4. DISCUSSION

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4.1 Remote Sensing in Agroecosystem

Satellite remote sensing technique having unique characteristics of synoptic viewing, repetitive coverage and reliability of the data has proved to have great potentials in the study of agroecosystems of the world. From the early days of Landsat 1 programme (1972) to the present time, scientists have made extensive use of Landsat data for agricultural research (Everitt **et al.**, 1988 and Rundquist and Samson, 1983). The photosynthetically active reference spectrum of vegetation that displays low reflectance in the visible (Ø.4 to Ø.7 nm) and high reflectance in the infra-red (Ø.8 to 1.3 nm) spectral region have been exploited for crop condition assessments, crop area estimation, yield model development, soil moisture study, renewable resource inventory and further for proper management and planning. In this study this technique has been successfully used to highlight agricultural degradation in the form of saline soils and the resultant stress on the vegetation. Data generated during the joint Indo-Soviet manned space flight in April 1984 by using hand held Kate-14Ø camera in the Salyut-7 space station has given very accurate information on the saline degradation of soil but it lacks the repetitive coverage of satellite information, making the Landsat or IRS-1A data more suitable for the study of temporal environmental degradation. Of the different platforms available, the Landsat TM and the IRS-1A LISS II having a resolution of 3Ø and 36.5 m respectively have been found to be more efficient than the multispectral modes in the saline soil delineation. For any successful study there is a need for selecting data of correct season as properly identified earlier in the delineation and mapping of saline soils (Dwivedi **et al.**, 1987). As the manifestation of salt efflorescence is reflected on the satellite image, careful selection of remote sensing data representing almost identical soil moisture condition at two different periods seems imperative. Further any data having an interference of ground vegetation or atmospheric clouds can mask the accurate delineation of the saline lands. So, the premonsoon cloud free data with scanty vegetation and meager cultivated crops has been found to be best suited for saline soil studies. However this is not suitable for vegetational mapping for which the cloud free postmonsoon datawere required.

4.2 Salinity Detection in the Agroecosystem

Saline soil delineation in agricultural environments using satellite imageries has been well known since the early seventies, (Colwell, 1974b; Everitt **et al.**, 1981, Myers **et al.**, 1983). The saline soils can be accurately mapped from the satellite data based upon the tonal variation in the visual interpretation and digital number in the digital analysis. Saline lands appear to be light or grayish white in the MSS black and white image of bands 5 and 7. As early as 1973 the use of band 5 and 7 in soil studies has been attempted by Elberson (1973). Of these two bands, band 5 gives the maximum information than band 7, confirming the report of Manchanda and Hilwig (1981). Much better delineation of saline soils is possible with the Landsat MSS FCC and TM FCC involving the combination of bands 4,5,7 or 1,2,3 respectively, in which the saline lands appeared white to bluish white in colour, making easier the saline soil detection. The use of false colour composite has been first employed in the delineation of saline areas from non-saline areas in the studies of Mahi Right Bank Command by Kalubarme and his co-workers (1983). Later with the development of thematic information segregation of three different categories has become a reality in the present study. The classification of degraded soils into slightly, moderately and strongly saline affected soils has been well marked particularly using the Landsat TM data. However in earlier studies, Venkataratnam (1980) has been able to distinguish not more than two categories viz. saline and highly saline soils. The significant per cent accuracy presented in Table 9 further supports and proves the categorisation of saline lands into three in the present study. Earlier work in 1987 by Nayak and his team reports an overall interpretation accuracy of 84 % in studies involving coastal salinity using TM data. According to their finding the main inaccuracy results from the misclassification of salt affected areas as non-saline areas i.e., agricultural lands, whereas, in our studies the major interference is from the non-saline soils like "Goradu" registering as moderately saline soils. Similar to the efficient use of FCC in the visual image interpretation in the categorisation of salinity, digital image processing scores over the visual interpretation (Anuta, 1977). It utilizes the entire dynamic radiometric range of sensor data integrating and simultaneously utilizing the data from the different spectral bands for classification purposes. Digital format also provides a convenient way to transmit, store, retrieve and use image data. Further it can be subjected to different processing algorithms keeping the original data intact. Thus, computer aided analysis of Landsat multispectral data has been found to be useful for delineating soils with higher efficiency and reasonable accuracy by various workers, (Kristof **et al.**, 1977; Roundabush, **et al.**, 1985; Weismiller **et al.**, 1977; Westin, 1982). It has also proved to be a good aid in saline soil delineation. (Al Mahawili 1983; Sommerfeldt **et al.** 1985; Singh and Dwivedi, 1989). Use of digital analysis has rendered delineation of two classes in each of the three earlier categories in the present study but the divergence matrix proves the inability of such classification. Thus it has clearly exhibited the difficulty in the elaborate categorisation of saline lands with the available thematic resolution in the Landsat or IRS-1A data.

