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1 PRESSURE

Kachchh district is a crescent shaped peninsula located on the western part of Gujarat State in India. It falls under the arid zone and is poorly endowed in terms of its ecosystem ecology, as about 23,310 km² (51%) area is covered by saline deserts (Greater and Little Ranns) along the northern and eastern part of the district and the main land area comprises of 22,342 km² (GUIDE 2007).

In arid ecosystems, vegetation is sparsely distributed, resulting in a heterogeneous horizontal pattern of vegetation patches alternating with areas of bare soil (Noy-Meir 1973). The distribution of rain in arid regions is extremely patchy and the primary production of the region corresponds directly to the rainfall (Rutherford 1980, Le Houerou 1984). Nevertheless, the distribution of rainwater on the ground depends, on the total amount of rain, on topography and runoff (Ludwig 1986), thus affecting the primary production, which subsequently leads to loss of ecosystem functions and its degradation. Rann of Kachchh is not an exemption to this.

1.1 Desertification in Rann & Its Environs

Desertification, as defined by UNEP in 1992 and adopted by United Nations Convention to Combat Desertification (UNCCD), is ‘land degradation in arid, semiarid and dry sub-humid areas resulting from various factors, including climatic variations and human activities’. In another words “Desertification is best to be treated as an extreme case of land degradation, which is expressed in a persistent reduction or loss of biological and economic productivity of lands that are under various uses by human whose livelihoods depend on this productivity, yet the reduction or loss of this productivity is driven by that use” (Vogt et al., 2009).

Desertification is more severe in drylands that encompasses an area of about 41% of Earth’s land surface and are inhabited by more than 2 billion people. The arid, semi-arid and dry sub humid regions (those regions where the ratio of the mean annual precipitation to the mean annual evapo-transpiration is in the range of 0.05 to 0.65, are collectively termed as drylands where soil moisture is limited by low rainfall and high evaporation. In India, about 50.8 mha land area (15.8% of the country’s geographical area) is arid, 123.4 mha (37.6%) is semi-arid and 54.1 mha (16.5%) areas falls in the dry sub-humid region. All together, about 228 mha area, i.e. 69% of the geographic area of the country is under drylands (MoEF, 2001). The dominant processes of land degradation
are water erosion, vegetal degradation, wind erosion, salinization/alkalization, water logging, etc. (Ajai et al. 2009), while the causes of desertification are change in frequency and amount of rainfall, reduction in vegetal cover, erratic agricultural management practices, cultivation on marginal lands, over-exploitation of the natural resources, excessive grazing, etc.

According to the ‘Desertification and Land Degradation Atlas of India’ (2007), about 68% of the Gujarat state is facing land degradation and desertification which is highest among the states of the country. In Gujarat, 65% area is experiencing desertification due to climatic factors and 35% area is undergoing human induced desertification processes. Among the factors responsible for desertification, water erosion contributes 35%, followed by salinization (14%), vegetation degradation (14%) and wind erosion (3%) in the state (SAC, 2007). The districts located along the periphery of the Rann of Kachchh are drought prone areas where climate is a major factor for land degradation. Salinization is another factor for desertification in some areas around Rann (Mudrakartha, 2007).

Desertification in agricultural land is spreading rapidly which is a grave problem, especially along the peripheral areas of Rann. Little Rann of Kachchh is also experiencing desertification due to water erosion, salinization and vegetal decline. Nevertheless, the outdated farming techniques and changing weather patterns such as flash floods in monsoon are also compounding the effects (‘Lilorann: The Pilot’, 2011).

The desertification in Kachchh is mainly the result of:

- Increase in population of both humans and livestock
- Mobility of saline dust from the broken and cracked coastal area
- Movement of salt particles due to high velocity of the wind during summer
- Increased salinity due to intrusion of saline water in fertile areas during the rainy season.

India occupies only 2.4% of the world’s geographical area to support 16.7% of the world’s human population; it has only 0.5% of the world’s grazing land but supports 18% of the world’s cattle population (MEA, 2005). The human population of the Kachchh region is very meager (density 35/km²) as compared to the population density of the country (density 312/km²), however, the region supports good population of livestock. The spatial pattern of land degradation in Kachchh
region including the Rann is very complex, but broadly severe and very severe erosion occur in the hilly terrain, while moderate erosion takes place in the coastal plains and some colluvial plains. Approximately 32% area of Kachchh experiences erosion problems, of which, 17.1% area is affected by very severe water erosion followed by 9.9% area under severe erosion and 5.2% under moderate erosion. Further, 65% area of the Kachchh faces various magnitudes of salinity problems, of which, 57.2% area is affected by very severe salinity problems (Kar and Singh, 2003). Much of the land degradation in Kachchh Region is primarily related to the natural causes, largely due to the periodic tectonic activities and partly due to the past changes of climate (especially in case of the relict mudflats and Ranns that emerged out of the sea due to the recession of the Arabian Sea). Human activities are only assisting in the aggravation of the degradation processes in some localities of the Kachchh (Kar and Singh, 2003).

The adjoining areas of LRK and eastern part of GRK received maximum rainfall during the last decade. Interestingly, rain fed agriculture decreased while irrigated crops (cash crops) notably increased in last three decades. Further, livestock population has increased in adjoining areas of Rann leading to more pressure on vegetation, and consequently land degradation. Overall, the talukas adjoining the Rann are facing high environmental risk leading to desertification, whereas the talukas towards coastal area face minimum environmental risk (GUIDE, 2011).

1.2 Environmental Concern in Rann

Rann is a specific kind of landscape surrounded by arid and semi-arid environment. Naturally, it is a high saline marshy land where seasonal water logging provides habitat for some unique types of biodiversity. Except the salt farming and tourism, there is no other specific linkage between human population and Rann. In general, the problems of Rann environment are mainly due to developmental initiatives like construction of roads and bunds which could block the natural flow of sea and fresh water into the Rann. The fringe areas of Rann are facing threats by overgrazing, increasing vehicular traffic, intensive salt farming, industrialization which cumulatively cause some extant of changes to the fragile ecosystem. The above activities result in disturbances to the unique wildlife, especially to the wild ass, floricans, bustards, flamingoes, pelicans, and other bird species (WII, 1993). During the past years, there is an increase in the conflict between Asiatic Wild Ass and local agro-pastoral communities around LRK. Cutting of trees on large scale to make charcoal is also an emerging issue in the adjoining areas of Rann.
1.2.1 Threats to Biodiversity in LRK

In Rann environment various types of threats have been identified from species level to the habitat level. The vast stretch of the shallow water bodies of Rann provides an important breeding and feeding ground for large number of bird species. Moreover, LRK is the only habitat for Asiatic Wild Ass. The infra-structural development in Rann and adjoining environment, increasing vehicular traffic and intensive salt farming cause degradation and fragmentation of habitat which is a threat to native biodiversity. The envisaged threats to Rann include:

a) Landuse study revealed that agricultural cultivation has increased by 0.63% (about 2,410 ha agriculture land from 1999 to 2009)(BCRLIP, 2007). Intensive agriculture practice has been undertaken due to availability of water from Narmada canal and watershed development programmes. It will cause changes in the landuse/land cover pattern. Because of the increased use of chemical fertilizers and pesticides, Rann will be the ultimate sink to receive all the residues of chemicals and pesticides from upstream agricultural farms which can lead to a bio-magnification in fish, prawns and aquatic birds.

b) Spreading of *Prosopis juliflora* (33 % of Bet areas and 8 % of total WAS area) were observed to be invaded by *Prosopis* (GEER, 1995) poses problems to Wild Ass and Chinkara by reducing their grazing ground and fodder.

c) Spread of diseases from domestic livestock to wild animal through use of common drinking water bodies and grazing land.

1.2.2 Wild Ass – Human Conflict

In a span of about 30 years from the first census by the Forest Department in 1976, Wild Ass population has increased from 720 to 3863. The increasing population has established its abode in adjoining habitat of Wild Ass Sanctuary. Interestingly, the concentration of Wild Ass in the WAS has been highest in the southern and eastern zones, where highest concentration of salt farming works is going on (BCRLIP, 2007).

Since Rann landscape is saline and remains submerged during monsoon and early winter months, few of the Wild Ass population moves to the surrounding agricultural landscape (Dave, 2010). Such seasonal migration in agricultural field results crop raiding, which cause conflict between Wild Ass and agro-pastoral communities. The crop raiding issues have recently increased because field results crop raiding, which causes conflict between Wild Ass and agro-pastoral use of natural dispersal of increasing populations into adjacent agriculture landscape (Shah, 2004 and Singh,
Although several efforts were made to estimate wild ass population in LRK (Ali, 1946; Gee, 1963; shah, 1993; Singh et al, 1999), issues related to quantification and mitigation of human-wildlife conflicts have not been addressed comprehensively. In addition to Wild Ass, other wild herbivores like Nilgai, Chinkara and Wild boar are also causing damage to the crops in agriculture lands. Such crop damage subsequently causes antagonism of local community towards large herbivores. According to Dave (2010), the invasion of Prosopis juliflora in the fringe areas of LRK causes increase in crop raiding by wild herbivore, as P. juliflora provides shelter to them and the nearby agricultural fields provide food for them.

1.2.3 Environmental Issues in GRK

a) A large portion of the Rann is rather inaccessible during the monsoon, while certain areas are not accessible throughout the year (Merh and Malik, 1999).
b) The evaporation rate is very high.
c) The inundation of Linear Trench Zone is caused mainly by saline water.
d) The flat topography of Rann proper makes it impossible to create suitable out-fall conditions for drainage.
e) Less/ no possibility of exploring productive ground water in the Rann area.
f) Excess Sodium concentration results in alkali soils in which reclamation is difficult.
g) Lack of up-to-date scientific information.

1.2.4 Recent Incident in Flamingo City

In a recent incident in GRK near Khadir Island, hundreds of flamingoes died accidently due to high tension electric wires passing over their feeding grounds (Times of India, 2011; Tere & Parasharya, 2011; Palliwal, 2011). Flamingos are highly sensitive to even small disturbances. A passing vehicle or even a flipping fish can create a flutter in the flamingo colonies which sometimes leads to collision with power cables before visualizing and avoiding it. Officials have attached radium tags on the high tension wires which act as reflectors during the day and night to repel the birds. The forest department has taken initiatives with the state electricity board for underground cables in bird sensitive areas.

1.3 Salt Pans and Issues of Agariyas in Little Rann of Kachchh

Intensive salt production is carried out in LRK contributing to a major salt requirement of the country. The local community around LRK known as “Agariyas” works as salt pan workers. Since there is a
paucity of other employment opportunities due to socio-economic backwardness, scarce water, fragile natural resource and poor conditions of land for agriculture, salt pan provide livelihood options to many local villagers around LRK.

In the year 1993, ‘Dhangadhra Prakruti Mandal’ and ‘Gondal Forest Youth club’ jointly filed public interest litigation. As a follow up action, the Government of Gujarat had initiated an Ecological Study of the LRK through GEER Foundation. Based on the recommendations, initiatives were taken for demarcating salt zones for salt production within the Sanctuary areas.

