the reservoir of desert side of the Lake to feed increasing population of livestock. This will help in reducing grazing pressure on dwindling vegetation depending on natural precipitation. In the waterlogged places, *Diplachne fusca* (Kallar grass) can be grown as fodder crop.

- **Encroachment by Mesquite:**

  Likewise other areas of Sindh, Mesquite (*Prosopis juliflora*) is increasingly encroaching the landscape in Chotiari. If proper and timely measures are not taken, it will alter the ecosystem. Some areas at the water margins are even not possible to access due to profuse growth of mesquite.

- **Wildlife Conservation:** Chotiari is famous for a variety of wild fauna that includes Hog deer, Crocodile, Otter and large number of migratory waterfowls. It is used to be an important breeding ground of Marbled Teal, which has been affected with the construction of reservoir and needs investigation about its present status. Although Pir Pagharo (a well-known spiritual and political figure of Sindh) has a traditional sanctuary for Hog deer and partridges, yet hunting of waterfowl is common. Sighting of Crocodile and Otter is also not frequent. To conserve such unique species, participatory conservation efforts are required immediately.

- **Improvement of Fish population:** It has been suggested that local communities should be encouraged and trained for establishment of fish hatcheries on their water affected agricultural lands. The fingerlings or fish seed should be released into the reservoir through purchase by the fisheries department or through some NGO's engaged in conservation activities. This will improve the fish population in the Reservoir and also serve as alternate source of income generation for the local poor communities.

- **Alternate Sources of Energy:** To reduce the pressure on ecosystem resources alternate sources of energy such as electricity, solar, wind energy, natural gas and or biogas may be explored and provided.

4.5 Conclusion

The Chotiari Wetland complex is posing environmental threats to the surrounding agriculture and desert areas which is in turn exerting pressure on livestock, pastures, agricultural fields, forests and thus seriously affecting the overall habitat quality. The process of deterioration is gaining momentum with the increase in seepage of water from the Reservoir. Although this ecosystem is rich in floral diversity with respect to number of species recorded (213 species). However, out of 85 plant species recorded in transects, there were 52 species in the category of rare and 9 species rated as vulnerable, 12 species less common while 12 species are rated as common. The rangeland carrying capacity is declining. This is indication of the fact that this fresh water wetland ecosystem is loosing its productive potential. Immediate rehabilitation measures like fish improvement, control on excessive grazing and replacement of exotic species like mesquite are needed. Planting of fodder trees and palatable grasses should be promoted through community participation in the area to overcome the grazing pressure. To control seepage of water from embankments water-loving tree planting and aquaculture seem appropriate measures.

5 - Pai Forest District Nawab Shah (A Forest Ecosystem)

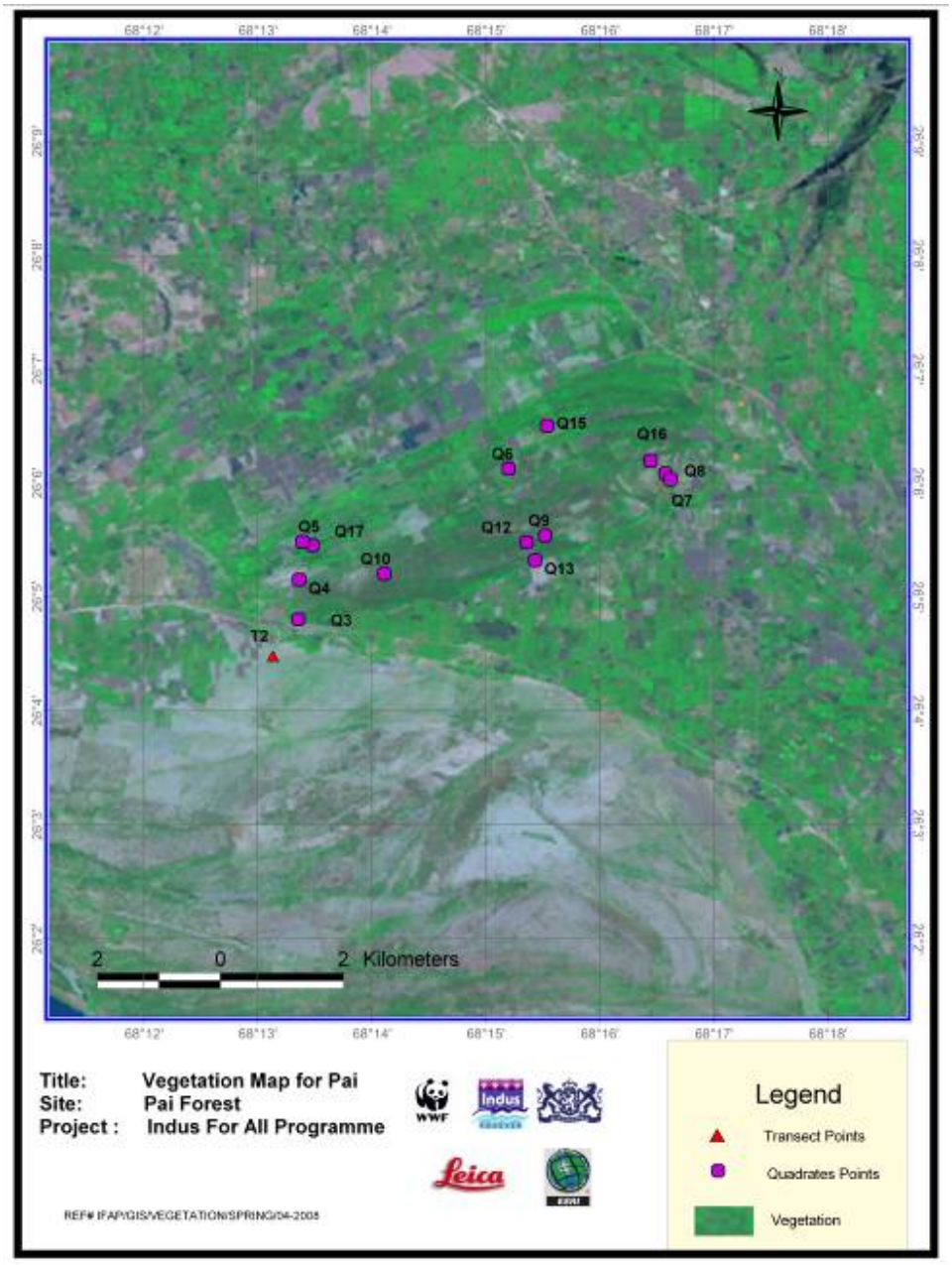


Figure 50 – Image of Chotiari Wetland Complex

5.1 Brief History of the Pai Forest Ecosystem

Prior to British era in 1943, the local rulers (Talpur/Mirs) in Sindh owned all the well-stocked forests in the province, who maintained them as hunting grounds. The cutting of trees in such forests was strictly prohibited. Creation and demarcation of state forests (as reserve and protected forests) was started in 1823 and continued till 1972. Pai Forest is situated on eastern side of the River Indus near Sakrand town of district Nawabshah in Sindh Province at about a distance of 5 km adjacent to National Highway.

Pai forest has a total area of 1933 ha (4777 acres). Out of the total area only 1502 ha (78%) are under tree cover while remaining 319 and 112 ha are either blank or on high lying areas, respectively. Presently 338 ha (17 %) are under Babul (*Acacia nilotica*), 107 ha (6 %) under *Eucalyptus*, 1045 ha (54%) under Kandi (*Prosopis cineraria*) and 12 ha (0.6%) under Shisham (*Dalbergia sissoo*) crop. Thus a total of 457 (24% of the total area) is irrigated and maintained as Irrigated plantation while remaining area (54 %) that is comprised of Kandi (*Prosopis cineraria*) trees does not receive irrigation water.

Climate of this area is generally hot and arid. Rainfall is scanty, erratic and mostly occurs during monsoon season *i.e.,* from June to September. The average annual rain fall is about 200 mm. Maximum temperatures in summer rises to 50^{o}C, and minimum temperature during winter is 8^{o} C. Hot summers usually extend from April to October. The Soil of this area is mostly loamy in nature with varying proportions of clay and sand. Most of the area has high salt concentrations due to hyper aridity and scarcity of irrigation water.

Prior to the construction of Sukkur barrage on River Indus at Sukkur, Pai forest depended for its water supply on the scanty rainfall and the unregulated water supply from the river through inundation channels. As water supply was not assured, the growing stock was poor both in quality and quantity. The Barrage was constructed during 1931-35, but no provision was made initially for supply of water to the Pai Forest. Establishment of tree plantations under agro-forestry system was, however, started in 1937-38 with the help of irrigation water. As water supply was small, only small areas of 20 to 40 ha were taken up each year for raising tree crops. This arrangement continued till 1946 - 47.

Due to construction of flood protection bund on the river, Pai forest has cut off from the riverine areas and became inland forest. Realising the gravity of the shortage of fuel-wood and charcoal in the province in 1946-47, the Government of Sindh sanctioned irrigation water from Rohri canal for maintaining Pai forest. Later on, due to poor management of water course and forceful use of water by neighbouring farmers, Pai Forest is completely deprived of canal water and now relying purely on ground water obtained from tube-wells.

Due to its ecological importance this plantation has been declared as a protected area (Game Reserve) by Sindh Wildlife department for conservation and sustainable management of wildlife and its habitat because it provides abode to different wildlife species. Important wildlife of the area includes Hog deer, Partridges, Asiatic jackals, Jungle cat, Porcupine, Wild boar, Snakes, etc. For this purpose Pai forest, was taken up for systematic conversion into irrigated plantation during 1960-61 under a development scheme titled "Industrial Wood Plantation Phase-I". An area of 506 ha was planted under this scheme. In addition, an area of 174 ha was planted under Industrial Wood Plantation Phase-II in 1988-91 and 455 ha planted under SFDP in 1996-97. Most of the

areas planted with Shisham during 1960-61 to 1969-70 under first development scheme were invaded by Devi (*Prosopis juliflora*) due to fires and shortage of canal water. Therefore, 13 tube wells were installed in Pai plantation to irrigate during water shortage periods but they are inadequate to support the entire game reserve.