Digital indices are also of great use when employing CCT information. Kauth and Thomas (1976) found that nearly all (98 %) of the variance in bare soil spectra from several different soil types can be explained by the SBI image. They have concluded that the bare soils may lie in a line parallel to the brightness axis and a globally valid soil line exists which can be applied to MSS agricultural scenes. Our study is also the first report of the successful use of MSS equivalent coefficient for IRS-1A LISS II data in generating the Soil Brightness Index (SBI) image delineating 5 different categories of soil based upon the soil brightness, of which three indicate to the salt affected lands. Though the similarity of the saline patches is clearly evident between the visually interpreted data and SBI images, Bittner and Csillage (1989) have recommended a new soil brightness and Normalized Vegetation Index image as they have found it to be far superior than the SBI output alone in soil categorisation. Though the supervised classification on the Multi Spectral Data Analysis System (M-DAS) based on the maximum likelihood algorithm attempted in this study has generated six distinct saline classes depending upon the spectral values, the Divergence Matrix proves clearly the close similarity of the two classes within severe and moderate categories, thus strongly suggesting not to attempt more than 3 classes in the saline soil categorisation. Robinove (1981) has suggested that such classification schemes may be rigid based on a prior knowledge and are difficult to develop and difficult to use. Nevertheless, they are widely employed because they theoretically provide a framework where the results can be comparable.

A multitemporal mapping of saline soil in Khambhat taluka has indicated an increase in the saline spread in these areas. The increase in saline soil in Khambhat taluka in a span of 12 years has been considerably high (Table 7). A gradual increase has been noted from the year 1975 to 1985 followed by a steeper increase during 1986-87, years of meager rainfall preventing proper leaching of salts during monsoon. In addition, the canal irrigation facility has become negligible leading to a decrease in the cultivation of crops as evidenced by the 93 % decrease of hectarage in the rice cultivation. (Table 37). The uncultivated fields having goradu soils and registering as saline soils may have partly caused the sharp increase in the acreage of saline lands. It is essential to avoid such interferences by the use of post-monsoon data alongwith the pre-monsoon satellite data and also with a prior knowledge of the history and details of the edaphic factors of the area under study. The availability of images being limited, details of soil have been taken into consideration while working at microlevel.

The salt accumulation in a soil profile largely depends on the soil drainage condition, in addition to topographic situation (Pathak and Patel, 1980). Of the several factors that have contributed to the development of salinity in Khambhat taluka, the implementation of heavy irrigation scheme and sea-ingress due to the proximity of this area to sea accounts for the two major factors. The topography of the MRBC area is quite uneven with a very gentle sloping that becomes totally flat in Khambhat taluka resulting in an inadequate drainage system, besides the poor outfall conditions near the Gulf of Khambhat. The unlimited use of canal water under inadequate drainage provision mixed with seepage through distributory system, stagnation of water due to field to field irrigation and poor outfall condition haveled to a rapid rise in water-table. Myers and others (1963) observed similar development of saline soils in many arid areas. Several other soil scientists have shown the rise of water level in soil and mineralisation due to irrigation (Chang **et al.**, 1985, Kharazhanov and Khaibullin, 1984; Kistanov and Shmyglya 1979; Somvanshi and Patil 1986). The water moving upwards brings considerable amount of dissolved salts which are deposited in the surface layers where the water is transformed into vapour phase (Nakayama **et al.**, 1973). Prior to canal irrigation cotton and wheat have been cultivated in the north of the taluka and the wheat has been grown in the southern region after the suppression of the surface salinity by natural leaching through the monsoon precipitation. The introduction of canal system provided farmers with perennial supply of water to their field. This has induced a change in the cropping pattern that finally resulted in waterlogging. The texture of the soil of this area being clayey to clayey loamy with an infiltration rate of 0.07 to 0.08 cm/hr has aggravated the situation as subsoil of this area is inherently saline yielding a rich efflorescence of the salt on the surface by the capillary rise (Plate 1 and 2). The Irrigation Department, Government of Gujarat since 1960 have indicated that the water table in the MRBC command has risen at a rate of 0.375 m/yr in clayey soils and 0.76 m/year in the sandy loam soils (Kalubarme et al., 1983). The southern part of the taluka is affected by sea-water ingress. Factors affecting coastal salinity have already been discussed by Chavan et al., (1984). Sea-water ingress near the coastal area becomes predominant specifically in the summer months of the year i.e., when the river flow either becomes limited or when it dries during the summer months.