The land area of Ranns belong to the Government of Gujarat and till date times it has been administered by five adjoining district collectors – Surendranagar, Patan, Banaskantha, Kachchh and Rajkot. Though administratively managed by five different collectors, this vast land mass has never been surveyed. Thus, the land lease given for the salt making in the Rann has never had any specific location or proper survey number like other revenue areas (Sandarbh, 2008).

1.4 Wild Ass Sanctuary and Related Issues

The Wild Ass Sanctuary presents a very unique place. The core area of the sanctuary has two distinct phases; dry and wet. These two phases support two distinct modes of livelihood options; salt production and prawn fishery. The Wild Ass, a globally threatened species, uses entire area of Rann and bets for foraging and breeding purpose. Currently, wildlife conservation and rural livelihood in the landscape are overlapping each other in many ways. There are a few important livelihood issues related to wildlife and sanctuary which includes:

- The incidence of crop raiding by wild animals (mainly wild ass, blue bull and wild boars) along the periphery of the sanctuary and killing of sheep and goats by wolves are increasing and almost touching the threshold level.
- No or very limited space for local people and their traditional knowledge systems in the planning and management of WAS.

1.5 Bromine Based and Other Industries in Great Rann of Kachchh

In GRK, the sea water enters through Kori creek and floods in the Rann. The distance between Kori creek and Pachchham Island in Kachchh is approximately 70-80 km, therefore, most of the water evaporates and fine mineral deposits are available in the Rann terrain. Two industries, namely
Solaris ChemTech Limited and Agrocel Industries Limited have been utilizing this salt water from GRK for Bromine extraction (Figure 1.0).

![Figure 1.0: Location of bromine manufacturing industries in GRK](image)

Solaris ChemTech Industries Limited (SCIL), Khavda, Kachchh is one of the largest manufacturers of bromine and bromine chemicals. The plant has the capacity to produce approximately 10,000 tones of bromine per annum and has expansion programme to increase the production to further levels. Agrocel Industries Limited, located near Dhordo along the fringes of GRK, manufactures 3000 MT Bromine and various Bromine compounds which are required for pharmaceuticals, agro-chemicals and specialty chemicals.

In addition to these, Archean Chemical Industries Pvt. Ltd (ACI) is planning to launch an industry in Lakhpat taluka of Kachchh and utilizing the marine waters from GRK in the production of Sulphate of Potash, Gypsum, Bromine and several industrial chemicals through conversion of naturally available marine mineral deposits. ACI will be among the first in India to manufacture Sulphate of Potash, an important ingredient in several fertilizers.

All these industries extract bromine and other minerals by collecting marine water from the GRK and store it in plots surrounded by earthen bunds and allow the water to evaporate to get fine mineral materials. This might disrupt the water flow in the GRK and thereby affect the natural process of Rann ecosystem and its biodiversity.
The Rann of Kachchh is a unique landscape located in the western part of Gujarat state (Figure 2.0) with unusual geomorphic terrain and is the only saline and marshy desert of the world (Maurya et al.; 2002) and is characterized by flat topography with average height up to 4m above MSL. Cubitt and Mountfort (1991) defined Rann of Kachchh as "a desolate area of unrelieved, sun-baked saline clay desert, shimmering with the images of a perpetual mirage". The monotonous flatness, salinity, and the unusual inundation have rendered the Rann as a place of mysterious ground. In spite of its unusual position and character, Rann has hardly been studied. Though the mainland of Kachchh has drawn the attention of many scientists and researchers, regrettably various aspects of Rann continued to be only feably understood. Literature on Rann of Kachchh is very scanty and old reports are mostly by travelers which have little scientific value.

Etymologically, the word Rann could have its origin in ‘Iranya’, meaning saline marshy land, virani or ‘vast expanse of flat land’ in Sanskrit or ‘Rann’ for desert in Persian. The vast saline wastelands comprise a rather unusual Quaternary terrain of western India. Rising barely above the sea level, the Greater Rann of Kachchh (GRK) and Little Rann of Kachchh (LRK) are separated from each other by highlands. The GRK marks the boundary between India and Pakistan in the northern Kachchh while the LRK defines the boundary with adjoining districts of Kachchh, Banaskantha, Patan, Surendranagar, and Rajkot. The GRK extends to about 290 km from...
Deserts are the world’s dryland where evapotranspiration is much higher than the precipitation. They are the barren lands which support only few life forms that are capable of surviving in the extreme conditions.

The Rann of Kachchh has been closed off by centuries by silting. During the time of Alexander the Great, it was a navigable lake, but it is now an extensive mudflat, inundated by sea water and during monsoon seasons.

There are many slightly raised isolated patches of land in GRK known as ‘bets’ (Islands) or ‘dhoi’. The important ones are Kuar bet, Dhramsala, Bedia bet, Bawarla bet, Bada Sarbela, Chota Sarbela, Vigukot, Karim Dhahi, Chad bet, Khadir, Bela, Trangadi bet etc. Similar to GRK, there are certain island like features, raised few meters (5-7m) above the Rann surface which are also termed as ‘bets’, having sparse vegetation. LRK is dotted with more than 74 bets, which encompass an area of about 185 km². Important bets of LRK are Wasraj and its chain of islands like Andheri Wen, Khijadia, Maharajawali, Miyan and Pancham. The other bets are Pung, Dhot, Mardak, Shedwa, Nanda and Jhilandar. Pung is the largest bet in LRK covering an area of 30.5 km² while Mardak bet is the highest, 55m above MSL.

Information on climate, specific to the GRK area is not available, though it experiences three seasons; monsoon that extends from end of June to September with October and November being the transition months; winter extends from December to February and summer between March to June. The temperature is predominantly high and it reaches a maximum of 48-49°C during May-June. The winter temperature goes down to 10°C with January and February being the coldest months. The average humidity is about 60 per cent, which ranges between 0.8 to 98 per cent. During summer, dust-laden winds are very frequent and the average wind speed recorded during winter, summer and monsoon is 16, 24 and 9 km/hr respectively (GUIDE, 2007).

LRK lies under desert and semi-arid steppe climatic zones of India and consequent to its biogeographic location, it lies partially in Desert and semi-arid bio-geographic zones of India. The climate is characterized by extremely hot and dry summer (average 44°C), wet monsoon with flooded land and cold winter (average 10°C) seasons. The rainfall is very scanty and annual
average rainfall is normally less than 60 cms. The peak summer of LRK is in May, peak winter from December to January and monsoon prolongs between July and August.

2.1 Geology

The landscape of Kachchh is unique as it has evolved as a result of several phases of tectonic movements since the late Jurassic. The long history of devastating earthquakes in Kachchh peninsula indicates continuous rejuvenation of this area. Sediments of the two Ranns and coastal mud flats with sandy beaches are recognized as Holocene deposits in the Kachchh region and are characterized as unconsolidated formations. The Great Rann and Gulf of Kachchh are also the sites of deposition of early Holocene sediments under estuarine deltaic environment (Vyas, 2011). The two Ranns, Great Rann in the north and Little Rann in the east comprise vast saline wasteland. The boundaries of these geographical areas are bounded by the major East-West trending faults. The residual depressions or low-lying regions between the uplifts consist of quaternary sediment successions (Figure 2.1 & 2.2). These low lying areas are marked by alluvial river terraces in the rocky mainland and the mud-flats and salt pans in the Great Rann, Little Ranns and Banni Plains (Biswas, 1987).

The sedimentary rocks formed by volcanic activity in this region range from Jurassic to Eocene age. The northern range is about 160 km long and broken into four islands (Pachham, Khadir, Bela and Chorar) in the Rann of Kachchh (Krishnan, 1982). The northern part of the Kachchh peninsula is covered by recent marine deposits on which Jurassic rocks form outcrops. Sedimentary rocks of this region are generally well indurated and behave like hard rocks. The pore spaces are mostly cemented with calcium carbonate and therefore are mostly impervious (Eidinger, 2001). Both limestone and sandstones are used as building materials in this region.
Mesozoic rocks of Kachchh region are exposed in three chains of east-west trending ridges. The 2000m thick successions of marine sedimentary rocks represent a phase of transgression of sea along the west coast during Jurassic-Early Cretaceous times. Mesozoic rocks of Kachchh region are grouped into several formations. Pachchham Formation marks the beginning of Jurassic marine transgression in Kachchh. It consists of 300m thick succession of limestone, marl and shale and has yielded pelecypods, corals and ammonites. The Great Rann of Kachchh has been the site of the 1819 earthquake which produced surface rupture known as ‘Allah Bund’ resulting in the upliftment of the northern part of the Rann (Macmurd, 1824).

Figure 2.2 Geological Map of Kachchh Basin

Source: Karanth and Gadhavi, 2007
During the year 1965, Indian army had constructed a road between Khavda to Kuwar Bet. This road has restricted the eastward flow of sea water into the eastern portion of Great Rann. The sea water flow entering through the Kori Creek has now changed the direction and flooding in the northern fringes of Banni grasslands leads to the advancement of Rann towards into Banni area by 244 km between 1961 and 1989 (Jothimani and Garg, 1992).

The soil type of the Rann varies from sandy loam to silty clay to clay in texture, and is slightly lighter in the lower layers. The lower depths indicate alternate reduction and oxidation conditions. The soils are generally stratified. A compact and impervious layer varying in thickness of about 0.15m to 1m and relatively was observed less saline in nature in some areas at a depth of 0.5 to 2 m below the surface (MFACDC, 1966). There is a paucity of information on soil permeability both horizontal and vertical, which is an important characteristic feature to assess the possibility of leaching of salts and reclamation of saline soils.

In the stratified and water saturated Rann soils, clay content varies from 19 to 49% and silt from 8 to 40% with water retention capacity from 30 to 70%. The pH ranges from 7.7 to 8.7 and EC from 6.0 to 61dsm⁻¹. Organic carbon ranges from 0.08 to 0.8%, available Phosphorus from 4 to 25 kg/ha and Potassium from 242 to 1250 kg/ha (GUIDE, 2007)

2.2 Geo-Morphology

The Kachchh landmass comprises hill ranges, gently sloping coastal tract, coastal erosion plain and tidal flats can broadly divided into four characteristic units, viz, Rann, Banni plains, Hilly tracts and Coastal plains. The Rann is a marshy and salt encrusted wasteland, the remnant of a very late marine transgression of Miocene Epoch, which is undergoing rapid siltation. The receding sea level, neo-tectonic activity and silting by the rivers have been attributed as the causes for the

Allah Bund
The 1819 earthquake gave rise to the slightly elevated land north of Sindree, known as Allah Bund. In the year 1844 there was a series of earthquakes, which further raised the elevated land around Allah Bund. This Bund comprises an important palaeo-seismic landform feature in the northwestern part of the GRK and represents an EW trending raised landmass. This upliftment that encompasses an area of about 2136 km² is responsible for the present day geomorphic configuration and the inundation pattern of the western part of the GRK.