5.2 State of Biodiversity

This Forest is dominated by four major species like Kandi (*Prosopis cineraria)* (very common with pure stands), Babul *(Acacia nilotica)* (common), *Eucalyptus camaldulensis* (Common), and *Tamarix spp*. (*Tamarix indica* (Common) and *Tamarix aphylla* (occasional). Whereas other species in the area include *Salvadora oleoides, Salvadora persica, Calotropis procera, Cadaba fruticosa, Ziziphus nummularia, Capparis decidua, Amaranthus graecizans, Cucumis melo var. agrestis, Zaleya pentandra, Solanum surattense, Corchorus tridens, Corchorus depressus, Abutilon indicum, Amaranthus viridis, Launaea procumbens, Brachiaria spp., Suaeda fruticosa, Rhynchosia minima, Mullugo pentaphylla, Salsola imbricata, Dactyloctenium aegyptium, Desmostachya bipinnata, Trianthema portulacastrum, Euphorbia prostrata, Eclipta alba, Eragrostis japonica, Eragrostis minor, Cleome brachycarpa, Aerva javanica* and *Cocculus hirsutus* etc.

Intensity of infestation of alien invasive species like Mesquite (*Prosopis juliflora*) could be visualised from the fact that in most of the sampling points it stood first and second to the main species forming community. In 12 out of 16 sampling transects, Mesquite was the most dominant species and hence plant communities are named after this species.

The major wildlife species in this game reserve include Hog deer, Partridges, Asiatic jackals, Jungle cat, Porcupine, Wild boar, Snakes, Desert hare, Rodents, Bats, Indian grey mongoose, Pangolin, Indian Bengal fox, etc. Whereas common birds include Green finch, Red vented bulbul, White cheeked bulbul, Pied chat, Pheasant tail crow, Grass tailed prinia, Turtle dove, Jungle babbler, Jungle sparrow, Crested lark and, Finch lark.

Agriculture is one of the major professions in the area. People grow wheat and fodder as winter season crops while cotton is the summer season crop. Cultivated woody perennials and herbs are given below in Table 20.

Table - 20 Cultivated plant species recorded at Pai Forest

Sr :	Family	Plant species	Life form	Habit
1	Acanthaceae	*Adhatoda vasica* Nees	Phanerophyte	Shrub
2	Combretaceae	*Terminalia arjuna* Wight & Arn.	Phanerophyte	Tree
3	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Phanerophyte	Subshrub
4	Labiatae	*Ocimum basilicum* L.	Chmaephyte	Subshrub
5	Meliaceae	*Azadirachta indica* A.Juss.	Phanerophyte	Tree
6	Myrtaceae	*Eucalyptus camaldulensis*	Phanerophyte	Tree
7	Papilionaceae	*Dalbergia sissoo* Roxb.	Phanerophyte	Tree
8	Papilionaceae	*Erythrina sp.*	Phanerophyte	Tree
9	Pedaliaceae	*Sesamum indicum* L.	Therophyte	Herb
10	Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	Phanerophyte	Shrub

5.3 Livelihood/ Social Aspects

The local communities of the surrounding area belong to Chandio, Jamali, Keerio, Lakha, Bhumbro and Jalbani tribes. Their livelihood is agriculture and mainly depends on forest area for their wood requirements and livestock grazing.

In the recent past, all of the riverine forests namely Mehrabpur, Maribelo, Moriolakho, Jaryoketi , which were about 20000-25000 acres, lying outside the protection bund have been totally encroached by local peoples. Now the pressure of surrounding villages (20-25 villages) is entirely on Pai forest for fuel, timber, hunting and grazing. This small chunk of land is the only refuge for dwindling population of Hog deer and other fauna of the area. On the other hand the same forest is also sole source of fire wood, timber and grazing land for surrounding communities. This situation has aggravated the pace of continuous degradation of forest and wildlife habitat. Keeping in view the ecological importance of this forest, WWF- Pakistan taken up this site for conservation and rehabilitation on sustainable basis through Indus for All Programme.

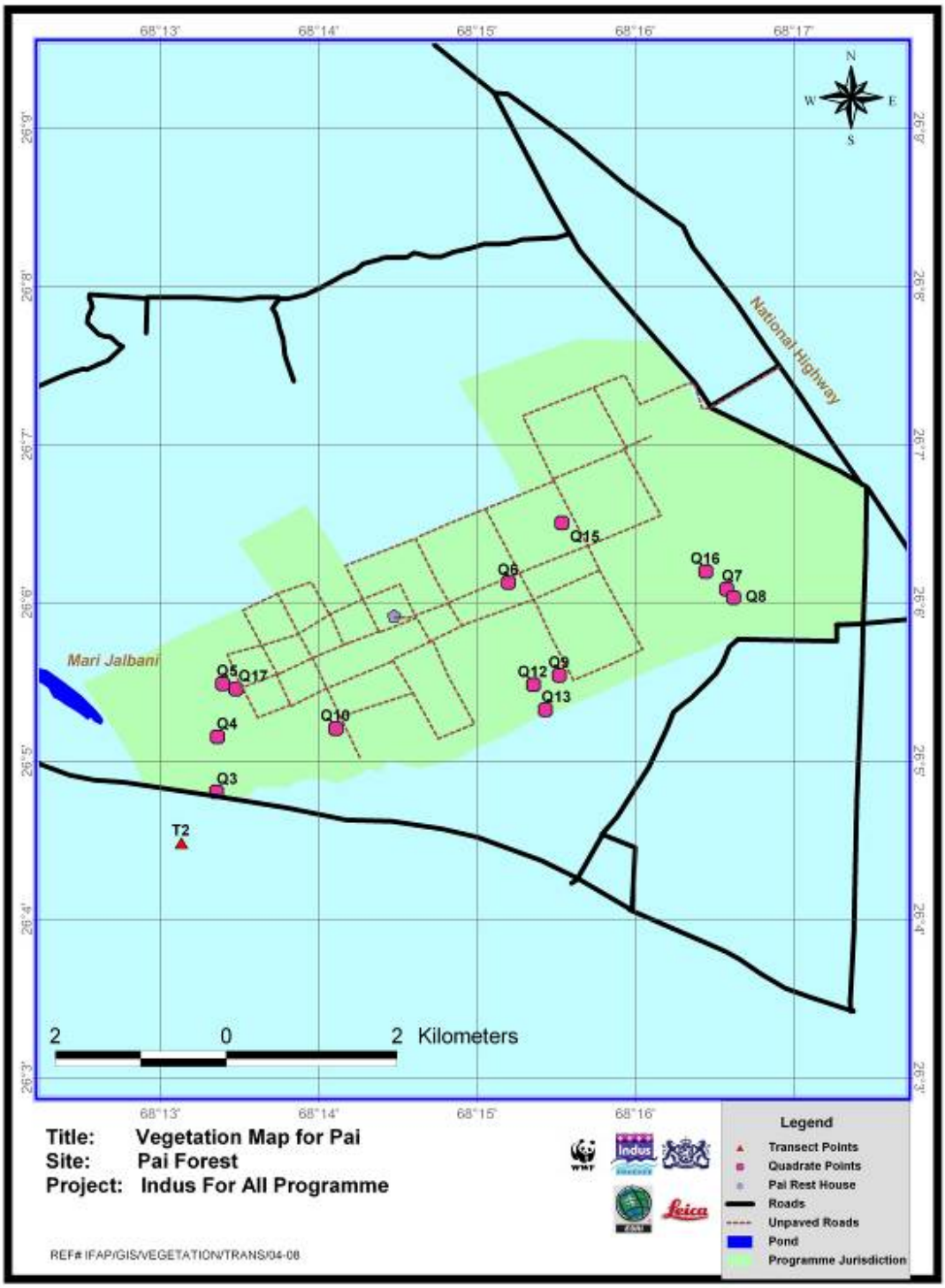
Villages around Pai forest have a mix of ethnic groups including Sindhi Samat castes such as Channa, Keeria and Machhi; Baloch tribes such as Magsi, Leghari, Zardari, Jamali and Jalbani; and Punjabi / Seraiki casts such as Gudara, Sial, Bhutta, Arain and Gujjar. The main livelihood sources are agriculture, livestock, and government service. School education infrastructure is widespread but health facilities are sporadic. Water supply through hand pumps is available and so is electricity in most villages. The area also has local civil society organizations and advocacy groups, in addition to the CCBs.

A recent socio-economic study undertaken by the Indus for All Programme revealed that Marri Jalbani is the largest village, the residents of which are reportedly involved in wood cutting and selling. Provision of gas to this village and other nearby communities is likely to reduce the wood cutting intensity to a considerable extent. Livestock ownership in most villages coupled by herds brought by tribesmen from Upper Sindh also threatens the irrigated plantation in Pai forest area. The average household size of the neighbouring rural population is 6.9 members. Large household sizes are of 14 to 18 or even of more members in the nearby villages. About half (49%) of houses are Katcha, while a significant proportion of houses (27% and 19%) respectively, are semi-Pacca (bricks and wood) and Pacca (bricks and iron or RCC structure. Agricultural, labor and services are prominent professions of the population of Pai forest site along with miscellaneous services and occupations. About one half of the family members of Pai households are engaged in service sector followed by 36% as agricultural labor. On an overall basis, the main occupations of family members other than the household head, were fishing (36.4%), agricultural and wage labor (32%) and miscellaneous labor oriented services (23%). It is clear from these indicators that the human capital is quite low over here. Most of the people are engaged in primary production sectors of agriculture and fishing and in labor oriented occupation.

Average monthly income per household is estimated as Rs. 7,000 only. Almost 52% households own buffaloes for milk.The average number of milking cows are 1 per household. Goat, sheep, and camel ownership are found as 22%, 9% and 5% households, respectively. Poultry birds are maintained by 16% of the households. Donkeys and horses are reported by 1.5% and 0.5% households, respectively.

Based on recent socio-economic assessment conducted by Indus for All Programme (Annexures D – VI to D – XIV), on an overall basis, 48% of respondents agreed that irrigation water resources have depleted during the last five years. Over 64% respondents agreed that forest resources have sharply depleted during the last 5 years.