The first study carried out in this area by Kalubarme and Co-workers (1983) indicated a progressive increase in salinity from 1972 to 1977 in the whole command area. However, talukawise information was generated for the first time in this work. Similarly, the Ukai Kakrapar irrigation scheme is one of the major river valley projects in the State of Gujarat Commissioned in 1954 and supplemented later by Ukai reservoir in 1972. (Mistry and Purohit, 1982). Sahai and others (1983) using multitemporal (1972-1981) and multispectral Landsat data supplemented with multi-temporal colour infrared black and white aerial photographs has revealed interesting results of changing cropping pattern in this areas, accompanied by increase in salinity. The use of multidate multispectral Landsat imagery supplemented by aerial colour infrared photograph has been a common technique in the delineation of saline lands in the eighties (Kalubarme **et al.**, 1985). As the use of aerial photographs has become more and more expensive, scientists interested in monitoring of saline lands have turned to purely satellite data. Mapping and monitoring of salt affected soil in Karnal district of Haryana has been achieved by Hooda **et al.**, (1989) by the help of Landsat MSS FCC of 1973, Landsat-TM FCC of 1986 and IRS-1A LISS II FCC of 1988 and they have proved that the saline area in the fields of this part is on the decrease from 12.85 to 3 % of the total geographic area studied.

4.3 Saline Mapping at Microlevel

Satellite remote sensing technique in monitoring of saline lands has progressed fast from the command area and localized district levels to taluka studies and also aerial photography supplementation to independent usage of satellite images, as the satellite sensors have evolved from MSS mode with pixel resolution of Ø.4 ha to TM resolution of Ø.Ø9 ha. The images have been expensive for frequent usage till the operationalisation of IRS-1A with two LISS sensors one with 72.5 m and the other with 36.5 m resolution. With the development of thematic sensors the modern satellite mapping from taluka level to village level became possible. The microlevel mapping of village at 1:50,000 scale has registered the saline patches in a more accurate and detailed manner. This study identifies that out of 101 villages of Khambhat taluka sixty three are affected by mismanaged irrigation. This microlevel salinity detection can help the planners at the district level to take the necessary action. This study has clearly proved that the potentiality of thematic satellite data can be fully tapped to suit the needs of Indian agro ecosystem. The further extension of this microlevel studies to plotlevel carried out by manipulating saline data on the village cadastral maps. The overall accuracy for plotlevel mapping has been found to be 90 % at 90 % confidence level. However, while working at the plot basis one has to keep in mind the resolution power of the images used. The satellite thematic data with a pixel resolution of 0.09 ha may have serious limitations to microlevel studies as some of the fields in the Indian villages may have areas lesser than a pixel resolution. This can be overcome by considering the plots in groups and also employing colour additive techniques in the form of FCC product. Moreover, the IRS-1A LISS II data is more economical than the TM data. The digital analysis can meet the challenge with its various techniques in the form of different classification or indices coupled with Geographical Information System (GIS) (Bracken and Webster, 1989). The second problem that arises in this study is a variation among the boundaries of the taluka census map with village boundaries and the village cadastral map available at the District Office. So while mapping at village level great care has to be taken to avoid the mapping error.