Panjabi Road in GRK
During the year 1965, Indian army had constructed a road between Khavda to Kuwar Bet. This road has restricted the eastward flow of sea water into the eastern portion of Great Rann. The sea water flow entering through the Kori Creek has now changed the direction and flooding in the northern fringes of Banni grasslands leads to the advancement of Rann towards into Banni area by 244 km between 1961 and 1989 (Jothimani and Garg, 1992).
formation and transformation of this landmass, which remains under the influence of seasonal flooding by precipitation and occasional high tidal waves. This unique landmass divides in two parts. The northern one, having its northern border with Pakistan and Thar Desert, is referred to as the Great Rann, which extends in E-W direction for 300 km and has width ranging from 30 to 100 km. The southeast patch, lying between the Kandla Port in the west and Santalpur in the east, is named as Little Rann (Figure 2.3 & 2.4).

The Great Rann and the Little Rann comprise unique examples of Holocene sedimentation (Biswas and Deshpande, 1970). The two Ranns mark the site of sediment accumulation in a shallow gulf that was marked by a fluctuating strandline since the beginning of the Holocene. The source of the sediment comprising the Ranns is believed to be the Indus drainage basin (Platt, 1962). The low parts of the Great Rann surface are salt encrusted and form salt covered desert areas “Sabkhas” during rainy season (Glennie and Evans, 1976). According to Gupta (1975), an average sedimentation rate is 2 mm per year and the Rann was inundated under about 4 m deep water throughout the year as late as 2000 years ago. The drying up of Rann is attributed to the tectonic uplift of the area in recent times.

The basin is filled up by sediments supplied from the Indus drainage basin, while the surface has been smoothened by the frequent earthquakes (Table 2.1). No complications from Pleistocene sea levels are involved in the transformation of the Ranns from a marine bay to a flat saline wasteland (Roy and Merh, 1977).
Table 2.1 List of Historical Earthquakes in the Kachchh Region up to 2007

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</tbody>
</table>

The Rann of Kachchh is therefore, the most promising area of Kachchh for neotectonic and palaeoseismic investigations. A study conducted by Rajendran and Rajendran (2001) has provided details of the surface deformation related to the 1819 earthquake and suggested that the previous event of a comparable magnitude occurred about 800-1000 years ago in the Great Rann.

The Ranns are geo-morphologically divisible into following four units:

- Bet Zone – North of Allah Bund
- Linear Trench Zone – Between Kori creek and Kuar bet
- Great Barren Zone – Eastern part of Great Rann
- Little Rann of Kachchh – Separated from Great Barren Zone by a narrow rise along Adesar Piparala.
**Bet Zone**

The Bet zone landscape points to a wetter past and comprises relicts of an ancient delta (Malik et al., 1999). It lies to the north of the line joining the Kuar bet and Bedia bet and forms a slightly uplifted area. The southern part of this upliftment is marked by the Allah Bund, while to the north it merges into the sand ridges of Sindh (Figure 2.5).

**The Linear Trench Zone**

Trench like feature lying between Banni and the Allah Bund comprises a depressed terrain, extending from Kori creek eastward up to Kuar bet, which is inundated by tidal water of the Arabian Sea through the Kori creek. The seawater in this depression gives rise to an extensive salt encrusted plain.

**The Great Barren Zone**

This is on eastern portion and is free from the seawater inundation. It is a vast saucer shaped depression, which to the north merges into sand dunes of the Thar Desert (Pakistan); to the south adjoins with Kachchh mainland; to the east it rises into the alluvial plains of Banaskantha and to the west it is separated from the Linear Trench Zone by a narrow high ground. The narrow high ground is now called as Panjabi road. The river Luni and other streams discharge rain water into this depression, therefore, this zone generally remains under a thin sheet of water during rainy season (Roy and Merh, 1977).

**The Little Rann of Kachchh**

It represents the former extension of the Gulf of Kachchh. The Little Rann was an extension of the Gulf of Kachchh when the sea level was high during the Holocene transgression (Malik et al., 1999). It is featureless marshy ground annually flooded under 0.5-1.0m deep water. The Little Rann gradually rises about 4 m above the high waterline (HWL) at its northern point. The inundation of Little Rann is caused by the tidal waters and the discharge by various inland rivers. Generally, the inundated water from Great Rann does not reach to Little Rann.
2.3 Hydrology

The hydrology pattern of GRK represents an interesting case of recent tectonic adjustments and consequential environmental changes of far reaching anthro-po-geographic significance. The causes of inundation in Rann are manifold (Malik et al., 1999) and are mainly due to the movement of rainwater along channels, seasonal rivers and streams. The inundation also due to direct precipitation and tidal water of Arabian sea entering through the Kori creek.

![Satellite imagery Oct - 97 (After Rain) & Satellite imagery April - 98 (Before Rain)](image)

Figure 2.6 Inundation Pattern in Greater Rann of Kachchh

The aquifer system of GRK and LRK is broadly classified based on yield potential as alluvium (>40 LPS) distributed extensively and Alluvium and sandstone (10-40 LPS) distributed discontinuously (CGWB, 1995). Apart from the meteorological factors such as rainfall, tidal movement etc., certain indirect factors also control water movement or water stagnation to a great extent, which include geomorphology of the area and the nature of sediments. Geo-morphologically, Rann has certain landforms that control the flow and stagnation. The fineness of the sediments and the presence of salts play an important role in the transfer of moisture through the profile, and this process has been found to be a major factor contributing to water logging at many places of Rann. Interestingly, rainwater carried by major rivers into GRK is questionable, because the only major river flowing into the GRK is Luni, which has a sizeable catchment area of 62093 km². However, inundation caused by this river is very inadequate, as most of its water has been dammed upstream for irrigation by the Rajasthan government. Therefore, it is clear that saline water from Arabian Sea or fresh water from small highland streams and monsoonal precipitation are the major causes of inundation of GRK (Figure 2.6).
No systematic data is available for the water table fluctuation in the GRK. The Ministry of Food, Agriculture, Community Development and Co-operation, Government of India (1966) estimated that the water table of Rann ranges between 1-2m. Further, Rann sediments are more impervious, hence their plasticity is increased due to inherent salinity of the soil. Thus a flat terrain with sediments provides an ideal site for inundation. As a result, sheets of water (including rain, river, and sea) inundate larger areas the Rann. The lower parts of the Rann surface are salt encrusted, and form salt palayas during rains. The deeper portion of the palaya lakes are made up of silty gypseous clay with traces of mica, while sand percentage increases along the margins. Due to excessive salinity, the sediments show poor organic life, however few worn out shells belonging to the family Rotalidae, Miliotidae and Elphidiiae were recorded from these areas.

Rann receives an average rainfall of 35 cm per year. The region does not have any perennial river and the development of drainage is poor. Only seasonal rivulets, originating from the central highland, drain the rain water of Kachchh region through the Rann. The streams flowing to the north of the highland and disappearing in the vast expanse of the GRK are Nara, Panjarwati, Chhari, Bhukhi, Tramdo, Kaila, Pur and Kaswali. The drainages of Bhamban, Kankavati, Machchhu, Godhra and Umai from the southern fringe, Saraswati and Rupan from eastern fringe and Banas from northern fringe debouch into the LRK. Therefore, inundation in LRK is mainly by tidal waters from the Gulf of Kachchh with major contribution from surface runoff from various inland rivers draining the adjoining region. To utilize the scanty water resources for irrigation purposes, many of the rivers and rivulets were dammed at many locations which reduced the fresh water flow into Rann areas.

2.4 Landuse/Land Cover Pattern

Rann of Kachchh is a coastal desert influenced by oceanic environment with annual precipitation below 500 mm showing coefficient of variability in annual rainfall (above 60%). Rann of Kachchh is a hot sub tropical coastal desert based on climatic conditions (Meigs, 1973). The coastal desert of Rann of Kachchh covers an area of 9000 km² (Sen and Shankarnarayan, 1977).

Land use refers to human activities and the various forms of utilization of land, whereas land cover refers to natural vegetation, water bodies, rock/soil and others, resulting due to land transformations. To a large extent, the land use/land cover reflects the quality of life of the
inhabitants of the region. The Ranns and their peripheral area represent a wide variety of land use/land cover type. In general, GRK and LRK comprise of vast expanse of saline wasteland which remains under shallow water during the monsoon season. The islands distributed in the Rann are dominated with wastelands with scrubby vegetation.

To understand the changes in land use and land cover pattern of Rann, a comparative analysis of satellite imagery of the year 1999 and 2009 of all talukas fringing the Ranns were undertaken (Figure 2.7). The land use and land cover (LULC) of Rann and its adjoining talukas were divided into seven geo-ecological classes, viz; saline area, barren land, agriculture, grassland, water, Suaeda and forest/vegetation area (Table 2.2).

In GRK and LRK, the saline area has been increased by 8.21 % and 8.46 % and barren land has increased to 1.13 % and 0.40 %, respectively. Very high reduction in area of Suaeda vegetation has been recorded; -7.41% in GRK and -6.30% LRK (Table 2.2). In general, high saline areas are devoid of vegetation due to the tolerance levels of plants to various salinity levels. Suaeda is a salinity tolerant plant that can withstand only 200 to 400 molm$^{-3}$ NaCl and shows inhibited growth in 600 to 1000 molm$^{-3}$ NaCl (Khan, et al. 2000). Higher saline soil (above 1000 molm$^{-3}$ NaCl) may be unsuitable for its growth. Therefore, the reduction in land under Suaeda has been gradually converted into either barren or saline areas, which are unhealthy habitats to support any vegetation. Area under agriculture has shown a reduction around GRK, but minor increase in periphery of LRK.
Interestingly, forest/vegetative cover has shown a slight increase in GRK areas, which may be due to plantation programmes. Even though rainfall has increased during the period, the areas under water bodies, grassland, and agriculture showed a decreasing trend.

Table 2.2   Landuse/ Land Cover Changes in GRK and LRK (Between 1999 and 2009)

<table>
<thead>
<tr>
<th>S. No</th>
<th>LU/LC Class</th>
<th>1999 Total Area (Ha)</th>
<th>1999 % Area</th>
<th>2009 Total Area (Ha)</th>
<th>2009 % Area</th>
<th>Change Area (Ha)</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saline</td>
<td>694473.03</td>
<td>48.51</td>
<td>806895.84</td>
<td>56.71</td>
<td>112422.81</td>
<td>8.21</td>
</tr>
<tr>
<td>2</td>
<td>Barrenland</td>
<td>39472.61</td>
<td>2.76</td>
<td>55253.17</td>
<td>3.88</td>
<td>15780.56</td>
<td>1.13</td>
</tr>
<tr>
<td>3</td>
<td>Agriculture</td>
<td>7158.18</td>
<td>0.50</td>
<td>6004.97</td>
<td>0.42</td>
<td>-1153.21</td>
<td>-0.08</td>
</tr>
<tr>
<td>4</td>
<td>Grassland</td>
<td>4626.35</td>
<td>0.32</td>
<td>2689.02</td>
<td>0.19</td>
<td>-1937.33</td>
<td>-0.13</td>
</tr>
<tr>
<td>5</td>
<td>Water</td>
<td>357368.04</td>
<td>24.96</td>
<td>329685.12</td>
<td>23.17</td>
<td>-27682.93</td>
<td>-1.79</td>
</tr>
<tr>
<td>6</td>
<td>Suaeda</td>
<td>326596.69</td>
<td>22.81</td>
<td>219195.09</td>
<td>15.41</td>
<td>-107401.60</td>
<td>-7.41</td>
</tr>
<tr>
<td>7</td>
<td>Forest</td>
<td>2029.21</td>
<td>0.14</td>
<td>3043.38</td>
<td>0.21</td>
<td>1014.16</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Greater Rann of Kachchh