Figure 51 – Location of transects and quadrats in Pai Forest



5.4 Results

5.4.1 Flora of Pai Forest: Vegetation assessment of Pai Forest was carried out during 2006, 2007 and 2008 in different seasons. Floristic account of Pai forest is given in Table 21, while the comparison of family's contribution recorded in three surveys is presented in Annexure D – II. A total number of 122 species in 88 genera and 35 families were recorded in Pai forest. Out of these, one species in one genus and one family is Pteridophyte, while 94 species in 66 genera and 31 families are dicotyledonous angiosperms and 27 species in 21 genera and 3 families are monocotyledonous angiosperms. Poaceae comes out to be the largest family with 21 species, followed by Fabaceae with 8 species, Amaranthaceae with 7 species, and Euphorbiaceae with 6 species. *Corchorus* was the largest genus with 5 species followed by *Tamarix* with 4 species. Transect-wise account of the phytosociological parameters of the flora of Pai Forest is provided in Annexure D – I. Besides the natural flora 10 cultivated species were also recognized (Table 20). The alphabetical checklist of species along their family, life form and habit is provided (Table 21).

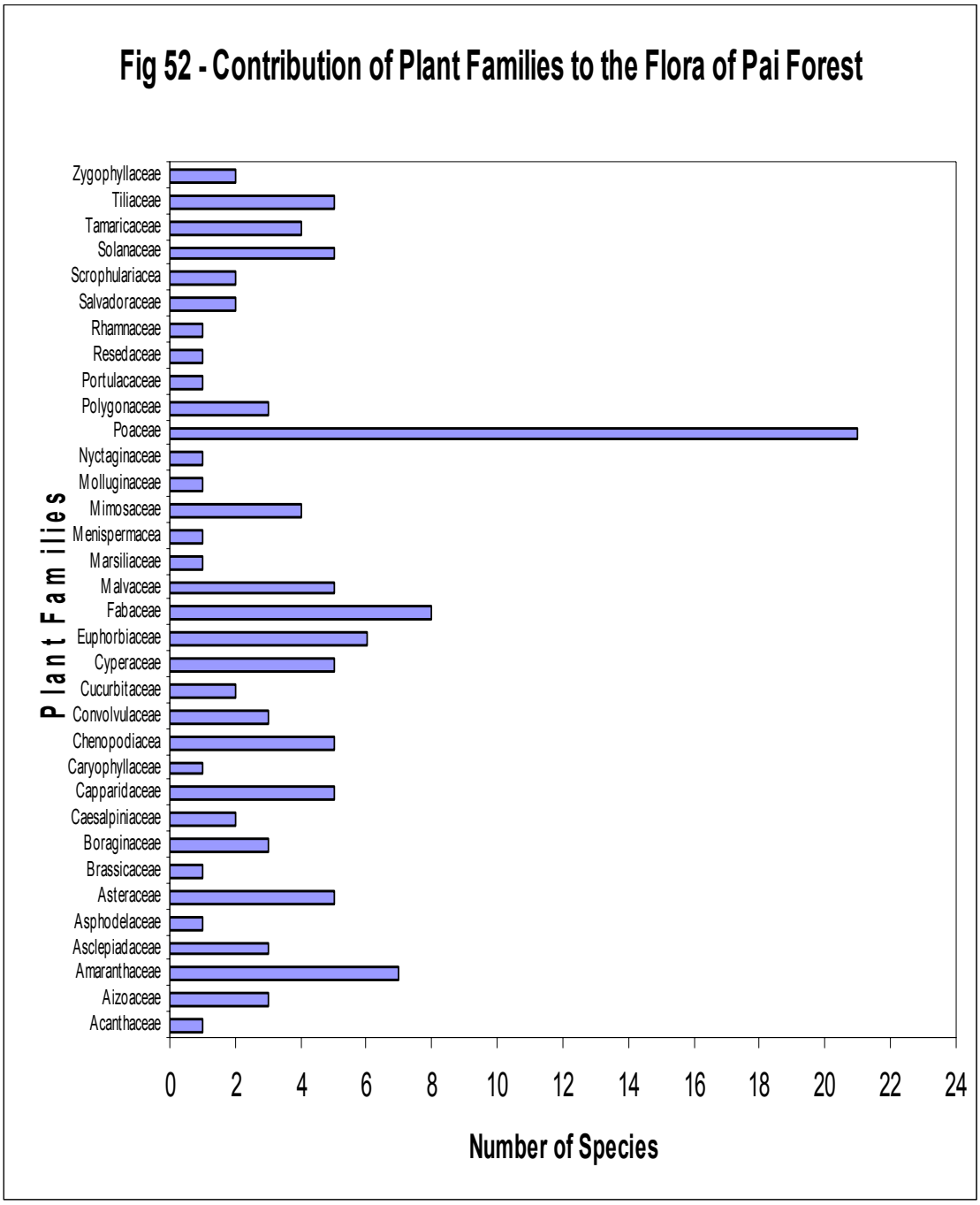
Table 21: List of plant species along with their families, life form and habit of Pai Forest.

Sr #	Family	Plant species	Life form	Habit
1.	Acanthaceae	*Peristrophe paniculata* (Forssk) Brummit	Therophyte	Herb
2.	Aizoaceae	*Trianthema portulacastrum* L.	Therophyte	Herb
3.	Aizoaceae	*Trianthema triquetra* Rottl. and Willd.	Therophyte	Herb
4.	Aizoaceae	*Zaleya pentandra* (L.) Jeffery.	Chamaephyte	Herb
5.	Amaranthaceae	*Achyranthes aspera* L.	Phanerophyte	Subshrub
6.	Amaranthaceae	*Aerva javanica* (Ait.) Ait.f.	Phanerophyte	Subshrub
7.	Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Chamaephyte	Shrub
8.	Amaranthaceae	*Amaranthus graecizans* L.	Therophyte	Herb
9.	Amaranthaceae	*Amaranthus viridis* L.	Therophyte	Herb
10.	Amaranthaceae	*Digera muricata* (L.) Mart.	Therophyte	Herb
11.	Amaranthaceae	*Nothosaerva brachiata* (L.) Wight	Therophyte	Herb
12.	Asclepiadaceae	*Calotropis procera* (Willd.) R. Br.	Phanerophyte	Shrub
13.	Asclepiadaceae	*Leptadenia pyrotechnica* (Forsk.) Dcne.	Phanerophyte	Shrub
14.	Asclepiadaceae	*Oxystelma esculentum* (L.f) R.Br.	Cryptophyte	Climber
15.	Asphodelaceae	*Asphodelus tenuifolius* Cav.	Therophyte	Herb
16.	Asteraceae	*Eclipta prostrata* (L.) L.	Chamaephyte	Herb
17.	Asteraceae	*Launaea procumbens* (Roxb.) Amin	Chamaephyte	Herb
18.	Asteraceae	*Pulicaria undulata* (L.) C.A. Meyer	Therophyte	Herb
19.	Asteraceae	*Sonchus asper* (L.) Hill	Therophyte	Herb
20.	Asteraceae	*Xanthium strumarium* L.	Phanerophyte	Shrub
21.	Brassicaceae	*Raphanus sativus* L.	Therophyte	Herb
22.	Boraginaceae	*Heliotropium crispum* Desf.	Phanerophyte	Shrub
23.	Boraginaceae	*Heliotropium ovalifolium* Forssk.	Chamaephyte	Herb
24.	Boraginaceae	*Heliotropium supinum* L.	Chamaephyte	Herb
25.	Boraginaceae	*Trichodesma indicum* (L.) R.Br.	Camaephyte	Shrub
26.	Caesalpiniaceae	*Senna holosericea* (Fresen.) Greuter	Chamaephyte	Subshrub
27.	Caesalpiniaceae	*Senna italica* Mill.	Chamaephyte	Subshrub
28.	Capparidaceae	*Cadaba fruticosa (*L.) Druce	Phanerophyte	Shrub

Sr #	Family	Plant species	Life form	Habit
29.	Capparidaceae	*Capparis decidua* (Forsk.) Edgew.	Phanerophyte	Shrub
30.	Capparidaceae	*Capparis spinosa* L.	Phanerophyte	Sub-shrub
31.	Capparidaceae	*Cleome brachycarpa* Vahl ex DC.	Chamaephyte	Herb
32.	Capparidaceae	*Dipterygium glaucum* Dcne.	Phanerophyte	Subshrub
33.	Caryophyllaceae	*Spergularia marina* (L.) Bessler	Therophyte	Herb
34.	Chenopodiaceae	*Chenopodium album* L.	Therophyte	Herb
35.	Chenopodiaceae	*Chenopodium murale* L.	Therophyte	Herb
36.	Chenopodiaceae	*Chenopodium opulifolium* Schrader ex Koch & Ziz.	Therophyte	Herb
37.	Chenopodiaceae	*Salsola imbricata* Forsk.	Phanerophyte	Shrub
38.	Chenopodiaceae	*Suaeda fruticosa* Forsk. ex J.F.Gmelin	Phanerophyte	Shrub
39.	Convolvulaceae	*Convolvulus arvensis* L.	Therophyte	Climber
40.	Convolvulaceae	*Convolvulus prostratus* Forssk.	Chamaephyte	Herb
41.	Convolvulaceae	*Merremia aegyptia* (L.) Urban	Therophyte	Climber
42.	Cucurbitaceae	*Cucumis melo* L. var *agrestis* Naud.	Chamaephyte	Climber
43.	Cucurbitaceae	*Mukia maderaspatana* (L.) M.J. Roem.	Chamaephyte	Climber
44.	Cyperacea	*Bolboschoenus affinis* (Roth) Drobov	Cryptophyte	Sedge
45.	Cyperaceae	*Bolboschoenus glaucus* (L.) S.G. Smith	Cryptophyte	Sedge
46.	Cyperacea	*Cyperus longus* L.	Hemicryptophyte	Sedge
47.	Cyperacea	*Cyperus rotundus* L.	Hemicryptophyte	Sedge
48.	Cyperaceae	*Schoenoplectus litoralis* (Schrad.) Palla	Cryptophyte	Sedge
49.	Euphorbiaceae	*Euphorbia helioscopia* L.	Therophyte	Herb
50.	Euphorbiaceae	*Euphorbia prostrata* Ait.	Therophyte	Herb
51.	Euphorbiaceae	*Euphorbia serpens* Kunth	Therophyte	Herb
52.	Euphorbiaceae	*Phyllanthus fraternus* Webster	Therophyte	Herb
53.	Euphorbiaceae	*Phyllanthus maderaspatensis* L.	Therophyte	Herb
54.	Euphorbiaceae	*Phyllanthus reticulatus* Poir.	Phanerophyte	Shrub
55.	Fabaceae	*Alhagi maurorum* Medic.	Phanerophyte	Subshrub
56.	Fabaceae	*Alysicarpus longifolius* (Rottl. ex Spreng.) Wight & Arnott.	Chaemophyte	Shrub
57.	Fabaceae	*Alysicarpus ovalifolius* (Schumach.) J.Leonard	Phanerophyte	Shrub
58.	Fabaceae	*Cyamopsis tetragonoloba* (L.) Taub.	Therophyte	Herb
59.	Fabaceae	*Melilotus alba* Desr.	Therophyte	Herb
60.	Fabaceae	*Melilotus indica* (L.) All.	Therophyte	Herb
61.	Fabaceae	*Rhynchosia minima* (L.) DC.	Chamaephyte	Climber
62.	Fabaceae	*Vicia sativa* L.	Therophyte	Herb
63.	Malvaceae	*Abutilon bidentatum* A. Rich	Phanerophyte	Subshrub
64.	Malvaceae	*Abutilon indicum* (Linn.) Sweet	Phanerophyte	Subshrub
65.	Malvaceae	*Abutilon theophrastii* Medic.	Phanerophyte	Subshrub
66.	Malvaceae	*Hibiscus lobatus* (Murr.) O. Kuntze	Chamaephyte	Herb
67.	Malvaceae	*Pavonia arabica* Hochst. ex Steud.	Chamaephyte	Herb
68.	Marsiliaceae	*Marsilia minuta* L.	Hydrophyte/Fern	Herb
69.	Menispermaceae	*Cocculus hirsutus* (L.) Diels	Phanerophyte	Vine
70.	Mimosaceae	*Acacia nilotica* Delile	Phanerophyte	Tree
71.	Mimosaceae	*Prosopis cineraria*(Linn.) Druce.	Phanerophyte	Tree
72.	Mimosaceae	*Prosopis glandulosa* Torr.	Phanerophyte	Shrub