4.4 Vegetational Status in Saline Lands

4.4.1 Remote Sensing

Landsat TM data has been found to be very useful in the vegetation mapping. In our study a large area with thick vegetation has been observed in the winter, after the regular monsoon, as compared to the summer and is registered in the FCC as light pink to red. Four vegetational levels, viz., Dense medium, Sparse and nil have been identified. The complete absence of red colour indicates the absence of vegetation. The tonal variation registered by the satellite sensors is mainly dependent upon the reflection from the vegetation. Healthy green vegetation generally reflects 40-50 % of the incident near infrared energy (0.7 to 1.0 μm) with the chlorophyll in the plants absorbing approximately 80 to 90 % of the incident energy in the visible (0.4 to 0.7 μm) part of the spectrum (Jensen, 1983). Dead, senescent or stressed vegetation reflects a greater amount of energy than healthy green vegetation throughout the visible spectrum (0.4 to 0.7 μm). Conversely, it reflects less than the green vegetation in reflective infrared region. In this study the winter data has been visually interpreted for the vegetation identification and the shortage of funds have forced us to use the summer CCT of IRS-1A data for digital analysis. The computer-assisted analysis techniques from the beginning has laid more emphasis on vegetative mapping application in agriculture (Fu **et al.**, 1969, Nagy, 1972, MacDonald **et al.**, 1975). A common approach to quantify canopy through multispectral data is to synthesize the information present in different spectral channels in the form of indices. The idea behind developing such indices is to compress the huge amount of multispectral data in such a way that spectral properties of canopy get enhanced and interference of other area features or variability due to different illumination condition is reduced. Vegetation index defined in terms of crop reflectance in red and near infrared bands has been found to be a sensitive parameter for monitoring vegetation in general and to distinguish normal plants (Tucker et al.,1979). Thompson and Wehmanen (1978) have used satellite (Landsat MSS) spectral response to derive greenness spectral vegetation indices for monitoring crop water stress. For digital vegetational analysis, in this study, the Green Vegetation Index (GVI) image generated using MSS equivalent coefficients has provided the base for further digital classification of different vegetational levels. The maximum likelihood supervised classification scheme adopted, classifies the image into 5 different vegetational classes. Supervised classification has been used for vegetational mapping with varying degrees of success (Dodge and Bryant 1976; Mead and Meyer, 1977; Williams and Haver 1976). A vivid negative correlation has been observed between the different saline categories and vegetational levels. Vegetation decreases with the increasing salinity in our study. The field survey confirms the above and brings out decreased crop and weed diversity in the degraded lands.

4.4.2 Crop Studies

From the list of crops cultivated at Khambhat taluka (Chapter III) it is very clear that farmers of this area do not have a good knowledge of saline resistant crops. Though, rice has been identified to be tolerant to salinity by earlier workers as against other crops like cotton, maize, tobacco, sorghum etc., its tolerance against salinity has been recognised very well to be cultivar specific by others (Flowers and Yeo 1981; Hegde and Joshi, 1974; Krishnamurthy **et al.**, 1987a; Paricha **et al.**,1975; Rathert 1983; Yoe and Flowers 1982). Also tolerance of rice to salinity varies at different stages of growth (Janardhan and Vaidyanath, 1984; Lehman **et al.**, 1984; Krishnamurthy, 1987). The salinity affects critically at the early seedling stage and later at the flowering stage decreasing the yield considerably. In fact salinity is regarded as the single soil toxicity problem facing rice production (Greenland 1984). Thus, there is clearly a need to develop saline resistant rice cultivars which has been approached by mass screening of 70,000 cultivars currently existent to identify those with natural salt resistance to use as donors of the trait. (Ponnamperum, 1984). Among the other crops cultivated in Khambhat Bajri (Pennisetum typhoides (Burm) stapf. Hubb can withstand moderate salinity with much reduced economic yield (Chapter III). Among the rabi crop wheat can grow in the fields of moderate salinity. Mondal and Sharma 1979 have also reported earlier the tolerant growth of wheat in saline medium of 8 dSm^{-1} and less and the successful wheat cultivation on saline and sodic soils depends upon the leaching of salts by rain water.

Further the same groups has identified, to reap a successful wheat crop in saline soils, the use of frequent irrigation with less water keeping the total water requirement as per the agricultural practices particularly when the irrigation water is saline (Sharma et al., 1977).