<table>
<thead>
<tr>
<th>S. No</th>
<th>LU/LC Class</th>
<th>1999 Total Area (Ha)</th>
<th>1999 % Area</th>
<th>2009 Total Area (Ha)</th>
<th>2009 % Area</th>
<th>Change Area (Ha)</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saline</td>
<td>233636.10</td>
<td>62.12</td>
<td>266665.92</td>
<td>70.58</td>
<td>33029.82</td>
<td>8.46</td>
</tr>
<tr>
<td>2</td>
<td>Barrenland</td>
<td>15524.23</td>
<td>4.13</td>
<td>17119.64</td>
<td>4.53</td>
<td>1595.41</td>
<td>0.40</td>
</tr>
<tr>
<td>3</td>
<td>Agriculture</td>
<td>7519.66</td>
<td>2.00</td>
<td>9929.76</td>
<td>2.63</td>
<td>2410.10</td>
<td>0.63</td>
</tr>
<tr>
<td>4</td>
<td>Grassland</td>
<td>5832.55</td>
<td>1.55</td>
<td>1112.12</td>
<td>0.29</td>
<td>-4720.44</td>
<td>-1.26</td>
</tr>
<tr>
<td>5</td>
<td>Water</td>
<td>27685.48</td>
<td>7.36</td>
<td>25962.01</td>
<td>6.87</td>
<td>-1723.47</td>
<td>-0.49</td>
</tr>
<tr>
<td>6</td>
<td>Suaeda</td>
<td>70182.00</td>
<td>18.66</td>
<td>46684.73</td>
<td>12.36</td>
<td>-23497.27</td>
<td>-6.30</td>
</tr>
<tr>
<td>7</td>
<td>Forest</td>
<td>15731.19</td>
<td>4.18</td>
<td>10335.96</td>
<td>2.74</td>
<td>-5395.23</td>
<td>-1.45</td>
</tr>
</tbody>
</table>

Little Rann of Kachchh

2.4.1. Rainfall and Landuse and Land Cover Pattern

Rainfall pattern of an area plays a significant role in Landuse and landcover pattern. There is no weather station pertaining to GRK, therefore, rainfall data available nearer to GRK was taken into account. During the period between 1932 and 2008 (a span of 77 years), Kachchh district experienced a total of 26 severe to very severe droughts (1 in 1932-1940, 2 in 1941-1950, 3 in 1951-1960, 4 in 1961-1970, 3 in 1971-1980, 4 in 1981-1990, 4 in 1991-2000 and 5 in 2001-2008). It is important to note that the number of severe droughts as well as severe consecutive droughts showed an increasing trend during recent decades (Table 2.3) with the magnitude further intensified.
between 2001 and 2010. This situation predominantly may affect the soil moisture and led to land degradation.

Table 2.3 Droughts in Kachchh (1901-2008) (Vijaykumar et al., 2011)

<table>
<thead>
<tr>
<th>Decades</th>
<th>Mild and Moderate Drought Years</th>
<th>Severe and Very Severe Drought Years</th>
<th>Number of Severe and Very Severe Droughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1932-1940</td>
<td>1938, 1940</td>
<td>1939,</td>
<td>1</td>
</tr>
<tr>
<td>1941-1950</td>
<td>1943, 1946</td>
<td>1942, 1948</td>
<td>2</td>
</tr>
</tbody>
</table>

(Note: DI Drought Index = (P - X)/SD Where P is Annual Precipitation and X is long-term average rainfall)

A further analysis of last two decades was undertaken with a view of recent increase in rainfall in Kachchh. The rainfall data of Kachchh region showed an increasing trend from 1990 to 2010. However, looking at the decadal patterns, it showed a decreasing trend from 1990 to 2000 and an increasing trend from 2000 to 2010. Interestingly, rainfall during the last few consecutive years was above normal and in excess being 663 mm in 2008, 498 mm in 2009 and 888 mm in 2010. This could also be a reason for increasing vegetation cover around GRK (Figure 2.8).
Figure 2.8  Average Rainfall Value (mm) of Kachchh District from 1990 to 2010
2.5 Biodiversity

Kachchh is a unique kind of ecological zone demarcated as Kachchh desert biotic province under desert bio geographic zone of the country (Rodgers & Panwar, 1988). It represents a distinct biological diversity and gene pool of Indian arid region (Chawla, 2004). The Rann is unique in a sense that it has the characteristics of both desert and wetland and therefore supports unique assemblages of flora and fauna. The eco region of Rann of Kachchh represents the saline and marshy habitat dominated by scrub vegetation and flooded grasslands with swampy land providing shelter to diverse wildlife. The environment of Rann is cyclic in nature, where during some part of the year land remains under water and rest of period remains dry making the Rann suitable for aquatic as well as terrestrial biota.

Rann harbors rich floral and faunal diversity besides providing habitat for some important threatened wildlife including Asiatic Wild Ass, Indian gazelle, blue bull, wild boar, desert cat, striped hyena, Indian wolf and caracal. The large and open wetlands of Rann are also a unique wintering and breeding ground for diverse avifauna such as Greater & Lesser Flamingo, Cranes, Falcons, Wild ducks, Ibis, Spoonbill, Pelicans, etc. Due to the presence of large number of rare and endangered fauna and flora in Rann, in year 2008 it was declared as a Kachchh Biosphere Reserve (KBR) under protected area network of India (MoEF, 2010).

2.5.1 Great Rann of Kachchh (GRK)

GRK is a kind of landscape characterized by variation in biological environment due to influx of marine water through Kori creek and fresh water through various seasonal rivers and rivulets. These seasonal changes make the GRK to support marine and fresh water species to sustain. GRK is an important site of many rare and endangered species and the only breeding ground for flamingoes in the world. The breeding and nesting ground of flamingo is situated on the Hunj Bet (Hunj is the local language name of Flamingo) of Greater

Wild Ass in GRK!!!

The great Rann is also important from the viewpoint of the conservation of Asiatic Wild Ass (*Equus hemionus khur*). Though the Little Rann is the stronghold of the wild ass and internationally known for this unique animal, the significance of the great Rann as habitat of the Wild Ass should not be overlooked. Wild Ass has been reported from Khadir, Tragdi, Vangara Bela and Jakhorta and also from Kalo Dungar (Tatu et al., 2001).
Rann between Pachchham and Khadir islands, popularly known as Flamingo city. To conserve the breeding ground of Greater Flamingos and some other species of conservation significance, the Kachchh Desert Sanctuary was established in the Great Rann in 1986.

The floral diversity of GRK (Rann proper and low lying salt encrusted areas) is scanty but rich diversity of flora is found in many of the bets falling under GRK. Pachchham is the largest island of the GRK and its diverse habitats support many plant species. Similarly, Khadir is another largest island of GRK having mixed thorn scrub and savanna types of vegetation that supports diverse floral species (Joshi and Sunderraj, 2009).

Some of the principal plant species of the Rann are *Accacia sp*, *Salvadora spp*, *Zizyphus nummularia* and *Streculia urens* etc. A few highly salt tolerant halophytes like *Suaeda* and *Atriplex*, grasses like *Aeluropus lagopoides*, *Sporobolus helvolus* and *Halophyrum mucronatum* and some xerophytes like *Capparis* sps, *Tamarix* sps and *Euphorbia nivulathrive* are surviving successfully. *Prosopis juliflora* is also predominant on the Bets and fringes of the Rann (Tatu et al., 2001).

Rare and Endangered plant species of GRK include *Citullus colocynthis*, *Commiphora wighitii*, *Convolvulus stoksii*, *Dactyliandra welwitschii*, *Dipcadi erythraem*, *Ephedra foliate*, *Helichrysum cutchicum*, *Heliotropium bacciferum*, *Heliotropium rariflorum*, *Ipomoea kotschyana*, *Indigofera caervula*, *Limonium stocksii*, *Pavonia certatocarpa*, *Sida tiagi* and *Trilumbs rajasthanisis* (Pardeshi et al., 2010). A study carried out by GUIDE has reported 261 plant species (Table 2.4 & 2.5) from the bets of GRK. This includes 138 species of herbs which showed dominance in the bet areas followed by 50 species of grasses, 37 species of shrubs and 18 species of trees (GUIDE, 2007).

Table 2.4 Plant Life Forms Recorded in Bets of GRK during the Year 2006 (GUIDE, 2007)

<table>
<thead>
<tr>
<th>S. No</th>
<th>Life Forms</th>
<th>No. of Species &amp; Relative Dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grass</td>
<td>50 (19%)</td>
</tr>
<tr>
<td>2</td>
<td>Herb</td>
<td>138 (53%)</td>
</tr>
<tr>
<td>3</td>
<td>Shrub</td>
<td>37 (14%)</td>
</tr>
<tr>
<td>4</td>
<td>Tree</td>
<td>18 (7%)</td>
</tr>
<tr>
<td>5</td>
<td>Climber</td>
<td>18 (7%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>261 (100%)</strong></td>
</tr>
</tbody>
</table>
The rann of Kachchh represents two Wildlife sanctuaries and one Biosphere reserve due to the presence of rich biodiversity and a unique landscape for wildlife. The Indian Wildass Sanctuary of LRK (4,954 km²), Desert Wildlife Sanctuary (7,500 km²) of GRK and Kachchh Biosphere Reserve (12,454 km²) of overall Rann together comprise the largest tract of protected area network in India. Three protected areas cover more than three-fourth of the North West part of Gujarat (Meena et al., 2005).

#### Table 2.5 List of Important Fauna Recorded in GRK & LRK

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>IUCN Status</th>
<th>GRK</th>
<th>LRK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asiatic Wild Ass</td>
<td>Equus hemionus khur</td>
<td>EN</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Chinkara</td>
<td>Gazella bennettii</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Nilgai</td>
<td>Boselaphus tragocamelus</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Indian Wolf</td>
<td>Canis lupus</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Black Buck</td>
<td>Antilope cervicapra</td>
<td>NT</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Striped Hyena</td>
<td>Hyaena hyaena</td>
<td>NT</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Caracal</td>
<td>Caracal caracal</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Pale Hedgehog</td>
<td>Paraechinus micropus</td>
<td>LC</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Long Eared Hedgehog</td>
<td>Hemiechinus auritus</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Indian Porcupine</td>
<td>Hystrix indica</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Honey Bodger</td>
<td>Mellivora capensis</td>
<td>LC</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td><strong>Herpetofauna</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indian Flapshell Turtle</td>
<td>Lessemys punctata</td>
<td>LC</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Star Tortoise</td>
<td>Geochelone elegans</td>
<td>LC</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Black Cobra</td>
<td>Naja oxiana</td>
<td>DD</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Spiny Tailed Lizard</td>
<td>Uromastix hardwickii</td>
<td>NT</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Common Indian Monitor</td>
<td>Varanus bengalensis</td>
<td>LC</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Skink</td>
<td>Ophisops microlepis</td>
<td>LC</td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

#### 2.5.1.1 Kachchh Desert Sanctuary and Flamingo City

The Kachchh Desert Sanctuary, declared as the largest sanctuary of the State in 1986, is an important breeding ground for Flamingoes in the world (also known as ‘Flamingo City’), located in the mud flats of the GRK, about 10 km from Kala Dungar in Pachchham island. In Khadir island of the sanctuary, an important archeological site of Harappan civilization is located which is known as Dholavira. It consists of nearly 5000 year old remains of well planned city, which attracts archeologists and tourist from all over the world.