Sr #	Family	Plant species	Life form	Habit
73.	Mimosaceae	*Prosopis juliflora* Swartz	Phanerophyte	Shrub
74.	Molluginaceae	*Glinus lotoides* L.	Therophyte	Herb
75.	Nyctaginaceae	*Boerhavia procumbens* Banks & Roxb.	Cryptophyte	Herb
76.	Poaceae	*Aeluropus lagopoides* (L.) Trin. ex Thw.	Therophyte	Grass
77.	Poaceae	*Brachiara ramosa* (L.) Stapf	Therophyte	Herb
78.	Poaceae	*Brachiaria reptans* (L.) Gard.	Therophyte	Grass
79.	Poaceae	*Cynodon dactylon* (L.) Pers.	Hemicryptophyte	Grass
80.	Poaceae	*Dactyloctenium aegyptium* (L.) Willd.	Therophyte	Grass
81.	Poaceae	*Desmostrachya bipinnata* (L.) Stapf	Cryptophyte	Grass
82.	Poaceae	*Dichanthium annulatum* (Forsk.) Stapf	Hemicryptophyte	Grass
83.	Poaceae	*Digitaria ciliaris* (Retz.) Koeler.	Therophyte	Grass
84.	Poaceae	*Diplachne fusca* (L.) P.Beauv. ex Roem & Schult.	Cryptophyte	Grass
85.	Poaceae	*Echinochloa colonum* (L.) Link	Therophyte	Grass
86.	Poaceae	*Echinochloa crus-galli* (L.) P.Beauv.	Hemicryptophyte	Grass
87.	Poaceae	*Echinochloa frumentacea* Link	Therophyte	Grass
88.	Poaceae	*Eleusine indica* (L.)Gaertn.	Therophyte	Grass
89.	Poaceae	*Eragrostis japonica* (Thunb.) Trin.	Therophyte	Grass
90.	Poaceae	*Eragrostis minor* Host.	Therophyte	Grass
91.	Poaceae	*Eriochloa procera* (Retz.) C. E. Hubbard	Therophyte	Grass
92.	Poaceae	*Hemarthria compressa* (Linn.f.) R. Br.	Hemicryptophyte	Grass
93.	Poaceae	*Phragmites karka* (Retz.) Trin.	Hemicryptophyte	Tall grass
94.	Poaceae	*Polypogon monspeliensis* (L.) Desf.	Therophyte	Grass
95.	Poaceae	*Saccharum benghalense* Retz.	Hemicryptophyte	Tall grass
96.	Poaceae	*Setaria verticillata* (L.) Beauv.	Therophyte	Grass
97.	Polygonaceae	*Polygonum effusum* Meisn	Therophyte	Herb
98.	Polygonaceae	*Polygonum plebejum* R. Br.	Therophyte	Herb
99.	Polygonaceae	*Rumex dentatus* L.	Therophyte	Herb
100.	Portulacaceae	*Portulaca oleracea* L.	Therophyte	Herb
101.	Resedaceae	*Ochradenus baccatus* Delile	Therophyte	Shrub
102.	Rhamnaceae	*Ziziphus nummularia* (Burm.f.) Wt.	Phanerophyte	Shrub
103.	Salvadoraceae	*Salvadora oleoides* Dcne.	Phanerophyte	Tree
104.	Salvadoraceae	*Salvadora persica* L.	Phanerophyte	Tree
105.	Scrophulariaceae	*Lindenbergia indica* (L.) Vatke	Therophyte	Herb
106.	Scrophulariaceae	*Verbascum thapsus L.*	Therophyte	Herb
107.	Solanaceae	*Nicotiana plumbaginifolia* Viv.	Therophyte	Herb
108.	Solanaceae	*Physalis peruviana* L.	Therophyte	Herb
109.	Solanaceae	*Solanum nigrum* L.	Therophyte	Herb
110.	Solanaceae	*Solanum surattense* Burm.f.	Therophyte	Herb
111.	Solanaceae	*Withania somnifera* (L.) Dunal	Phanerophyte	Shrub
112.	Tamaricaceae	*Tamarix aphylla* (L.) H. Karst.	Phanerophyte	Tree
113.	Tamaricaceae	*Tamarix indica* L.	Phanerophyte	Tree
114.	Tamaricaceae	*Tamarix kermanensis* Baum	Phanerophyte	Tree
115.	Tamaricaceae	*Tamarix pakistanica* Qaiser	Phanerophyte	Shrub
116.	Tiliaceae	*Corchorus aestuans* L.	Therophyte	Herb
117.	Tiliaceae	*Corchorus depressus* (L.) Stocks	Chamaephyte	Herb

Sr #	Family	Plant species	Life form	Habit
118.	Tiliaceae	*Corchorus olitorius* L.	Therophyte	Herb
119.	Tiliaceae	*Corchorus tridens* L.	Therophyte	Herb
120.	Tiliaceae	*Corchorus trilocularis* L.	Therophyte	Herb
121.	Zygophyllaceae	*Tribulus terrestris* L.	Therophyte	Herb
122.	Zygophyllaceae	*Zygophyllum simplex* L.	Therophyte	Herb



5.4.2 Two Ways Indicator Species Analysis (TWINSPAN)

The cover data were compiled using spreadsheet in Microsoft® Excel® programme. These values were then analyzed using software "*Two Ways Indicator Species Analysis (TWINSPAN*)". No phytosociolical data were recorded in 2006 to analyse through TWINSPAN. However, all these parameters were recorded in subsequent years of 2007 and 2008. A detail of the yearwise analysis is given in Annexure D – III. The results of the analysis are discussed below.

5.4.2.1 *Prosopis – Salvadora* Plant Community (2007)

Transects 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 represented this plant community. All these transect were located within forest area. The community was comprised of species like *Prosopis cineraria, P. juliflora* (Mimosaceae) and *Salvadora oleoides* (Salvadoraceae). The dominance of these species indicates that the edaphic and climatic conditions favour salt and drought tolerant species. Pai forest is represented by a single landform. It is comprised of a tropical thorn forest type (Champion *et al.* 1968). Dry matter forage production of this community varied from as low as 7.8 Kg/Ha to as high as 1318 Kg/ha. This huge variation is the result of moisture due to irrigation water in some areas that promoted growth of herbaceous flora and protection from grazing of livestock which is otherwise very high in most parts of the forest.

Figure 53 – Sites Represented By *Prosopis – Salvadora* Plant Community (2007)

5.4.2.2 *Suaeda – Tamarix* Plant Community (2007)

The aforementioned community was represented by transects 11, 12, 13 and 14. The species of this community were *Saueda fruticosa* (Family Chenopodiaceae) and *Tamarix pakistanica* (Family Tamaricaceae). These transects were located inland around the forest. Dominance of this community reveals that soil bears high salt contents which allow salt tolerant species only. Xerophytic and halophytic nature of species recorded shows the scarcity of soil moisture and high salt concentrations in the area. Dry Matter forage production of the sites represented by this plant community ranged from 0 to 1490 Kg/ Ha.

Figure 54 - Sites Represented By *Suaeda – Tamarix* Plant Community (2007)

5.4.2.3 *Prosopis juliflora – Prosopis cineraria – Salvadora oleoides* Plant Community (2008)

This plant community was represented by transects 6, 8, 12, 13, 15 and 16. The community represented highly drought tolerant species. Other associated species found over here were *Prosopis cineraria, Prosopis juliflora*, *Leptadenia pyrotechnica, Aerva javanica* and *Ochradenus baccatus. Capparis decidua, Desmostachya bipinnata, Prosopis cineraria, Salvadora oleoides,Tamarix indica, Ziziphus nummularia.* Forage production of these sites ranged from 165 to 1490 Kg/Ha.