Mainly the crop response to salinity depends upon crop type, fertilizer type and soil and climatic conditions. So successful cultivation depends upon the thorough knowledge of the edaphic and climatic factors of the study area in addition to repeated laboratory and field experiments to decide the correct crop and its cultivar to be cropped in the degraded soils. While selecting the cultivars for propagation under saline condition, shortcut physiological trails like accumulation of proline or polyamines or increased titrable acid number in the shoot system can be of great advantage (Krishnamurthy et al., 1987b; 1987c; Krishnamurthy and Bhagwat, 1989). In the present study, only laboratory and field trials have been used to select the correct cultivars for the saline lands of Khambhat, as a detailed study in the selection of crops and their cultivars of great dimension is beyond the scope of this work. This study has identified some rice cultivars like Mahsuri, SRB-26 and SLR-51425, to survive salinity upto 14-16 dSm^{-1}. These along with other saline resistant South Indian rice cultivars can become good substitutes in the Kharif season at Khambhat. Considerable decrease in the economic yield met in the above investigation under strongly affected soils provokes the question whether just the biomass accumulation can be encouraged in the absence of considerable grain yield as a method to trigger successional factors to normalize the land. Normalization means practically getting the toxic salts out of the soil to make it suitable for cultivation and give it structural and physicochemical properties of the right type. Generally any crop requiring heavy irrigation may damage the land further under the above said conditions. So the choice of the crop has to be one which requires light irrigation. Even among rice cultivars upland salt tolerant cultivars can be a good try coupled with other agricultural knowhow developed specifically for saline reclamation such as, addition of organic material in the form of compost i.e. organic manure or green manure or blue green algae that has been well known to reduce the adverse effect of salinity (Dargen **et al.**, 1976; Kaushik and Subhashini 1985; Singh **et al.**, 1984; Anand, 1986). Maintenance of selected species of weeds or trees in the bunds between the canals and cultivable lands; much reduced irrigation with sprinklers or trickle irrigation in place of field to field irrigation; digging drainage ditches to siphon out the fluid accumulated in the drainage pits and use of gypsum and other chemical reclamative methods. Decisive field trials have to be undertaken before implementing them on a large scale to save the degenerating arable lands. Basic approaches to get rid of the soil salinity to some extent, is to keep the land under continuous cropping and avoiding to keep it fallow for a considerable period. This helps in checking the accumulation of salts in the upper crust of the soil. Preliminary trials carried out at Khar land Research Station, Paragon, Maharashtra, indicates successfully that it is also possible to grow other salt tolerant crops like spinach, radish, mustard, water-melon, chilli, Asparagus, barley and vegetables with minimum protective-irrigation in rabi season for better economic returns to farmers (Operation Research Group, 1984). Similarly recent work at Cannings (West-Bengal) has proved that cultivars of chilli, barley, linseed, mustard, sunflowers and sugarbeet can be used as rabi crops fairly well at saline levels of ECe range 5-10 dSm^{-1}. Also some of the above suitable cultivars can also be grown in summer in the partly reclaimed soils. Another approach to this problem is to consider the cultivation of good quality fodder where the food crop cultivation becomes a major constraint. The quality checked straw from the tolerant cultivars can be of good forage value in the degraded lands during kharif season. Further some native species that possesses some remarkable salt tolerance and exhibit superior growth performance and production potential under a range of salinity stress can be considered seriously to develop a good herbage cover in the degraded lands. Good forage production by growing some selected grass species like Karnal grass, paragrass, etc. interspaced with or without trees, along with the other economically important grasses like Vetiver (recommended as wonder grass by World Bank) needs very serious consideration here (Grewal and Abrol 1989, Sinha **et al.,** 1988). Sinha and other (1986) reported an increased dry and green forage yield of sorghum helepense at high soil salinity.