This sanctuary represents one of the largest seasonal saline wetlands having water depth varying between 0.5 to 1.5 meters. In the summer season, water dries up and the entire area turns into saline desert. The sanctuary supports wide variety of water birds and mammals’ species. Chinkara, Desert fox, Striped Hyena and Nilgai are common and abundant.
mammal species of this sanctuary. Apart from the numbers of resident and migratory avifaunal species some raptors and Houbara bustard are also found occasionally. Many timid and harmless Spiny-tailed lizards, with their typical hide and run activity are found in abundance in this sanctuary.

The Sandal bet, right in the centre of the GRK, popularly known as Flamingo city is a part of Kachchh Desert Wildlife Sanctuary. It was first reported and discovered in 1886 by Maharao Khengarji (Patel, 1971). Dr. Salim Ali, a well known ornithologist, also visited Flamingo city and estimated a population of half million birds. The flamingo city after rainfall transforms as a marshy island where large number of Greater and Lesser flamingoes visit for breeding. They construct their muddy nests, lay eggs and rear young ones. Nesting takes place during monsoon in between July and October when the area gets covered with shallow stretch of water partly from fresh water outflow due to monsoon and partly from the sea. However, depending on rainfall and inundation conditions, nesting has also occurred as late as March-April. Besides Greater and Lesser flamingo, Rosy pelican and Avocet have also been recorded to breed in the GRK in the past.

In GRK, the diversity of wild animals is very scarce (GUIDE 1999). The faunal composition including sixteen species of herpetofauna (15 species of reptiles and 1 species of amphibian) belonging to 13 genera and 9 families, 14 species of mammals and 49 species of birds belonging to 42 genera and 25 families recorded from GRK (GUIDE, 1997)

The Jurassic and Cretaceous rocks on Khadir, Kuvar and Pachchham bets are having plenty of fossils of vertebrates, invertebrates and plants embedded within it. There is also the first record of oldest fossil dinosaur from the earliest Middle Jurassic period (approximately 165 million years ago) from Kachchh by a team of Geologists from ONGC, Mumbai. They have excavated fossils of dinosaurs (large number of well-preserved bones) and tree trunks of Middle Jurassic rocks of Kuar bet in GRK (Satyanarayana et al. 1999). There are plenty of marine fossils in hillocks located in GRK and Pachchham areas. Fossilized forests have also been found in the rocks belonging to
Jurassic and Cretaceous period. The Jurassic period was considered as a golden age for the large herbivorous dinosaurs. These fossils of Jurassic dinosaurs and trees have highlighted the fact that the GRK and surrounding areas once had a luxuriant forest to support populations of dinosaurs. The marine fossils in and around GRK indicate the fact that the area was submerged under ocean for some time. These evidences highlight some interesting paleo-archeological facts about GRK.

Interestingly, there is no mangrove in GRK and under high saline conditions the habitat is unsuitable for the growth of mangroves. However, a single isolated patch of mangroves is located in Guneri village of Lakhpat taluka of the Kachchh district. This patch encompasses an area of one acre and the nearest mangrove patch is located about 15 km distance along the coast of Narayan Sarovar.

2.5.2 Little Rann of Kachchh (LRK)

The LRK is located between 23° 10’-23° 45’ N latitude and 70° 45’-71° 45’ E longitude on the eastern fringe of Kachchh district encompassing an area of 6,530 km². The LRK is southward extension of GRK usually described as a flat, saline waste or salt marsh. The LRK is similar to GRK in physiographic, edaphic, eco-climatic conditions and vegetation pattern. LRK is situated close to and connected with the Gulf of Kachchh and falls under Kachchh, Rajkot, Surendranagar, Banaskantha and Patan district of Gujarat. It is a unique landscape comprising saline mudflat and marshes, which gets transformed into a large seasonal wetland in monsoon proving a heaven for the migrant avifaunal species. The LRK is the only habitat for the last remaining population of endangered Asiatic Wild Ass in the world. It is also a major nursery ground for the famous endemic “Kachchh Prawn” (*Metapenaeus kutchensis*) and a feeding ground for numerous fish and invertebrate species. This large saline mudflat has been the traditional breeding ground for the lesser flamingo since 1893. It lies in the migratory route of a large number of bird species and a common ground for waterfowl and demoiselle and common cranes.

The landscape of LRK comprises of five major habitats a) Rann fringe, the elevated rim that carries thorn-scrub forest and human habitations; b) Bets or uplifting islands also carry thorn-scrub; c) Inflowing riverine tracts d) Water bodies and e) barren mudflats. The LRK is enriched with high
floral and faunal diversity. Floral diversity is composed of both aquatic and terrestrial vegetation (Table 2.6). Aquatic flora is mainly composed of grasses and sedges. The vegetation in islands and fringe areas is scattered thorn type intermixed with grass patches dominated with luxuriant growth of *Prosopis juliflora*. Bets and fringe area of extensive marine saline flats of the LRK mainly support a variety of indigenous plants like *Suaeda* spp., *Salvadora persica*, *Capparis decidua*, *Calotropis procera*, *Tamarix* sp., *Aeluropus lagopoides*, *Cressa cretica*, *Sporobolus* spp., *Prosopis cineraria*, etc (Table 2.7). A total of 253 flowering plant species have been recorded from LRK region (Meena *et al.*, 2005), however Ishvana *et al.* (2011) recorded 108 plant species (44-herbs, 35-grasses, 10-trees and 7-climbers) from LRK. The dominant families representing more than 10 species are Fabaceae, Asteraceae, Cyperaceae and Poaceae. Herbaceous taxa are predominant over shrubs and trees. 107 species of algae are present in the water bodies of the area. Some of the ecologically important plants like *Cressa cretica*, *Aeluropus lagopoides*, *Urochondra setulos*a, *Acacia nilotica*, *A. Senegal*, *Capparis deciduas*, *Salvadora oleoides*, *S. persica*, *Suaeda fruticosa*, *S. nudiflora* and *Tamarix aphylla*, which are also helpful in reclaiming the fragile soil of the LRK have also been reported (Ishvana *et al.* 2011). Due to the similar habitat conditions, the floral assemblage of LRK is similar to GRK.

Among the vertebrate species of LRK, 21 species of fish, 29 species of herpetofauna, 178 species of birds and 33 species of mammals have been recorded. A total 93 species of invertebrates including 25 species of zooplanktons, one species of Annelid, 4 crustaceans, 24 insects, 12 mollusca, 27 spiders have been recorded from different bets of LRK (BCRLIP, 2007). The mixing of tidal water from the Gulf of Kachchh with the freshwater discharged from the rivers takes place in the Little Rann of Kachchh, making it an important spawning ground for prawns. A total of 11 species of prawn have also been recorded from LRK, remarkably *Metapenaeus Kachchhensis* is the most dominant and important endemic species of prawn in this area. The LRK supports one of the largest concentrations of a threatened and migratory bustard in Gujarat, namely, Mac Queen’s Bustard. About 81 terrestrial (9 migratory) and 97 water birds (42 migratory) have been recorded from 16 sites of the Wildass sanctuary in LRK (Singh, 2001). However, a survey conducted during 2004 by Corbett Foundation has reported 186 bird species from this area. In 1998, a large breeding colony of lesser flamingo was also observed in the LRK (Pardesi *et al.* 2010).
Table 2.6 Vegetation Types of LRK and Their Distribution

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Major Location and Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Prosopis juliflora</em> forest</td>
<td>Entire Rann fringe, all the bets, village gauchars and wastelands. Seed dispersal mainly by livestock and herbivorous. Spreading rapidly and forming dense thickets</td>
</tr>
<tr>
<td><em>Salvadora persica - Suaeda nudiflora</em> Scrub</td>
<td>Mostly in saline periphery of few bets including the Dhut bet</td>
</tr>
<tr>
<td><em>Cassia auriculata</em> scrub</td>
<td>Mainly in the village wastelands</td>
</tr>
<tr>
<td><em>Salvadora persica - Tamarix</em> scrub</td>
<td>Saline periphery of few bets</td>
</tr>
<tr>
<td><em>Suaeda fruticosa</em> scrub</td>
<td>Entire Rann fringe and saline periphery of bets like Saheblana, Dhut, Khijaliya, Lai etc. in association with Aeluropus, Cressa cretica, etc.</td>
</tr>
<tr>
<td><em>Capparis</em> scrub</td>
<td>Interior parts of bets, less saline fringe areas and periphery of villages.</td>
</tr>
<tr>
<td>Short grasslands</td>
<td>Patchily on bets and other open areas in the village fringes and gauchars</td>
</tr>
<tr>
<td>Saline grasslands</td>
<td>Vast extent in the southern fringe areas and on bets having saline alluvial soil. <em>Aeluropus lagopoides</em> is the most dominant grass.</td>
</tr>
<tr>
<td>Saline herbaceous</td>
<td>Patches of <em>Cressa cretica</em> and <em>Suaeda fruticosa</em> grows in the mudflats and periphery of bets. Wild ass feed on the plant</td>
</tr>
<tr>
<td>Marsh</td>
<td>Patches of <em>Cyperus</em> species (Theg) are present in the waterlogged areas. Its bulbs are the major food for cranies and many birds and reptiles.</td>
</tr>
<tr>
<td>Mangrove scrub</td>
<td>Patches of <em>Avicennia marina</em> are found in the creeks near the Surajbari.</td>
</tr>
</tbody>
</table>

Source: Adopted from GEER (1999) and BCRLIP, (2007)

Table 2.7 List of Threatened Plant Species of LRK

<table>
<thead>
<tr>
<th>Species</th>
<th>Type</th>
<th>Global Threat Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aeluropus lagopoides</em></td>
<td>Grass</td>
<td>En</td>
</tr>
<tr>
<td><em>Arthrocnemum indicum</em></td>
<td>Herb</td>
<td>Vu</td>
</tr>
<tr>
<td><em>Suaeda maritime</em></td>
<td>Herb</td>
<td>En</td>
</tr>
<tr>
<td><em>Suaeda nudiflora</em></td>
<td>Shrub</td>
<td>En</td>
</tr>
<tr>
<td><em>Urochordra setulosa</em></td>
<td>Grass</td>
<td>En</td>
</tr>
<tr>
<td><em>Tamarix troupii</em></td>
<td>Shrub</td>
<td>En</td>
</tr>
<tr>
<td><em>Commiphora wightii</em></td>
<td>Small tree</td>
<td>En</td>
</tr>
<tr>
<td><em>Polycarpea spicata</em></td>
<td>Herb</td>
<td>?</td>
</tr>
</tbody>
</table>

Source: GEER (1999)

2.5.2.1. Indian Wild Ass Sanctuary

The famous Indian Wild Ass Sanctuary, which is the only natural habitat of the endangered Indian wild ass (*Equus hemionus khur*), is located in the LRK. This sanctuary covers an area of 4954 km²
characterized by vast cover of saline mudflats with scanty vegetation on the fringes and bets. Vegetation is largely xerophytic with the ground cover predominated by ephemerals. Although the islands and fringes both have been colonized by *Prosopis juliflora*, the islands have a richer floral diversity than that in fringe areas.