Figure 55 – Sites Represented by *Prosopis juliflora – Prosopis cineraria – Salvadora oleoides* Plant Community (2008)

5.4.2.4 *Prosopis juliflora – Suaeda fruticosa – Eucalyptus* Plant Community (2008)

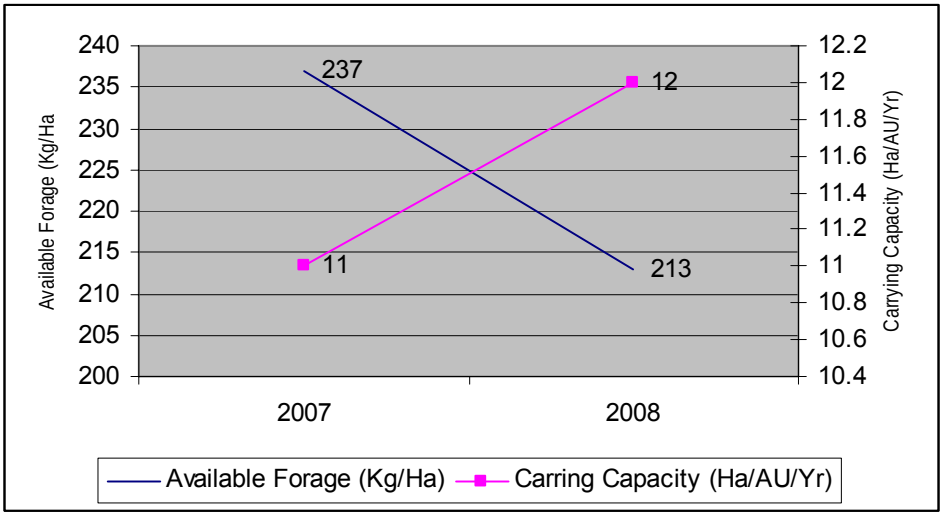
This plant community was represented by transects 3, 4, 5 and 17. Mostly salt tolerant plants represented this community. Other associated flora included *Desmostachya, Salvadora sp., Cadaba fruticosa, Capparis decidua, Desmostachya bipinnata, Prosopis cineraria, Prosopis juliflora, Salvadora oleoides, Salsola imbricata, Suaeda fruticosa* and *Tamarix aphylla.* Dry matter forage production varied from 175 to 250 Kg/Ha.

Figure 56 - *Prosopis juliflora – Suaeda fruticosa – Eucalyptus sp* Plant Community (2008)

5.4.3 Carrying Capacity

Carrying Capacity of Pai Forest was determined in terms of hectares per animal unit per year continuously for three years. Likewise other sites, forage production during 2008 was far less than the year 2007 (Annexure D – IV). The reason was early spring survey during 2008 when most of the herbaceous flora was absent (Figure 57). The study also revealed that the area is either over populated by wildlife or is over grazed by domestic livestock of surrounding areas. During the data collection process, it has been observed that there is limited number of wild animals whereas illegal grazing by surrounding communities is a common practice.

Figure 57 – Carrying Capacity of Grazing Areas in and Around Pai Forest



5.5 Discussion

The Pai forest is found to be floristically not very rich, particularly the ground flora is poor and sparse. This is characteristic of planted forests as compared to natural forests, the latter being much richer in biodiversity. The main tree species of the forest are *Prosopis cineraria, Eucalyptus camaldulensis, Acacia nilotica, Tamarix aphylla, Tamarix kermanensis, Tamarix indica, Salvadora oleoides,* and *Salvadora persica* along with heavy infestation by invasive species *Prosopis juliflora.* Among shrubs, *Capparis decidua, Cadaba fruticosa, Tamarix pakistanica, Salsola imbricata,* etc. are common. On the forest floor, *Suaeda fruticosa* and *Desmostachya bipinnata* are the commonest species with sporadic *Diplachne fusca, Cynodon dactylon, Bolboschoenus glaucus* etc. with *Cyperus longus, Cyperus rotundus, Schoenoplectus litoralis* and *Marsilia minuta* along water channels. Majority of the forest floor species is halophytic, indicative of saline conditions of soil. Although floristically Poaceae is the largest family at this site as well, like other sites, but the number of grass species is the lowest here as compared to other sites. Besides this, most of the 21 grass species of this site were collected from the cultivated fields in and around forest, while *Desmostachya bipinnata* was the most abundant species in the wooded area. A summary of the Phytosociological details showing transect-wise plant communities, associated plant species and forage production is provided in Annexure D – V.

The phytogeographical data show *Prosopis juliflora* to be overwhelmingly dominant species followed by *Prosopis cineraria, Salvadora oleoides, Suaeda fruticosa* and *Euclyptus camaldulensis.*

The primary productivity in terms of DMY and carrying capacity in terms of Ha/Au/Yr are quite low. The average carrying capacity in the 2008 survey was found to be even poorer than that of 2007 survey, indicating that the carrying capacity is particularly low in winter season. The most common species of forest floor is *Desmostachya bipinnata* which was found heavily grazed. This indicates a severe competition between livestock and wild herbivores in obtaining their food. The intense grazing also poses the danger of desertification.

5.5.1 Problems and Threats:

Pai forest being the only irrigated plantation in the area and surrounded by almost more than 25 villages of varying sizes is faced with a number of problems and threats. Some of the principal threats and problems are summarised below.

5.5.1.1 Scarcity of irrigation Water: Pai Forest has an allocation of sanctioned canal water of 30 cusecs which is sufficient for irrigating 1,212 ha of plantation. But out of sanctioned water, no irrigation water is generally received because the plantation is located at the tail end of the irrigation channel and the water channel has either been diverted by surrounding landlords or eroded away due to lack of proper maintenance. In order to overcome this problem, 13 tube wells have been installed inside the plantation at different times to irrigate the tree plantation. Presently, the plantation does not receive sanctioned water supplies and only regeneration areas and young crops are given water through tube wells. Due to scarcity of irrigation water, the plants are of low quality and give a dry look. Moreover, lack of canal water has put even the hardiest drought resistant tree species of *Prosopis cineraria* under severe stress.

5.5.1.2 Deforestation: Currently, this plantation is in miserable condition mainly due to uncontrolled massive wood cutting. Most of Kandi *(Prosopis cineraria)*, Lai (*Tamarix* spp.) and Khabbar *(Salvadora oleoides*) have been severally lopped and chopped. Wood cutting is observed throughout the plantation. This practice of illegal wood cutting is destroying soil cover and wildlife habitat.

5.5.1.3 Exotics & Invasive Species: Pai forest has some area under *Eucalyptus* trees that is highly water demanding on one hand and transpires huge amount of water, on the other thus creating more stressful conditions for the growth and survival of other tree species. Moreover, Mesquite (*Prosopis juliflora*) is forming a major community within the plantation and some areas have been infested severely. This species is an aggressive competitor and is replacing important indigenous species of the plantation.

5.5.1.4 Continuous Overgrazing: Due to heavy encroachments in riverine forests, the pressure of grazing has been shifted towards this plantation. Yearlong intensive grazing mostly by goats and large mammals is widely observed in the Pai forest. These animals harm the young seedlings while trampling the soil impedes further regeneration. Livestock also proved a direct competitor to Hog deer which is also facing feed shortage inside the forest and forced to go out in search of nutritious feed and thus commonly killed either by the dogs or by the traffic on national highway.

5.5.1.5 Encroachments: Neighbouring rural communities have encroached the land of Pai forest and brought under agriculture. There are a number of court cases under trial. Due to political influence of these encroachers, Sindh Forest Department seems helpless in spite of its concerted efforts for recovery of its land. Such encroachments not only weaken the writ of Forest Department but also encourage others to adopt similar illegal approach. The extent of encroachment could be well-visualised by the nearby Mari Riverine, Mehrabpur, Mario Lakho Bela, Jaryo Keti forests where most of the state-owned area has been grabbed by the encroachers. These encroachments encompass more than 20 thousands acres of forestland (personal communication).

5.5.1.6 Degraded Wildlife Habitat: Pai forest is a Game Reserve because of the good population of Grey partridges and Hog deer. By looking at the monoculture of core area, one wonders how it could be called a Hog deer habitat. This area not only lacks any natural herbaceous flora on which Hog deer can survive but also does not have irrigation water. Due to encroachments in the riverine forests the animals use this area for shelter and breeding purposes and go outside in private agricultural areas to meet their feed requirements. Frequent movement of Hog deer to outside area makes them more vulnerable to external threats. For example, last year death of one Hog deer has been reported due to capturing by the local farmers. In addition, it has also been reported that two Hog deer were found killed in road accident on National Highway. Under such stressful conditions survival and reproduction of Hog deer is affected severally.

5.5.1.7 Dichotomy in Management: This plantation is being managed by Sindh Forest Department for the conservation and production of timber. On the contrary, this plantation has been declared a Game Reserve, therefore, the Sindh Wildlife Department is responsible for the protection and hunting of the game animals. It has been observed that the forest department has not succeeded in obtaining the sanctioned canal water supply for the plantation and recovery of land from encroachers. Being a core habitat of Hog deer, the Pai forest must have a variety of herbs, forbs and palatable grass species in addition to trees and shrubs within the area. Planting of *Eucalyptus* and *Acacia nilotica* at a spacing of 6 x 6 feet is not helpful for wildlife habitat. A dense canopy generally does not permit under storey of shrubs, herbs, forbs and grasses to persist thus putting the wild herbivores under severe stress of feed shortage. This situation is creating complexity in attaining the two contrasting objectives from the same forest ecosystem, *i.e.,* a wildlife habitat for a Game Reserve and a commercial forest.

5.5.1.8 Excessive Use of Chemicals on Agricultural Crops: The surrounding areas of Pai forest are mostly under agriculture. The main cash crop of the area is cotton. It requires heavy pesticide sprays during different stages of growth. Hog deer and bird fauna especially partridges visit surrounding agriculture fields for their food requirements. By consuming lethal pesticides sprayed on the cotton crop along with associated herbs, grasses and insects, the wildlife is under severe threat of mortality. Although the department has adopted a good practice of raising organic cotton and fodder crops within the plantation yet there is need that the adjacent farmers are motivated either not to spray hazardous chemicals on the crops or they should opt for biodegradable pesticides such as Neemokill which is less harmful as compared with inorganic pesticides.