Production of agricultural crops in irrigated arid and semi-arid areas is greatly influenced by the presence of soluble salts in the root zone of the soil. The main factors for the degradation of crop and vegetation in our study area is the salt accumulation in soil, resulting in the development of saline toxicity. The pH values ranging between 7.5 to 8.0 in the affected soils of this area confirms the soil to be saline. The soil pH of 7.7 under strong salinity might have been resulted from the constant use of acidic green manure (Luken 1962). The ion toxicity of the saline areas are due to the accumulation of exchangeable cations like Na^{+} and anions like Cl^{-} and SO_4^{2-} as evidenced by the increasing trend in their presence from normal to severe soils collected in winter and summer. Mostly the ionic levels of winter are lower than that of summer mainly due to their leaching in monsoon. The severe drought of 1987 has allowed negligible leaching of the surface soil in our study area. Sometimes such shortage in water can lead to vertical leaching which is also not evident in our studies as the ionic content of the surface soil collected in winter is more than the soil at one feet depth, indicating to the acute shortage of the rainfall in this area in the year 1987 to allow any vertical percolation. Increasing exchangeable Na^{+} in the soil affects the ratio of Na^{+} to Ca^{2+} + Mg^{2+} as a result the toxic Na^{+} competes more effectively with Ca^{2+} + Mg^{2+} for cation exchange sites, making the ESP values very important in saline soil studies. Surprisingly in some site of Khambhat a high content of Ca^{2+} has been noted indicating to the ameliorative attempts using gypsum by the farmers. A high ESP in the soils, can very well create deficiency of other important exchangeable essential elements like, Zinc, Manganese or Iron, due to which the plants may succumb rather than due to Na^{+} toxicity alone (Singh 1989).

Under severe salinity reports of toxic levels of Zn^{2+} and Mn^{2+} are not uncommon. In addition to the Na^+, increase in Cl^- or SO_4^{2-} can also affect the plant growth adversely (Greenway 1965a; Ashraf **et al.**, 1986). Study on saline soils and saline resistant varieties is not complete without the mention of saline resistance mechanisms in crops.

The mechanism of salt resistance involves avoidance of salt intake in the system by exclusion, excretion or dilution and tolerance of salt by avoiding the ion imbalance by storing the excess salt in the vacuoles or tolerating it by special adaptations (Levitt, 1972). Saline substrate affects the plants by imparting osmotic stress, well-known as physiological stress first in the roots which is later transmitted to other parts (Nieman 1965). This effect is counteracted by the synthesis of organic osmoregulants and by the increased uptake of inorganic ions. In halophytes the osmotic adjustment is mainly due to Na^+ absorption (Yake **et al.**, 1965). Generally there is increased uptake of sodium and chloride when halophytes or glycophytes are subjected to NaCl salinity. Yeo and flowers (1983) have noticed a strong negative relationship between shoot sodium level and survival of rice cultivars. In rice the high sodium uptake results in least survival as depicted by the increased mortality in our studies and else where (Miyamoto, 1984). Imamul Huq and his Coworkers (1983) reasons out that the increasing toxic levels of Na^+ as a result of NaCl exposure inhibits the entry of different valuble essential inorganic ions like K^+, Ca^{2+} and Mg^{2+}, resulting in their deficiency (Solovev, 1969). Salt sensitive cultivars have low accumulation of K^+ levels, paralleled with high sodium and alternatively other tolerant cultivars indicate the reverse or a decreased percentage in the reduction of essential elements (Greenway, 1963, 1965a, 1965b; Krishnamurthy **et al.**, 1987a). This mechanism is evident in the rice cultivars in the present study too. The ratio of K:Na seems to be an important factor in deciding the resistant capacity of crops. However, the weeds present in the severe saline soil indicate definite saline resistance by avoiding the toxic Na^+ ions. The presence of Ca^{2+} in the root saline medium is very important, as Ca^{2+} has long been known to antagonize the injurious effects of the Na^+ ion (Levitt, 1972). The accumulation of the Na^+ and K^+ in rice here, indicates selectivity in the uptake of K^+ ions and partitioning of salts in stem is attributable in the presence of high salinity.