The Sanctuary is inhabited by about 93 species of invertebrates (including 25 species of zooplanktons, 1 species of annelid, 4 crustaceans, 24 insects, 12 molluscs and 27 spiders), 4 species of amphibians (frogs and toads) and 29 species of reptiles (2 species of turtles, 14 species of lizards, 12 snakes and 1 crocodile). The sanctuary provides an important feeding, breeding and roosting habitat for a large number of birds due to its strategic location on bird migration route and its connection with the dynamic Gulf of Kachchh. According to an estimate about 70,000-75,000 birds nests in an area spread over 250 acres. Nine mammalian orders with 33 species/subspecies have been reported from the sanctuary, including the world’s last population of the khur sub-species of the Wild Ass (GEER, 1999).

**The Indian Wild Ass**

The Indian Wild Ass (*Equus hemionus khur*) is a large size ungulate and a ‘flagship’ species, listed as an endangered species in IUCN’s redlist of threatened animal (2011) and a Schedule-I species in Indian Wildlife (Protection) Act, 1972. The last remaining population of this species only survives in the Little Rann of Kachchh around the world. Historically, Wild Ass was widely distributed in the whole arid zone of north–west India including Sindh, Pakistan. Later on, the species was restricted to the Little Rann of Kachchh. Recently, some of the population of wild ass has migrated towards agricultural field adjoining this sanctuary (BCRLIP, 2007).

According to the census carried out in 2009, the total population of wild ass is about 4038
The population census in 2004 by the Forest Department showed that maximum individuals of this species have been found in Rann and fringe areas (Table 2.8). Interestingly, about 17% of the population has been recorded from outside of this sanctuary. According to the wild ass census of Gujarat State Forest Department in 2004, more than 650 wild asses were recorded beyond 10 km of the Wild Ass Sanctuary. A family band of about 25 individuals was reported in the north-eastern part of Nal Sarovar. Conclusively, the population trends of wild ass in last six decades (Figure 2.9) suggests that the wild ass population is growing exponentially and the increased animals are dispersing and occupying different habitats well beyond the LRK. Most of these dispersed animals raid the nearby crop fields to meet their food requirement. This is one of the major issues of human-wildlife conflicts in the entire landscape. The increase in the population of Wild ass is remarkable mainly due to the absence of natural predators, increased fodder availability and strict conservation measures.

Table 2.8 Habitat Wise Records of Wild Ass Population

<table>
<thead>
<tr>
<th>S. No</th>
<th>Habitat</th>
<th>1998* Population</th>
<th>1998* %</th>
<th>2004** Population</th>
<th>2004** %</th>
<th>Importance of Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bets</td>
<td>541</td>
<td>18.4</td>
<td>554</td>
<td>14.4</td>
<td>Most critical habitat for Wild Ass. Provide year round fodder &amp; drinking water. Also, used as breeding ground.</td>
</tr>
<tr>
<td>2</td>
<td>Rann</td>
<td>688</td>
<td>23.4</td>
<td>1433</td>
<td>37.1</td>
<td>Provide grounds for galloping, social-congregations and breeding. Suaeda provide good fodder value.</td>
</tr>
<tr>
<td>3</td>
<td>Fringe Area</td>
<td>1271</td>
<td>43.2</td>
<td>1210</td>
<td>31.3</td>
<td>Provide good grazing resources in the form of <em>Aeluropus lagopoides-Cressa cretica</em> cover. <em>Prosopis</em> thickets provide good shelter.</td>
</tr>
<tr>
<td>4</td>
<td>Outside WAS</td>
<td>440</td>
<td>15.0</td>
<td>666</td>
<td>17.2</td>
<td>Wastelands with sparse cover of <em>Prosopis juliflora</em> and crop fields provide assured foods as well as drinking water.</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>2940</strong></td>
<td><strong>3863</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Based on GEER Foundation Survey, ** Based on Wild Ass Census by Gujarat State Forest Department

2.6 Agariyas in LRK

Gujarat is the largest salt making State of India, accounting more than 70% of India’s total salt production. It is also the only Indian State that
uses sea brine and sub-soil brine as the source of marine and inland salts, and both types of brines are used in LRK for salt farming (Sandarbh, 2008). Salt produced in LRK is known as ‘Vadagaru’ salt. It is believed that the British used to call the large salt pans of Rann as “Bada Agar” which became vada agar and from there the name ‘Vadagaru’ was derived. Salt production is one of the major livelihood options and is the traditional and old age occupation of the local people living in LRK. The community involved in this occupation is known as “agariyas” that lives on the edge of the LRK and is having a unique relationship with the Rann and their traditional salt farming practices. LRK is the only desert in the world where salt production is carried out by making small salt pans (AHRM 2007).

The salt manufacturing activity in LRK is continued for eight months by the Agariyas and during the monsoon they migrate to the sea coast for manufacturing salt from marine water (AHRM 2007). After the monsoon, the Agariyas migrate to the Rann and stay there in extremely poor living conditions with almost no facility for eight months up to mid-summer. Just before the onset of monsoon, they sell their entire produce to traders and return to their native villages. They migrate with whole families to salt pans as the salt making process is highly labour intensive and each of the family member including children shares the work. This led to poor education of children for which an innovative initiative was undertaken by a NGO for improving the educational standards (Pandya 2010).

Table 2.8 highlights that during the year 2001 LRK contributed 23% of the salt produced in the Gujarat State while in 2003 it decreased to 17%.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Production in ‘000 tons</th>
<th>% of Marine in Total</th>
<th>% of Recognized in the Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Marine</td>
<td>Inland*</td>
</tr>
<tr>
<td>2001</td>
<td>9647.8</td>
<td>7408.0</td>
<td>2239.8</td>
</tr>
<tr>
<td>2002</td>
<td>13107.8</td>
<td>11254.9</td>
<td>1852.9</td>
</tr>
</tbody>
</table>
| Year | inland | LRK | other | total |认 | % |%
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>10585.9</td>
<td>8816.7</td>
<td>1769.2</td>
<td>8874.5</td>
<td>1711.4</td>
<td>83.29</td>
<td>83.8</td>
</tr>
</tbody>
</table>

* Inland salt in Gujarat meant salts produced from LRK & ** Unrecognized sector include salt pans of less than 10 acre size.

**Source:** Annual Report: 2003-2004. Salt Dept, Ministry of Commerce and Industries
3 Impacts

3.1 Desertification and Soil Erosion

Desertification, which by definition occurs only in drylands, causes adverse impacts on non-dryland ecosystems (MEA, 2005). For example, dust storms resulting from wind erosion, driven by degradation of the dryland vegetation cover, may affect people and ecosystems elsewhere. Similarly, transport of sediments, pesticides, and nutrients from dryland agricultural activities affect coastal ecosystems. Droughts and loss of land productivity are considered predominant factors in the migration of people from drylands to other areas (MEA, 2005).

Among dryland subtypes, ecosystems and populations of semiarid areas are most vulnerable to loss of ecosystem services. The unsustainable management within the drylands often led to over-exploitation of the natural resources and a decline in productivity, the consequent desertification, followed by poverty and migration (MEA, 2005).

The Banni grasslands located on the periphery of GRK faces severe salinity problems that support the spread of hardy Prosopis juliflora in major part of Banni. The Pachchham and Khadir areas of GRK face severe soil erosion threats. The soil of Rann has been categorized into 4 types (Rao & Aggrawal, 1964) which are; Sandy strand, Rocky sandy strand, Salt marsh and Slack and mud formations. The tidal mudflats having deep to very deep fine loamy saline soils at the base and deep coarse sandy soils with predominant halophytes like Suaeda are facing desertification. The areas affected by salinity, water logging and wind erosion are subjected to severe to very severe desertification hazard. In some pockets, Kachchh region faces severe desertification hazard due to lack of vegetation cover. The saline flat water logged areas of Rann which are flooded during south west monsoon get dry during late winter and summer, which gets salinization through high velocity winds and evaporation.

3.2 Intensive Salt Farming in LRK

The LRK covers 108 villages of Kachchh, Rajkot, Surendranagar, Patan and Banaskantha districts. The livelihood of the people is highly dependent on the resources of the Rann i.e. salt farming on the dry Rann and its underground brine, seasonal brackish water prawn fisheries in the flooded parts of
the Rann, and livestock grazing in the bets and fringe areas. The industry is now facing a setback due to shortage of water that has led the salt pan owners to start digging deeper and farther in the Rann (BCRLIP 2007). Salt pans on the fringes of the Rann are indicative of salinity spread in the area, which degrades the fragile and delicate ecosystems of the area (GEC and GES 1999). Remote Sensing data reveals that the salt work area has increased from 69.48 km$^2$ in 1982 to 133.57 km$^2$ in 1995 (GEER, 1998).

Salt pans and salt production pave the way to habitat fragmentation to many faunal species. Further, the continuous bunds of salt pans cause disruption or blockade of saline water and fresh water flow, thereby increasing the salinity levels in many areas of LRK which cause problems to wetland birds (Cranes, Ducks, Waders etc), prawns (*Metapenaeus kutchensis*) etc. *M. kutchensis* is a significant source of seasonal fishery in shallow estuarine water of the LRK during the monsoon months. The average annual catch of the species has been reported to be 605 tons by Deshmukh (2006).

The intensive salt production in Rann and the livelihood of Agariyas are facing some conflicts by displacement of agariyas in LRK. This creates an uncertainty of future of salt making at one side and socio-economic impoverishment of Agariyas on other side. Agariya Hit Rakshak Manch (AHRM), a forum of salt workers has taken initiatives for overcoming the issues of Agariyas and devising strategies for collaboration between various salt producing states to discuss upon the issues of the salt workers and to adopt a common strategy for the future. An outline of national consultation was designed in collaboration with respective states and office of central salt commissioners. However, it would take some time to reach out to a common understanding of the legislature.

There are two independent scenes being enacted in this sector. Due to severe escalation in input cost, the economy of the salt making in the lower fringe (which has some of the high density of salt pans) is becoming unviable. With enforcement of regulation on the activity, the primary producers would be limited to certain areas and its inherent nature of water availability, which can or cannot
suit the economy. What needs more exploration is, how far these locations are going to be located and what would be implications on families in terms of their movement.

3.3 Impact on Biodiversity

Uncontrolled expansion of salt pans around Suraj Bari area and in GRK, bunds erected to divert water from creek to their pans, are causing serious damage to prawns, fishes and other microorganisms which also form food for flamingos. Due to such diversion of water, there is a shortage of food in the potential breeding areas and thus flamingoes are abandoning the site (GUIDE, 2002). Apart from this, developmental activities like construction of road and watch tower for security purpose, electrification of area and regular disturbances through fishermen communities are major threats to the biodiversity. The cutting and lopping of *Prosopis juliflora* cover for making charcoal cause’s destruction of hides, breeding and dening areas of wolf, common fox, desert fox, hyena etc and make them more vulnerable. The increase in the saltpan area is also a threat to the habitat of Wild Ass and other faunal diversity. The conservation of biodiversity in landscape is imposed mainly due to following proximate threats:

1. Degradation of bets & fringe habitats mainly due to excessive grazing and, as a result of this, the spread of *P. juliflora*.