5.5.2 Suggestions for Improvement:

Pai forest provides abode to the only remaining population of Hog deer in lower Indus and it is the only intact and healthy forest ecosystem left so far in lower Indus. It is heartening to note that many educated people in the neighbourhood also want that this ecosystem should stay healthy and maintained on scientific grounds. Based on the team's feedback from concerned government officials, community members and other important stakeholders, following suggestions are put forth for the improvement of this important forest ecosystem.

5.5.2.1 Participatory Management Approach: Since there is tremendous pressure of neighbouring communities on this forest for want of fuel wood and fodder, there is a need that both Forest and Wildlife Departments should involve these communities in a co-management regime where certain benefits should go to the communities in lieu of their assistance in conservation. These include the following.

- **Erection of Entry Gate and Collection of Entry Fee:** Pai forest is situated right at the national highway and provides excellent opportunities not only to the population of neighbouring cities like Nawabshah and Sakrand but also others from various parts of the province and the country to visit this beautiful Protected Area. Due to absence of any proper promotional campaign very few people know about this forest. It is imperative that a properly designed entry gate should be erected and a certain amount should be decided as entry fee. Local Community-based Organisation should be made responsible to collect the entry fee of which 80% should be retained by the CBO while 20% should go to the Forest Department for administrative charges. This arrangement would also provide incentive to the communities to help the department for conserving this forest ecosystem.

- **Tourist Facilities Inside the Forest:** To manage a forest in a way to share its benefits to the people at large and also to generate income sources for the department and the neighbouring communities, a well-thought-out management plan is pre-requisite. Such management plan must include *inter alia* a proper signage scheme, development of Information Centre (jointly managed and run by the concerned CBO), bird hides for bird watching, well-designed lecture places for the visitors, promotional material, camping sites, picnic spots, activity areas and a modest tuck shop etc. Such arrangements would not only generate income but will also attract large number of school children and tourists. These measures will certainly promote goodwill for the Forest and Wildlife departments, as well. Care is required that such recreational area should be confined to certain pre-allocated part of the forest so that other areas are not disturbed

5.5.2.2 Alternate Energy Sources: To address the fuel wood requirements of neighbouring communities other avenues must be explored such as initiation of dialogue with Sui Southern Gas to provide natural gas connection to at least big villages. Another option could be to raise energy plantations at the riverside encroached Belas and Mari Riverine forest area which is totally devoid of trees and area has been leased out to farming community. Energy plantation on these areas would be successful if local communities are involved in watch and ward, planting and after-care operations under a scheme of wood sharing on 6-year rotation. This could be worked out involving Nazims of concerned Union Councils and Forest Department.

5.5.2.3 Fencing of Game Reserve: As discussed earlier in the preceding text, Pai forest has enormous pressure of encroachments and illegal wood cutting and grazing. Hog deer also go outside the forest in search of food. To overcome these problems, the entire forest needs to be fenced all around.

5.5.2.4 Watering and Feed Resource Development: There should be watering points at suitable places for Hog deer along with forage and fodder reserves. The core habitat of the Hog deer should not have access to anybody except the concerned staff to ensure undisturbed breeding ground for these animals.

5.5.2.5 Re-construction of Hog deer habitat: Hog deer require a specialised habitat to thrive. This includes marshy area, thickets of *Tamarix* and *Saccharum* species with openings. To ensure persistence of good population of this animal, such habitat should be re-constructed along with promotion of highly palatable grasses like *Cynodon dactylon, Cenchrus ciliaris, Ochthochloa compressa, Aristida* spp. Reseeding of such species should be part of the operational plan of the Game Reserve.

5.5.2.6 Restoration of Sanctioned Irrigation Water Supply: In consultation with the irrigation department and the community activists, the sanctioned amount of water should be made available to the forest by renovating the damaged irrigation channel with a regular plan of its maintenance.

5.6 Conclusions

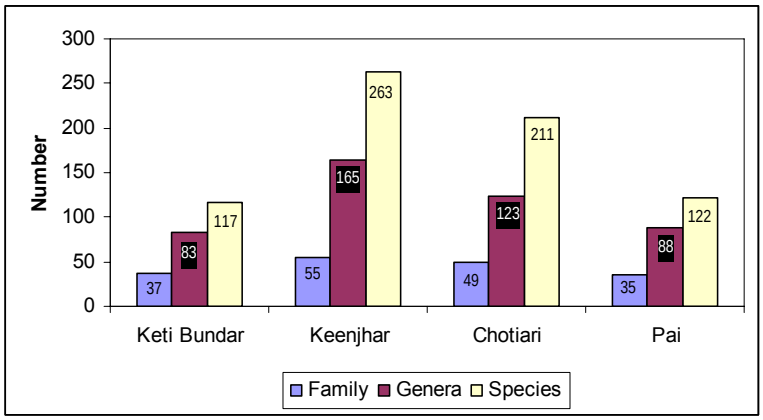
Pai forest is the only large forest of its type in the area, however, it requires much concerted efforts for its management. The floral diversity is low with respect to palatable grasses, herbs and shrubs because of severe shortage of irrigation water. Salinity level in the soil is on the increase due to the shortage of irrigation water which will further decrease the floral diversity. Immediate rehabilitation measures like restoration of irrigation water, control over encroachments, overgrazing, replacement of exotic species (like *Eucalyptus,* mesquite etc.) by introducing local fodder species and reseeding of palatable grasses is needed. Moreover, a participatory management approach is required whereby local communities are involved in conservation efforts on one hand and to generate their livelihoods on the other. To ensure such approach, a well planned management plan is required in which interventions like eco-tourism, recovery of sanctioned water, re-construction of Hog deer habitat, fencing of Pai forest, raising of energy plantation and establishment of an Information Centre should be crucial interventions.

6 - General Results and Discussion

6.1 Floristic analysis:

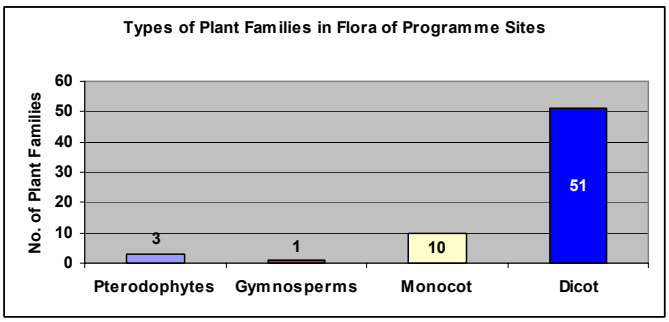
After three years survey, Keenjhar Lake comes out to be the richest site for plant biodiversity with a total of 263 species, followed by Chotiari Wetland Complex (211 Spp.), Pai forest (122 Spp.) and lowest in Keti Bundar (117 Spp). In fact this pattern is persisting since the beginning of the study till now (Annexure F – III & G - I). Overall picture of the flora on each site is given below in Figure 58.

Figure 58 – Overall Profile of Flora over Programme Sites



The major components of the flora are Dicotyledonous Angiosperms followed by Monocotyledonous Angiosperms while Pteridophytes are represented by only three species and Gymnosperms by only one species. The extremely scanty representation of the later two groups is in conformity to the arid conditions of the region. The year-wise and site-wise comparison of the four groups is given in Figure 59 while the cumulative comparison of the number of their families, genera and species in different sites is given in Figures 60 & 61.

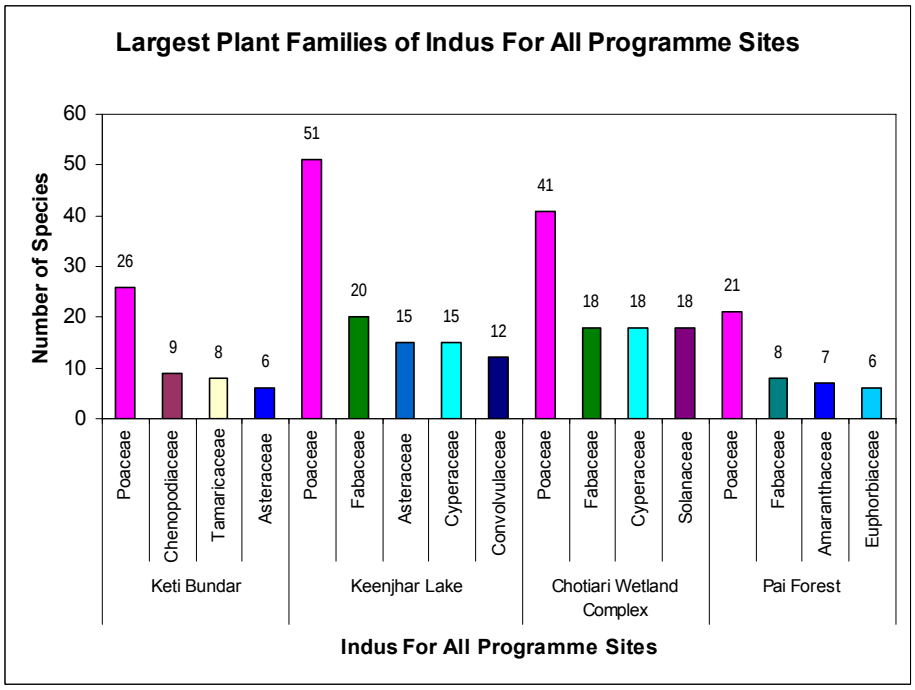
Figure 59 – Types of Plant Families in Programme Sites



The cumulative list of all the species of all sites is given in Annexure G-I. Poaceae is found to be the largest family with 36 genera and 68 species, followed by Fabaceae with 13 genera and 27 species, Cyperaceae with 6 genera and 22 species, Asteraceae with 12 genera and 17 species, Chenopodiaceae with 7 genera and 12 species, Convolvulaceae and Boraginaceae with 5 genera and 12 species each, and Solanaceae with 6 genera and 11 species. Other families are represented by less than 10 species per family. The site wise comparison of larger families is shown in Figure 60 and

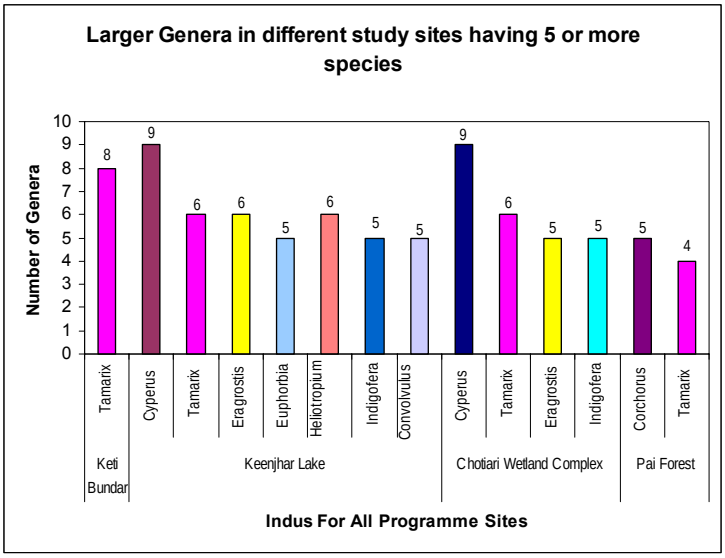
Annexure G - II which reveal Poaceae being invariably the largest in all sites, followed by Fabaceae in three sites, but in Keti Bundar Chenopodiaceae was the second largest.