4.4.3 Phytosociological Studies of Weeds

Phytosociological analysis of plant communities at five different sites has revealed distinct influence of soil salinity on the weeds of the rice fields. This is evident from a severe decrease in the Species Diversity Index and the Species Richness Index with increasing soil salinity. Similar observations have been made by Sinha and others (1988). Correlation between harshness of climate and a reduced species diversity has already been evident from the work of Mac Arthur (1975). Though the species diversity is low in the affected fields, certain plants growing in this area has the ability to withstand high salt levels which has been considered by McNaughton (1977) to be a decisive factor in imparting stability to a system. These low diversity communities mainly tend to share the resource in accordance with the Niche pre-emption model. In the Niche pre-emption model the most successful species is seen to be pre-empting a fraction of the Niche the next, a fraction of the reamainder and so on to give a geometric series distribution of relative abundance. The dominance diversity curves presented in the present study also fit best in the geometric series of Niche pre-emption model. Curves approximating geometric series are of fairly wide occurrence and appear for some communities that have rigorous environment with only a few species widely scattered along the logarithmic scale of relative importance (Whittaker, 1965). Less steep geometric slopes also appear for some communities with less severe environments and moderate species diversity. Whittaker (1965, 1970, 1972) has reviewed data from some plant communities generally with a few species and either in a successional stage or in a harsh environment, where the species abundance distribution approximates a geometric series. The curves for the species distribution has also flattened from normal to strongly salt affected soil as suggested earlier by Odum (1971).

Various indices of diversity, dominance or eveness have been reviewed by Whittaker (1972), Dickman (1968), Pielou (1969), Johnson and Coworkers (1968), Hurlbert (1971), De Benedicts (1973) and many others. The Similarity and Eveness Indices, studied in this study, follow a decrease from normal to strongly saline soils. This decrease in Indices of Evenness and Similarity may be due to the appearance and disappearance of certain species with increasing soil salinity. This trend of appearance or disappearance of these species can give an indication of salinity emergence in a given area. For example the weed Commelina benghaleasis L. has come into existence with the appearance of slight soil salinity, while with the increasing soil salinity most of the species including Commelina disappeared and only those which can tolerate high salinity survived in the strong saline soils. There is also emergence of salt tolerant species like Cressa Critica L., Suaeda fruticosa forsk ex gmel. Aeluropus lagopoides, and Prosopis Cineraria. This is very well depicted from the low values of Similarity Index between the species of normal and low and low and moderate saline soils and total dissimilarity between the species present in normal and moderately salt affected or strongly salt affected fields. The role of soil salinity regime on the distribution of the species is indicated by the low indices of similarity between the communities from normal and saline affected fields. The total dissimilarity indicated that under stress condition there is natural selection for those species which have more efficient means to recover and propagate after the stress, (Mac Arthur, and Wilson, 1967).

Natural communities are mixture of species which are unequally successful, but still in a given community the dominants overshadow all others in their mass and biological activity and may strongly affect the condition of environment for other species (Whittaker, 1965). These dominants increase in number with the increase in stress condition reducing the species diversity greatly. This is very clear from the Important Value Indices (IVI) of the phytosociological study carried in the fields of Khambhat taluka. The phytograph prepared considering the maximum IVI values in each category has brought out this picture more clearly when compared to the phytograph prepared considering the average IVI values at each salinity level.

4.5 Reclamation of Saline Soils

Several remedial measures have been adopted in the degraded lands of Khambhat taluka for reclamation. The major one is of hydrotechnical amelioration and consists of the leaching of the ions, through small drains, by building trenches below the root zone. Besides, chemical amendments in the form of application of gypsum and sulphur and biological amelioration like application of organic manure have also been attempted. The methods to be adopted for reclamation have necessarily to be based upon a proper understanding of causative factors which have led to the development of saline and alkaline conditions in the soil. Kelley (1951) reviews for any reclamation technique to be met with, firstly by the complete removal of salt or alkali from the root zone, secondly by preparation of land from reverting to the original conditions and thirdly by the substantial repair of the damage already done to the soil. In actual practice the reclamation can be made much more effective and speedy by combining various ameliorative methods since the interaction between them can possibly bring in more spectacular results then when they are applied singly. Also the implication of different reclamation techniques may differ from place to place depending upon the varying nature of the degradation, soil texture and topography.

Several countries have adopted different practices for reclaiming the saline lands. The U.S.A. has made rapid strides in the establishments of salinity tolerance differences amongst a large variety of crops, water and salt movement and leaching requirement, computation of regional salt balance etc. while the U.S.S.R. and Egypt have gained valuable experience on various reclamation methods in the fight against salinity depending upon various soil types. Among the major practices are the use of chemical amendments, especially gypsum, use of biological manures, leaching of salts and growing of Dhaincha along with crops (Boyko, 1966, Agarwal **et al.**, 1982; Mathur **et al.**, 1982a, Mathur **et al.**, 1982b; Rathor and Bajpai, 1977).