2. Fragmentation of Rann desert mainly due to inland salt-work

3. Degradation of wetland habitat mainly due to change in hydrological regime

4. Degradation of creek habitat mainly due to marine salt-work

5. Human-wildlife conflicts in the form of crop depredation by wild herbivores and lifting of sheep and goats by wolf

6. Local people’s antipathy to PA based conservation and non-participation in conservation practices
Apart from desertification, the Rann of Kachchh and its adjoining environment are facing some natural and anthropogenic pressure and, consequently, have some impacts on the natural environment and local communities. Desertification is a global problem, and it is attributed to climate change and global warming. Though it is a gigantic problem, difficult to be addressed in a short time, the combined efforts of government, public and private partners can help combating desertification to some extent by applying following measures:

- Afforestation following shelter belt plantation/wind break plantation and grassland development in fringe areas.
- Recharging ground water through water harvesting structure.
- Management of pastures and range lands
- Promotion of productive dry land agriculture based on soil, water, climate factors
- Reorient cropping method with application of dry land farming technique and mulching
- Application of appropriate control measure to soil by wind erosion and conservation of water through watershed development.
- Reducing pressure of grazing and protecting natural vegetation.
- Treatment of industrial effluents before discharging into Rann environment
- Rehabilitation of mine spoil areas around Rann
- Control of water logging and salinity-alkalinity through agronomic practices
- Drainage management and improvement of irrigation system
- Management of arable land, permanent pastures and rangelands

These solutions to control desertification and land degradation in drought prone areas around Rann require technological improvements in traditional methods to reverse land degradation that are firmly anchored in the socio-economic and policy contents of the government.

4.1. Programmes for Combating Desertification

The programme and initiative to combat desertification is broadly categorized in strengthening 6 areas including land, water, livelihoods, renewable energy, science and technology initiatives, and sustainable land and ecosystem management. A total of 27 programmes were initiated for the period between 2007 and 2010 by the Government of India in collaboration with UNCCD (MoEF,
India is a party to the UN Convention to Combat Desertification (UNCCD) and MoEF is the National Coordinating Agency for the implementation of the UNCCD in the country. A 20 years’ comprehensive National Action Programme (NAP) to combat desertification in the country has been prepared. The objectives are:-

- Community based approach to development,
- Activities to improve the quality of life of the local communities and create awareness.
- Drought management preparedness and mitigation,
- R&D initiatives and locally suited interventions and,
- Strengthening self governance leading to empowerment of local communities.

Rann, though hostile environment, has considerable utilization potential. The activities like salt farming in a planned manner, prawn fishery, Artemia culture, and biodiesel production are some of the future prospects of the Rann of Kachchh.

4.2. **Livelihood Improvement of Salt Producers**

There are significant ways to improve the quality of life of the communities engaged in salt making viz., ensure primary education to every child that goes to the pan or stays at home, ensure drinking water at the pan level through centralized mechanisms or decentralized technologies at the farmer level, ensure routine health and medical services for communities on salt pan and main land NGO networks, promotion of technologies to improve salt manufacture less of drudgery and make available plant oil at competitive prices so as to make significant cost savings in the salt making operation.

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**Programmes for Conservation of Land Resources**

- Land Development and Conservation Programmes
  - National Watershed Development Project for Rainfed Areas (NWDPRA)
  - Soil Conservation in the Catchment of River Valley Projects (RVP/FPRs)
  - All India Coordinated Research Project for Dryland Agriculture (AICRPDA)
  - CAPART Aided Watershed Projects

-Programmes for Natural Resource Conservation

-Programmes for Ecorestoration of Degraded Lands
  - Integrated Afforestation and Eco-development Project Scheme (IAEPS)
  - Integrated Wastelands Development Programme (IWDP)
  - Eco-Task Forces
  - Scheme for Reclamation of Alkali Soils

-Special Programmes for Desert & Drought Prone Regions
  - Desert Development Programme (DDP)
  - Drought Prone Areas Programme (DPAP)
There should be formulation of Government policies for salt producers to ensure that they get the best price for their hard work and there should be some subsidies or schemes for Agariyas so that they can buy machineries to produce salt and improve their livelihood.

4.3. Conservation and Management Measures

Conservation and management of an area requires clear understanding of the role of different environmental, ecological and social factors. One of the necessary prerequisites for conservation of any area depends on the various environmental attributes prevailing there. Keeping these aspects in mind following measures could be opted to improve the environmental conditions in the Rann.

- Develop a comprehensive conservation plan and collect information on physico-chemical properties of soil and water which directly have an effect on biodiversity of the area. The research project should also focus on the species and area specific threat factors and their magnitude to prioritize the conservation and management plan.

- Apart from protection measures, it should be essential to monitor sensitive areas to assess and understand the ecological information about rare and endangered species in Rann area.

- Local communities including fishermen and Agariyas should be well informed about the breeding areas of flamingoes and the protected area boundaries to avoid conflicts.

- Environmental awareness amongst defense personnel and local villagers for the protection of biodiversity in the area.

- Environmental Impact Assessment should be a statutory requirement, even for a small scale development in the Rann area.

4.4. Is Land Reclamation Possible in GRK? A Case Study by GUIDE

Restoration of ecosystem functions is of paramount importance for the benefit of the society. Further, it is important to note that the natural recovery following degradation is a slow process; it depends on time and space, and is influenced by geographical, climatic factors and ecological conditions of the site (Singh & Jha, 1992). Therefore, a successful restoration/reclamation programme attempts to accelerate the natural recovery process through eco-friendly exercises in order to achieve the goal in a short time.
In order to restore the productive and protective functions, a degraded land needs human assistance, i.e. protection, pre-treatment for habitat rectification such as soil moisture conservation amendments, slope modification, nutrient and organic matter amendments, etc. (Singh & Jha, 1992). Further, soil, water and vegetation are the most vital natural resources for the survival of man. To obtain optimum production of vegetation, the other two resources, i.e. soil and water, will have to be managed efficiently. Man’s struggle for land resource conservation started in antiquity. Until recently, most of the success in obtaining higher productivity from arid and semi-arid regions came through the traditional techniques of land resource conservation (Altieri & Toledo, 2005).

It is also important to note here that, Chapter 22nd of the 3rd Five Year Plan of Planning Commission (1960) emphasized a pilot project for examining the methods and economics of reclaiming desert lands in a portion of the Rann of Kachchh through suitable soil conservation measures including afforestation and pasture development. The afforestation of *Prosopis chilensis* along the Banni-Rann fringe covering an area of 31,500ha during the year 1960-61 was the outcome of the above recommendations of the Planning Commission. However, no other interventions were carried in the Greater Rann of Kachchh or in any of the Bets in it (Kar et al. 2009).

With the above background, to overcome the existing ecological issues in the Greater Rann of Kachchh and to enhance the ecological status of Rann as well as socio-economic status of the local inhabitants living along the fringes of Rann, the project on “*Integrated Rann Reclamation and Development in Kachchh District, Gujarat*” was initiated on a pilot basis with financial assistance from Department of Land Resources of the Ministry of Rural Development, New Delhi.

GUIDE had undertaken the project on land reclamation from 2001 to 2007 in Great Rann of Kachchh which covered an area of 1440 ha of wastelands, including 940 ha located in the Kuar/Mori Bet area and 500 ha in adjoining Rann areas.

The aim of the GUIDE project was to create a long-term sustainability in the project area by reclaiming the saline soil through various soil amendments and water conservation techniques which may render the habitat conditions suitable for developing vegetative cover and ecological advancement. The implications are:

- Development of vegetative cover would reduce the saline underground water coming on the surface through capillary action and thereby improve the soil quality.
Soil amendments would create a suitable moisture regime for growth and production of plant species.

Addition of mixed leguminous plants will help in improving the soil fertility of the area and support further vegetative growth.

Apart from the land improvement and ecological sustainability, the developed vegetative cover would also support to meet the fodder deficit of the Kachchh district.

The development of vegetative cover would also help in enhancing the faunal diversity of the area.

Looking at the topography of the project area and the suitability / usability of contour bunding under soil and water conservation programmes in the entire Kuar and Mori bets and adjoining Rann area, a total of 99,433 CMT of contour bunds, 48,504 CMT of earthen bunds and 11,462 CMT of bunds in the Rann (50-150m from the fringes of Bet) were constructed with a height varying from 0.75 to 2.5m. As part of rain water harvesting and improvement of soil moisture, a total of eight earthen check dams, eight storage tanks and sixteen open tanks, with a total water storage capacity of 17,00,846 CMT, were developed in the project area. Apart from the above, nallah bunds (10,981 CMT of additional storage capacity), staggered trenches (1440 CMT), continuous staggered trenches (12,704 CMT), loose boulders and silt traps (4878 CMT) were also developed in many parts of the Kuar/Mori bets for land reclamation. Further, 56 earthen mounds that constitute 15,761 CMT were also developed in the high saline Rann for vegetation development on an experimental basis.

4.4.1 Vegetation Cover Development

To improve the vegetative cover, 57,480 saplings of the tree species including Acacia nilotica, Salvadoria persica, Suaeda sp., Tamarix aphylla, Phoenix sp., Casuarina sp., Delonix sp., Azadirachta indica, Aloe barbadensis, Acacia senegal, Grewia tenax, Prosopis cineraria, Albizia lebbeck and Parkinsonia aculeate were planted. In addition, 28000 saplings of Agave and 10200 saplings of Aloe were planted during the monsoon season on hilly and barren area for erosion control and development of green belt. Vegetative cuttings of Commiphora wightii (3000 nos.) were planted on rocky barren area. Seeds of different grass, shrubs and tree species were broadcasted in the project area. About 7,132 kg of different species of grass seeds and about 1,636 kg of seeds of shrub and tree species were broadcasted with healthy/nutritive soil for reclamation purposes especially in newly developed barren sites or non productive lands. It improved the ground cover
and fodder resources with a view to stabilize the bet and the fringes of the Rann areas (Figure 4.1 & 4.2).

In total, 1776ha (1324 ha in Bets and 452 ha in Rann proper) area has been reclaimed under the project. The comparative analysis of the post monsoon imageries of 2001 and 2006 highlights results of the reclamation activities of bets and Rann areas. Dense scrub has been increased from 91ha to 200 ha (+120%), grassland from 366 ha to 778 ha (+113%), surface water storage spread from 1ha to 42 ha (+4100%), while the barren area has been reduced from 857 ha in 2001 to 235 ha in 2006 (-73%).