Figure 60



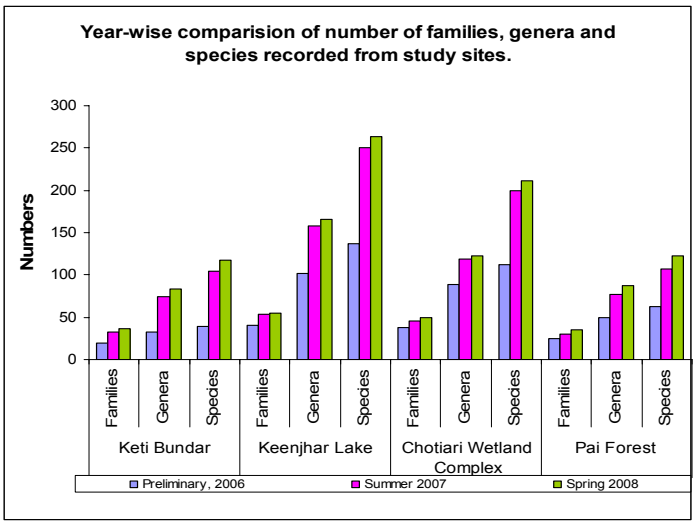
Among genera, *Cyperus* is found to be the largest genus with 12 species, followed by *Tamarix* with 11 species, *Eragrostis, Euphorbia* and *Heliotropium* each with 7 species. The comparison of larger genera of different sites is shown in Figure 61. Among the woody genera, *Tamarix* is the largest, with its richest diversity recorded in Keti Bundar where it is represented by 8 species.

Figure 61



The Keenjhar Lake site is not only the floristically richest site but it is also unique by having the highest number of such families and species which are not represented elsewhere in programme sites (G – IV and G – V). Seven dicots and four monocot families and total 70 species are exclusively recorded only from this site, not shared by any other site. The site-wise comparison of such families and species is given in Figure 62.

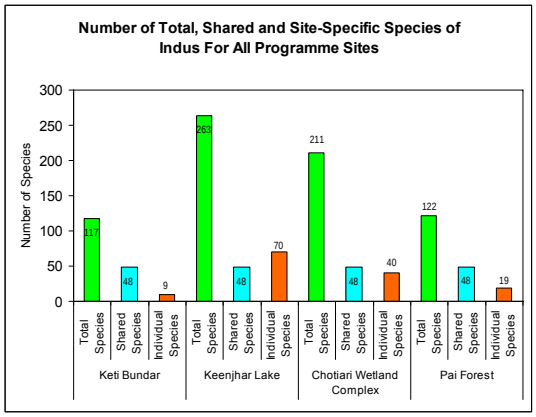
Figure 62 - Year wise Comparison of α -diversity in Programme sites



6.1.1 α, ß and γ Diversity (BD) and Similarity Index (CC):

As mentioned earlier, the highest value of α-diversity in terms of number of species is found in Keenjhar Lake with 263 species, followed by Chotiari wetland complex with 211 species, Pai forest with 122 species and Keti Bundar with 117 species. The over all number of species of all the four sites (γ-diversity) comes out to be 348 in 197 genera and 68 families. Year-wise comparison of Similarity Index (CC) and Beta diversity (BD) is given in Figure 63. Among locality pairs, Keenjhar and Chotiari have consistently shown the highest value of Similarity Index thus the lowest Beta diversity followed by Chotiari and Pai, while Keti and Chotiari have shown the least value of Similarity Index thus the highest value of Beta diversity. However, with each survey there has been overall increase in CC values and decrease in BD values, as with more adequate sampling the number of shared species has increased.

Figure 63 – Number of Total, Shared and Site-Specific Families



The overall ß - diversity of all the four sites was 2.715 in 2006 which came down to 1.95 after the 2008 survey (Table 22)

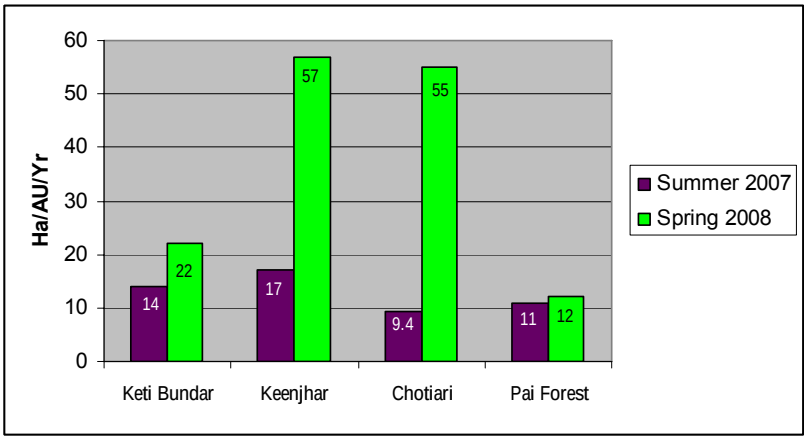
Table- 22: Similarity Index (CC) and β-diversity (BD) Three years comparison.

S. No	Locality pairs	2006			2007			2008		
		Shared species	CC	BD	Shared species	CC	BD	Shared species	CC	BD
1	Keti - Keenjhar	27	0.30	1.691	82	0.46	1.54	96	0.51	1.49
2	Keti - Chotiari	13	0.16	1.832	68	0.45	1.55	78	0.48	1.52
3	Keti – Pai	12	0.23	1.767	48	0.45	1.55	60	0.51	1.49
4	Keenjhar - Chotiari	57	0.45	1.548	145	0.65	1.35	162	0.68	1.32
5	Keenjhar - Pai	30	0.3	1.7	80	0.44	1.56	94	0.5	1.5
6	Chotiari – Pai	30	0.33	1.667	78	0.51	1.49	88	0.53	1.47
7	All four localities	8	-	2.715	42	-	2.15	48	-	1.95

6.2 Primary Productivity (Dry Matter Kg/Ha) and Carrying Capacity (Ha/AU/Yr)

Comparing Carrying capacity over the years of 2006, 2007 and 2008, Keenjhar Lake was outstanding among all the four sites followed by Chotiari and Keti Bundar. Pai Forest showed the lowest values mainly because of tree growth. Spring season markedly exhibited higher values mainly because of presence of annual flora which generally disappears during scorching heat of summer. It is evident from the Figure 64 that these values have shown year-wise fluctuations which are the usual pattern of arid lands. Archibald (1995) mentions that primary productivity in dry lands can vary between 0-1200 Kg/Ha/Yr depending upon the amount of rainfall received in a particular year. The average values are, however, in conformity with the usual average values of primary productivity in arid lands with less than 300mm annual rainfall (0-600 Kg/Ha/Yr) as given by Archibald (1995) for Sahara Desert. Due to low primary productivity, the carrying capacity of arid lands is also low, therefore increase in the number of livestock poses the risk of overgrazing and subsequent desertification.

Figure 64 - Carrying Capacity of Programme Sites in Two Different Seasons



6.3 Alien Invasive species:

Prosopis juliflora and *P. glandulosa* (native of tropical America) have invaded all the sites, exerting negative impact on the natural flora by out-competing it. *Prosopis juliflora* is in general more aggressive, forming pure populations by replacing indigenous flora; but in Keti Bundar *Prosopis glandulosa* was comparatively more frequent.

Among aquatic species serious threat is posed by notorious invasive species *Salvinia molesta* and *Eichhornia crassipes* in Keenjhar Lake and Chotiari water reservoir. Both these species are very aggressive, forming dense mats on water surface thus replacing indigenous floating plant species and cutting-off the light and oxygen supply for the submerged plant species, phytoplankton, and aquatic fauna. These mats may also pose problem in the movement of boats and also deprive the birds of their food by killing native plants, fish, and algae.

6.4 Significant findings:

Vegetation assessment carried out over three years and in three different seasons resulted in remarkable results by exploring and documenting three new species to the floral world (*Tamarix, Sporobolus, Fimbristylis*) and rediscovering a number of other species (Figure 65).

6.4.1 New Records

Figure 65. New Findings and Discoveries in Vegetation Assessment Programme

NEW RECORDS

S.#	Plant Family & Species	Description	Photograph
1	**Tamaricaceae** *Tamarix sp. Nov*	*Tamarix Sp. Nov.:* A new species of *Tamarix* is recorded from three sites, i.e., Keti Bundar, Keenjhar and Chotiari Wetland Complex. This species would be named and described Later.	
2	**Chenopodiaceae** *Chenopodium opulifolium*	This species is collected from the Pai Forest. It is the first record of this species from Pakistan	
3	**Euphorbiaceae** *Euphorbia helioscopia*	This species is collected from Pai Forest. It is a new record for the province of Sindh.	
4	**Papilionaceae** *Lotus kryloviі*	This delicate species with pretty pink and yellow flowers is collected from Shah Belo (Keti Shah, Sukkur Dist.) This is the first record of this rare species from the province of Sindh. Previously it was reported only from Chitral in Pakistan (Rechinger 1984).	
5	**Ranunculaceae** *Ranunculus scleratus*	This species was collected from Shah Belo. Previously only one specimen of this species was collected from Sindh (Shikarpur), as reported in Flora of Pakistan. It is collected after a gap of 50 years.	
6	**Rosaceae** *Potentilla henyii*	This species is collected from Shah Belo, this species was previously collected only once from Sindh (Shikarpur). It is collected after a gap of about 40 years. Flora of Pakistan mentions it as a rare species; however in the present study, this species was found to be fairly common on the wet soil exposed by the receding water of Indus river.	