Based upon our studies and others in this area, the need for preventive and reclamative efforts to salvage the degrading agroecosystem of Khambhat taluka has been strongly realised. The preventive measures that needs consideration, include afforestation, canal lining, soil surveys, 'x' limits for limiting perennial crops, volumetric supply, perennial blocks, Vara bandhi system, conjunctive use, adjustment of cropping pattern and so on. The possible reclamative measures that are worth trying in the study site depending upon their suitability are the following:

1) Repeated leaching with salt free good irrigation water by allowing water to stand for atleast a day and subsequent draining by percolation (Leaching combined with application of farm yard manure has been found to be considerably improving the productive capacity of such soils).

2) Deep ploughing and thereby improving the drainage,

3) Application of heavy quantities of green manure or farm yard manure,

4) Application of fertilizer containing nitrogenous compounds, urea etc.

5) Avoiding the use of saline water for irrigation,

6) Irrigating the land with a small quantity of water at frequent intervals instead of large quantity at a time,

7) Building up of farm ponds and three tier system of surface drainage to tackle the problem of water stagnation (The rainfall is stored in such a way that it cannot harm the standing crop and can be recycled for rabi crop).

8) Layering of canal bunds towards its outerside with grasses interspaced with trees to stop seeping of water from them,

9) In addition, using biological reclaimants like salt tolerant grasses or microbes to remove the surface salts and

10) Finally planning greening programmes with the use of species endemic to the degraded areas, such as Aeluropus lagopoides, Suaeda fruticosa etc.

4.6 Epilogue

To sum up the study, we can say that mistakes made by the Sumerians in Tigris and Euphrates basin of Mesopotamia (Iraq) over 400 years ago are being repeated today among our midst by our irrigation systems, resulting in the undermining to varying degrees the productivity of our agro-ecosystem. In addition to the sea-ingress, excessive irrigation and inadequate drainage are the principle causes of salinity in Khambhat taluka. In the United States of America the salinity in terms of damage to agriculture amounted to $\$113 \times 10^6$ and expected to increase to over $\$250 \times 10^6$ (in constant US dollars) by the year 2000 A.D. (Holburt, 1984). In Australia, the annual cost to agriculture resulting from salinity is estimated to be $\$32 \times 10^6$, nearly 70 % of which is attributed to dryland salinity. Although these costs are relatively low at the present time, the cost of not investing in appropriate control measures may be considerable in course of time. In Khambhat taluka, having a maximum cultivation of rice and the best rabi wheat, taking into consideration the present market value, there is seasonal net loss of Rs. 24,000 in the case of rice, Rs. 30,000 in wheat and Rs. 10,000 in Bajri per ha of land getting severely salinised according to our survey. In other words, there is a net loss of Rs. 64,000 per annum for every ha of severely degraded land in Khambhat taluka taking it for granted the cultivation of rice in Kharif, wheat in Rabi and Bajri in summer. At the taluka level it may very well amount to Rs. 470 million at present and may increase in future as the increasing trend in salinisation keeps continuing so far. In short the soil damage due to salinity will drastically affect the future economy of this taluka beyond repair. In such condition for an efficient planning of reclamation measures, a quick and temporal monitoring of the degraded land is essential. Satellite images with their synoptic viewing repetitive cycle and cost effectiveness play a vital role in the monitoring of the saline soils. A combination of remote sensing analysis in the form of visual image interpretation and digital additive techniques such as SBI or GVI and ground information about the area and its earlier history becomes important aids to scientists working for the planners. The cost effectiveness of the data products of the Indian Remote Sensing Satellite (IRS) makes satellite remote sensing more suitable for regular monitoring of our soil resources.

Thus, the point to be highlighted here is the need for a revolutionary awakening amongst national policy makers, at the taluka level to protect and salvage our vast agricultural resources making it necessary for scientist of different disciplines and engineers to come together and apply the new scientific technologies like remote sensing and new reclamative measures for saline soil reclamation in a proper manner in converting these hostile areas into hospitable ecosystem to support our teeming billions. Further to achieve this it is essential to encourage active participation of the farmers in the implementation of the new techniques by educating them regarding the present day knowhow. Thus, enabling the amelioration and prevention of soil degradation.