Table 4.1 Plant Life Forms Recorded in the Project Area between 2001 and 2006

<table>
<thead>
<tr>
<th>S. No</th>
<th>Life Forms</th>
<th>No. of Species in 2001 &amp; Relative Dominance</th>
<th>No. of Species in 2006 &amp; Relative Dominance</th>
<th>% Increase of Species from 2001 to 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grass</td>
<td>12 (11%)</td>
<td>50 (19%)</td>
<td>316</td>
</tr>
<tr>
<td>2</td>
<td>Herb</td>
<td>47 (42%)</td>
<td>138 (53%)</td>
<td>194</td>
</tr>
<tr>
<td>3</td>
<td>Shrub</td>
<td>27 (24%)</td>
<td>37 (14%)</td>
<td>37</td>
</tr>
<tr>
<td>4</td>
<td>Tree</td>
<td>18 (16%)</td>
<td>18 (7%)</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Climber</td>
<td>9 (7%)</td>
<td>18 (7%)</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>113</td>
<td>261</td>
<td>131</td>
</tr>
</tbody>
</table>

*Note: Percentage are Given in Parenthesis*

Though there are reports on the failure of artificial restoration/reclamation of degraded lands (Westoby et al. 1989; Bronner, 1990), the experiment carried out by GUIDE in high saline wastelands of Greater Rann of Kachchh and its Bets like Kuar/ Mori were extremely successful. Excellent ground cover in the project area has been developed through soil amendments and water conservation measures and development of grass, herbs, shrubs and trees. Table 4.1 highlights that total 261 plant species were recorded from Kuar and Mori bet of GRK, which showed an increase from 113 species in 2001 to 261 species in 2006.

The density of trees increased from 15/ha in 2003 to 145/ha in 2006, while the shrub density has increased from 181/ha in 2003 to 3292/ha in 2006. As per the monitoring data, the biomass developed in the project area at the end of the project was 1,659 tones (at the rate of 1152kg/ha
of grass fodder which could reduce the financial burden of the government by about Rs. 33 Lakhs (assuming the subsidized rate of Rs. 2/kg of grass) annually. The enormous seed production and tillers of grass species would further increase the biomass production to the tune of 2 to 3 times in the successive years (GUIDE, 1997).

Figure 4.1 Satellite Imageries of Kuar & Mori Bet (2001 & 2006 Post Monsoon)

Fig. 4.2 Land Cover Development in Kuar and Mori Bet in GRK

4.5 Prawn Fishery in LRK

The LRK supports seasonal prawn fishery, principally constituted by juveniles of *Metapenaeus kachchhensis*, during the monsoon months. About 2770 fishermen are actively engaged in the fishery with 307 boats and 1600 fishing nets. An estimated catch of 2311.5 tones of prawns was exploited during the year 1980. Surajbari is the biggest of the landing centers with an estimated catch of 688.7 tons. Juveniles of 71-95 mm length formed the mainstay of the fishery (Rao 2009).
The Gulf of Kachchh and adjacent estuarine system supports prawn fishery of considerable magnitude. Srivastava (1953) reported prawn fishery of the Gulf of Kachchh and Lakumb (1960) described the marketing and socio-economic condition of the fishermen of the region. Ramamurthy (1963a) described the prawn fishery of the creeks and also studied the prawn fishery at Adesar camp (1963b). Many other species of prawns were also reported from LRK areas; *M. stebbingi* (Ramamurthy, 1964) and *M. alcocki* (George and Rao, 1966).

### 4.6 *Artemia* Culture

Vast area of GRK is inundated by sea water from Arabian Sea through Kori creek. Since the water travels over 90 km, the salinity levels of the water spread in the Rann area has been found to range between 70-150 ppt. During summer, salinity further increases up to 180 ppt and decreases to 40-45 ppt during monsoon due to mixing of rainwater from rivers and rivulets that debouch into Rann (GUIDE, 2007).

Commercial importance of Brine shrimp (*Artemia* species) is tremendous since it is an ideal food for the larvae of cultivable crustaceans (such as shrimps). In India, brine shrimps are widely distributed in the salt pans of Gujarat, Tamil Nadu and Maharashtra, which are identified as potential states for their commercial culture. The economic importance of *Artemia* for shellfish and marine larviculture is substantial.

Brine shrimp (*Artemia* species) is a unique marine organism having adaptability to tolerate and flourish in extremely wide range of environmental milieu (Salinity 10–138 ppt, Dissolved Oxygen-0.5-3.5 ml/l; pH 7.5-11). The salinity conditions of GRK, with salinity up to 150 ppt during summer and 40-50 ppt during monsoon provides an ideal habitat for culturing *Artemia* in GRK. The experiments conducted by GUIDE at GRK for *Artemia* cyst production from Great Rann of Kachchh region could be of immense use for future research.
Saltpan-produced cysts of bisexual *Artemia* (Thothukudi strain, TN) were collected and were used for the experiment. The number of cysts carried by the female varied from 41 to 113 (63 ± 8) in the control pond, 52 to 146 (68 ± 8) in pond fertilized with inorganic fertilizer, 68 to 196 (84 ± 8) in pond fertilized with chicken manure and 48 to 123 (65 ± 8) in pond fertilized with cow dung. It has been reported that the female *A. franciscana* produces an average production of 107 cysts, with a maximum of 303 cysts. During the present study the biomass production of *Artemia* cyst was on the higher side when fertilized with chicken manure compared to other organic and inorganic fertilizers. Thus the present study is a milestone in the case of *Artemia* cyst production from Great Rann of Kachchh. This preliminary attempt indicates that the *Artemia* cyst production is possible in Rann. Present study also indicated that fertilization pond is necessary for the production of *Artemia* cyst. Further attempts are needed to optimize the standard protocol for the production of *Artemia* cyst from the Rann region.

### 4.7 Aquaculture Potential

The prevailing scenario of GRK also prompted to explore the possibilities of experimenting aquaculture using economically important species with the consultation of experts of Marine Product Export Development Authority (MPEDA), GoI. Based on the expert advice, three experiments using different species like *Metapenaeus kutchensis* and *Chanos chanos* were carried out in GRK. The success of the experiments would help us to decide the reliability of such models by the villagers located along the fringes of Rann area. It would also help in improving the socio-economic condition of about 25 villages of Kachchh district located along the fringe of Rann besides providing a nutritive food source to the local people of Pachchham, Banni and Security Personnel, covering a population of about 30,000. Some species, which are experimented, are described below:

*Metapenaeus kutchensis* is an endemic prawn species available in the Gulf of Kachchh. It possesses a wide tolerance to different environmental conditions, especially salinity and temperature, which makes it a prospective candidate for culture in suitable sites of Rann, especially in GRK. For undertaking prawn culture using *Metapenaeus kutchensis* and other species, a culture pond was developed in the project area, which included a reservoir to collect excess rainwater from Aqua check dam (a back up check dam to support the experiment), a mixing pond (to get appropriate salinity range for the experiment by mixing saline water from Rann and fresh water from reservoir)
and a culture pond (for culturing activities). Though the candidate species were amendable under the prevailing conditions in the Rann area, in reality, the experiment was not successful due to severe droughts that prevailed during 2002-03 (78mm) and 2004-05 (16mm), and heavy floods during 2003-04 (over 544mm in 36hrs). This unexpected heavy downpour and highly raised water table in the Rann (sea water from Kori creek, rain water from Kachchh mainland, Rajasthan and even from Pakistan) damaged some portions of the aquaculture structures. Due to this damage, the experiment was not undertaken during the project periods. However, the area has the potential to undertake aquaculture trials during normal rainfall years.

### 4.8 Biodiesel Potential and Diatoms

Rann environment is ideal for the growth of diatoms with high lipid contents, suitable for extracting biodiesel. No attempt in this direction has been taken so far. The marine team of GUIDE has submitted a proposal to MoES on Culture, Screening and Characterization of Marine Diatoms for Biofuel Potential from Rann of Kachchh, Gujarat with the following main objectives:

- **a)** Collect and screen potential species of diatoms from Rann of Kachchh for lipid production in their natural environment.
- **b)** Characterize selected strains by triggering lipid production; quantify growth rates and lipid productivity as biodiesel feedstock.

The study will identify the most potential local diatom strains in Rann for mass culture attempts for the purpose of lipid and biodiesel extraction. The proposed investigation will characterize the productivity and lipid (oil) yields of various strains of diatoms which will have a significant bearing on the industrial level outdoor culture conditions. Desirable characteristics like high productivity, high lipid content and tolerance to fluctuations in temperature, salinity and light intensity will be conclusively known for the identified strains which will have practical application in outdoor mass culture activities.

### 4.9 Tourism Options

Most of the areas of GRK are under the control of Indian Army and therefore inaccessible for civilians due to security reasons. However, the white Rann located near Dhordo village of Banni attracts thousands of tourists every year. Rann of Kachchh is in highlight during the recent years due to “Rann utsav” initiatives by the Government of Gujarat. It gives an opportunity to the visitors
from India and also from other parts of the world to enjoy the scenic beauty of White Rann. This programme has been boosted the Gujarat Tourism Nigam Limited in a great success. Apart from this, Kalladungar (Black Hills of Kachchh) which is the highest point (410m) in Kachchh district located in Pachchham area of GRK, the Harappan excavations of Dholaveera in Khadir island of GRK and LRK (WAS) attract many tourists and researchers of diverse interests.

4.10 Research Gap

There is an urgent need to identify research gaps, as very sparse and fragmentary information is available on environmental aspects of Rann of Kachchh. GRK is a unique environment with high amplitude of salinity variation during summer and monsoon. This condition provides ideal habitat for a variety of microorganisms, flora and fauna. A detailed study of microorganisms in GRK is very essential since many have excellent commercial values. In the same time, intensive survey and research needed on the rare and threatened flora and fauna for their conservation and management point of view. The above activities will help in maintaining the environment and ecological system of Rann remain naturally and forever.
Bibliography

Agariya Hit Rakshak Manch (AHRM) (2007) Workshop on issues of salt workers, organized by AHRM in Association with Central Salt Commissioner’s, Office of Industry Commissioner – Gujarat & Tamil Nadu Salt Corporation Ltd. supported by Care (India) Snehal Programme.


BCRLIP (2007) Biodiversity Conservation and Rural Livelihood Improvement Project for Little Rann of Kachchh Landscape Indicative Plan prepared by Centre for Environment and Social Concerns (CESC), Ahmedabad


Burnes, A. (1835) A memoir on the Eastern Branch of the River Indus giving an account of the alterations produced by it by an earthquake in 1819, also a theory of the Runn, and some conjectures on the Route of Alexander the Great, drawn up in the years 1827-28, Royal Asiatic Soc., 3: 550-588.

Business Standard (2006) SolarisChem to invest Rs. 120 cr over 3 years, New Delhi, May 2006


GUIDE (2002) Kachchh sub-state biodiversity strategy and action plan under the national biodiversity strategy action plan (NBSAP).


GUIDE (2011) A Study on the Effects of Desertification and Climate Change in Kachchh, Banaskantha, and Patan Districts of Gujarat State


Jothimani, P. and Garg, J. K. (1992) Mapping and monitoring of Rann (tidal) ingress in Banni plains, Kachchh, Gujarat using multi-temporal satellite data, remote sensing applications group, space application centre, ISRO


Macmurdo, J. (1824) Paper relating to the earthquake which occurred in India in 1819. Philosophical Magazine and journal, 63: 105-119.


SANDARBH (2008) Ahmedabad, for National Consultation on Salt Workers, India, Yet to be Freed Agariyas’ Lives and Struggle for Survival in the Little Rann of Kutch.