NEW RECORDS

S.#	Plant Family & Species	Description	Photograph
7	**Tamaricaceae** *Tamarix sarenensis*	This rare endemic species was till now known only from its type locality, i.e. Saren Lake, Diplo in Tharparker District. In the present study it has been collected from Keti Bundar and Keenjhar Lake.	
8	**Tamaricaceae** *Tamarix cf. Szovitsiana*	This species mainly distributed in Nothern Iran, was till now reported only from Mastung (near Quetta) in Pakistan. In the Flora of Pakistan, it was mentioned as a rare species in Pakistan. Several specimens of this species have been collected from the road sides and fields periphery in the vicinity of Chotiari reservoir where it was fairly common. Phytogeographically this species belongs to Irano-Turanian region, and its occurrence in the hot and arid Saharo-Sindian region is quite unusual and interesting. These specimens are somewhat different from the typical *Tamarix szovitsiana*. Critical detailed studies would be made afterwards to determine their correct taxonomic position.	
9	**Poaceae** *Sporobolus sp*	One new species of *Sporobolus* has been collected from Keenjhar. This species will be named and described later.	
10	**Cyperaceae** *Fimbristylis sp*	A new species of *Fimbristylis* has been collected from Chotiari. This species will be named and described later.	
11	**Cyperaceae** *Pycreus dwarkensis*	This rare species is collected after a gap of more than 70 years. The only specimen of this species from Pakistan was collected by W. Koelz in 1934, and that specimen is presently in Kew Herbarium. According to Hooper (1985) the typical habitat of *Pycreus dwarkensis* is by studying water near the junction between desert and tropical or subtropical scrub vegetation zones. Likewise, this was also collected at water-margin of Keenjhar Lake at Daulatpur.	
12	**Tamaricaceae** *Tamarix sultani*	This species is endemic to southern Sindh. It is collected after a gap of more than 30 years.	
13	**Poaceae** *Haemarthria compressa*	This species is for the first time collected from Sindh province.	

6.4.2 Endemic species:

The Saharo-Sindian region is not rich in endemism as a vast majority of endemic species is confined to the Irano-Turanin region in the mountainous areas in north and north-western parts of Pakistan (Ali and Qaiser 1986). Nevertheless, about twenty endemic species and intra specific taxa are recognized from the Sindh province (Table 23 and Figure 66), of which 10 are confined to Sindh only while the other ten occur in some other parts of Pakistan, as well. Except for three species (*Atriplex stoksii, Pulicaria boissieri, Tamarix alii*), all others can be regarded as rare or vulnerable to even extinct.

Three endemic species of *Abutilon* are outright endangered in the province of Sindh, *Abutilon sepalum* being at the brink of extinction. Most of the specimens of these species from Sindh had been collected from Karachi, and Karachi University Campus in particular. In case of *Abutilon alii* and *Abutilon karachianum* even the type specimens were from Karachi University Campus, while all specimens of *Abutilon sepalum* were from Karachi University Campus and nearby PCSIR, except for one specimen from Thatta district. About one and a half decade back, the administration of Karachi University took up the task of removing all wild plants from the University premises to "Clean" the campus. Since then all natural flora is routinely destroyed with tractor blade, hatchets, shovels and even fire. Any regeneration of natural vegetation after rains is promptly removed. In this scenario, the above mentioned species have not been witnessed for the past several years along with scores of others, except for *Abutilon sepalum* which is still sporadically found but continuously becoming rarer with the passage of time. Any better situation may not be expected for other parts of Karachi either in the face of rampant habitat destruction. Since *Abutilon alii* and *Abutilon karachianum* have a distribution up to Lasbela district in Balochistan, it may be hoped that they would be existing there, but the eradication of *Abutilon sepalum* from Karachi would mean its total extinction. Another threatened taxon is *Acacia nilotica* subsp*. hemispherica.* This subspecies is distributed on a few square kilometre area in the Paradise Point area of Karachi. This area is increasingly being disturbed by mining of stones, gravel and sand resulting in habitat destruction of this rare subspecies.

Two species of *Asparagus* described by Blatter in Flora of Indus delta (Blatter *et al.* 1929) have not been collected in past several decades, therefore, they may be considered as extinct.

Figure 66. Endemic Plants of Sindh

ENDEMIC SPECIES OF SINDH

S.#	Plant Family & Species	Description	Photograph
1	**Acanthaceae** *Justicia vahlii* subsp. *scindica* Malik & Ghafoor	It is very rare species only collected form Karachi and Dadu District (Thana Bula Khan)	
2	**Malvaceae** *Abutilon sepalum* Husain & Baquar	It is endangered species which is found only in Karachi Division and Thatta District. This species is still sporadically found but continuously becoming rarer with the passage of time.	
3	**Malvaceae** *Pavonia glechomaefolia* f. *karachiensis* Abedin	It is very rare species only collected form Karachi	
4	**Mimosaceae** *Acacia nilotica* subsp. *hemispherica* Ali & Faruqi	According to the conservation status of this species it is ranked as Vulnerable/ threatened species. This sub-species is distributed on a few square Kilometers in the Paradise Point area of Karachi. This area is increasingly being disturbed by mining of stones, gravel and sand resulting in habitat destruction of this rare sub-species.	
5	**Tamaricaceae** *Tamarix sarsnensis*	This rare endemic species was known only from its type locality, i.e., Saren Lake, Diplo in Tharparker District. In the present study it has been collected this species from Keti Bundar and Keenjhar Lake.	
6	**Tamaricaceae** *Tamarix sultanii*	This species is endemic to southern Sindh. It is collected after a gap of more than 30 years.	
7	**Tamaricaceae** *Tamarix salina* Dyer	Conservation status of this species is still not known. The species have been collected only form Khairpur MirpurKhas, Sukkur, and Karachi	
8	**Tiliaceae** *Corchorus pseudo-olitorius* Islam & Zaid	It is a rare/vulnerable species which have been collected only from Karachi and Hyderababad Districts.	
9	**Asparagaceae** *Asparagus deltae* Blatter	The species was described by Blatter in Flora of Indus Delta (Blatter *et al.* 1929). It has not been collected in the past several decades, therefore, it may be considered as extinct. This species was only collected form Thatta District (Ghulam Ullah)	
10	**Asparagaceae** *Asparagus gharoensis* Blatter	The species was described by Blatter in Flora of Indus Delta (Blatter et al. 1929). It has not been collected in the past several decades therefore they may be considered as extinct. This species was earlier collected form Southern Sindh.	

Table-23: Endemic species found in the province of Sindh.

S.No	Species with family	Distribution	Conservation status
	Dicots:		
	Burseraceae		
1	*Commiphora stocksiana* (Engl.) Engl.	Lasbela District, Karachi Division, Thatta and Sangarh Districts.	Rare
	Chenopodiaceae		
2	*Atriplex stocksii* Boiss.	Coastal areas of Sindh and Balochistan.	Fairly common
	Compositae		
3	*Pulicaria boisseri* Hook.f.	Sindh, southern Balochistan, Punjab	Fairly common
	Convolvulaceae		
4	*Convolvulus scindicus* Stocks	Balochistan (Sibi) and Sindh (Dadu and Thatta Districts)	Rare
	Malvaceae		
5	*Abutilon alii* Abedin	Karachi Division and Lasbela District	Endangered
6	*Abutilon karachianum* Husain & Baquar	Karachi Division and Lasbela District	Endangered
7	*Hibiscus scindicus* Stocks	Sindh and southern Balochistan	Rare
8	*Sida spinosa* var. *kazmii* Abedin	Sindh and souterhn Punjab	Not known
	Tamaricaceae		
9	*Tamarix alii* Qaiser	Southern Sindh (Karachi, Thatta Dist. Nagar Parker) Coastal parts of Balochistan.	Fairly common
	Monocots:		
	Asparagaceae		
10	*Asparagus dumosus* Baker	Coastal areas of Sindh and Balochistan.	Vulnerable

6.5 Soil Analysis:

Almost five composite soil samples from each of the four programme sites were subjejected to analysis. The results (Annexure H -1 and H – 2) revealed that almost all the soils in study areas are either sandy loam or loamy in texture with pH ranging from 7.4 to 7.8 for Keenjhar, 8 to 8.4 for Pai Forest, 7.8 to 8.5 for Chotiari and 7.9 to 8.2 for Keti Bundar exhibiting slightly alkaline to alkaline soils all over the Programme sites except Keenjhar where the soils fall in normal category (Annex I –I). All sites were found deficient in organic matter contents except that of Keenjhar lake where three out of five samples showed adequate organic matter. EC was found alarmingly high in Keti Bundar soils showing hyper saline conditions while rest of the sites exhibited almost normal conditions. Phosphorus was found mostly in satisfactory range all over the sites, however, Keti Bundar samples reflected adequate Phosphorus while almost similar patter was observed for Potassium.

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Our Mission

WWF - Pakistan aims to conserve nature and ecological processes by:

- Preserving genetic, species and ecosystem diversity
- Ensuring that the use of renewable natural resources is sustainable, both now and in the longer term
- Promoting actions to reduce pollution and the wasteful exploitation and consumption of resources and energy

Vision of the Indus Ecoregion Programme

"Mankind coexists with nature in complete harmony and biodiversity flourishes in its respective habitat"

Indus for All Programme, WWF - Pakistan
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via P.O. Mirpur Sakro,
District Thatta, Sindh.
Tel: 0298-620406, 610976, 619

Keenjhar Lake
House # B/112,
Hashimabad Society Makli,
District Thatta, Sindh.
Tel: 0298-772318, 772319, 610426

Pai Forest
House # A-3, M.U.C.E.T. Employees
Co-operative Housing Society,
District Nawabshah, Sindh.
Tel: 0244-366364, Fax: 0244-282496