CHAPTER 5
DISCUSSION

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REMOTE SENSING

VISUAL INTER PRETATION:

The recent population explosion and the resultant food deficites and land scarcity are impelling a country like India to use areas not really suitable for Agriculture. However the day by day degradation of the agricultural lands by different land hazards was quite evident in India from earlier reports. (Bhargawa and Abort, 1990 and Vohra, 1988). The present study carried out in Khambhat taluka in delineating and monitoring of waterlogged soils by satellite remote sensing technique, was also confirmed these reports by showing a total area of 353 km^2 and 375.75 km^2 waterlogged land, out of 1094.8 km^2 area of Khambhat taluka in the years 1983 and 1986 respectively. These results indicated the increasing level of waterlogging hazards in this study area day by day. Thus the gradual increase of waterlogging areas ultimately leads to salinization, which is also increasing gradually as reported by Bhagwat (1989). The degradation of land into waterlogging and salinity in this area was found to be due to the unlimited use of canal water or excessive irrigation under inadequate drainage and further the frequent cultivation of crops like paddy requiring stagnated water caused the deep percolation to ground water reservoir leading to a rapid rise in the ground water table. (Kalubarme *et al* 1983, and Bapat *et al* 1985). For the reclamation or conservation of these culturable wastelands, the delineation and monitoring of these lands could be of immense help for planning out the remedial measures expeditiously and efficiently. The remote sensing technique had shown a great potential for identification, delineation and monitoring of the degraded land by providing quick inventory and pictorial representation of the affected area and also for monitoring of reclamation/conservation efforts. (Venkataratnam, 1980, Murthyet al 1983, Sahai et al 1985). In this present study, the two categories of waterlogged lands have been identified and delineated by using the remote sensing technique, based on the differences in the tonal variations. The decreasing reflectivity in the electromagnetic spectrum with increasing moist surface over dry surface made it possible to delineate two different categorisation in waterlogged areas, like permanent waterlogged land with smooth dark blue tone and moist surface land with coarse, dark brown bluish tingh. Generally based up on the earlier satellite imagery information allowed only delineation of waterlogged lands and were not delineated into more than one category in waste land mapping. (Venkataratnam, 1980, 1983, 1984, Manchand et al 1984, Saha, 1990.). Later Sahai et al (1982) Kalubarme et al(1983),Bapatet al(1985) attempted categorised the waterlogged soil into three types Viz. Standing shallow surface water, soil moisture and presence of perennial vegetation. The first two catagories of their study, had adopted in this present study based on the blue tonal variations. However the third type separation needs the thorough knowledge of cropping pattern by checking crop calenders in the date in which area was sensed by satellite. During ground truth survey in this study, it has been noticed some patches of flood water was completely covered at the surface with the aquatic vegetation like Typha and Ipomea (Plate 33,34) thereby obscuring the flooded nature of the land. Due to the difficulties in identifying the perinnial vegetation from other crop vegetation in the imagery, the categorisation fallowed by the above workers was not attempted here. Further, Singh et al (1988) in Etah district U.P.,categorised the waterlogged lands into four types Viz waterlogged lands along stream banks, Isolated/Ponded waterlogged land, wet lands and permanent waterlogged land, based on the same type of image characters adopted for the categorisation in the present study, where it was merged into two distinct types. A classification based on the depth of water in the waterlogged land would be the best type, but not feasible due to surface scanning capacity of the sensors with visible and infrared regions of electro magnetic spectrum, as revealed by Venkataratnam (1988). In reality, all the saline land in the study area was also waterlogged as salinization in Khambhat taluka resulted from the evoporation of the excessive surface water, from the raised water table. However due to the limitation in the satellite sensors, these lands were classified as a different type due to their whitish tonal variation. Similarly the flooded area with perennial vegetation, in the reports of Kalubarmeet al (1983) and Bapat et al (1985) registered a pink tonal veriation and it might mislead in the image interpretation due to the absence of blue tone. The recent advancement in remote sensing in the form of microwave could be the answer to these problems due to their penetrative capabilities to acquire information few meter below the surface. (Sood, 1983).

Plate 33 **Typha angustata** - covering the water surface

Plate 34 **Ipomea** sps. - obscuring the watersurface to be sensed by sensor.

The selection of seasonal data was found to be most useful in the categorisation of waterlogged areas. Though pre-monsoon season data was potentially most useful in the categorisation of waterlogged land, the post monsoon data, helped in the delineation of seasonal and permanent waterlogged areas. The substraction technique, by superimposing both the pre and post monsoon scenes, yielded a distinct demarcation of the permanant waterlogged land, prevailing through out the year. However, the post monsoon data, was found to be having it's limitation in the categorisation of waterlogged lands, because of the luxurient vegetational growth obscuring some of the permanent waterlogged land and the surface moist soil, due to the monsoon activity. This attempt was already reported by Singh et al(1988).

Besides the seasonal and cloud free data band selection was also played an important role. in delineating the different types of waterlogged areas. The FCC of Landsat/MSS with bands 4,5,7 and FCC of Landsat/TM and IRS/LISS II with 2,3,4 were found to be potentially useful for the categorisation of waterlogged lands in this present study. Since 1974, many works have used the False Colour Composite of Landsat MSS to identify the waterlogged areas by bands of either 5,7 or 4,5,7 (Rylandet al 1974 Aggarwal and Mishra 1987, Bajbai, 1989, Singhet al 1988 Kalubarmeet al 1983, Sahai et al 1984 Bapat et al 1985) similarly, the waterlogged area had been clearly distingnished from the other major land features mainly from cultivated non-saline lands on the FCC of Landsat/TM with bands 2,3,4 (Sahaet al1990). Of all the available satellite data at present, information from IRS-1A/LISS-II with a high resolution was proved superior that of Landsat/TM and MSS due to its cost effectiveness and thematic information. Thus the categorisation of the waterlogged area by using the visual interpretation of remotely sensed data for identification and had shown accurate results depicted by the accuracy level at 99% with 85% confidence level, in the present study.

The temporal analysis, carried out here, using the images acquired on premonsoon season, in the year 1983, 1986 and 1989, confirmed the sporadic spreading of land degradation due to the waterlogging from the southern region of the taluka towards the estern region of normal cultivable lands. Conversion of some patches of permanent waterlogged land to the surface soil moisture with scanty vegetation around Kenewal tank and the shrinkage of waterlevel in the tank in the drought year 1986, revealed the roles of waterbodies and irrigation system in transfarming the land to permanent waterlogging leading further to salinization. Earlier studies in this area by Kalubarme et al (1983) was confirmed the sporadic spread of waterlogging and salinity. The quantified out put of the different categories of waterlogged land from 1983 to 1986 carried in the present study also confirmed the gradual increase of waterlogged land and signelled an alarm to the decision makers, planners for the betterment of the agricultural production and to prevent the fertile land turning futile. The decreasing area of surface moist soil could be due to the increase in the permanent waterlogged land and the saline land in the year 1986 as in the report of Bhagwat (1989).

VILLAGE LEVEL AND MICROLEVEL STUDY :

The first attempt to generate the delineation of waterlogged level in the village level of the study area Khambhat taluka, in both 1:250,000 and 1:50,000 scale yielded a very interesting results and could be of immense guidence to carryout the remedial measures by the district dept of agriculture at the grass level of villages through gram sevaks. With the constitution of NWDP (National Wasteland Development Programme), it was decided to map the various categories of waterlogged land at 1:50,000 scale. The study carried out by enlarging the selected villages around Kenewal tank gave the clear tonal differenciation for an efficient categorisation of the waterlogged land and the easy location of the interpreted area during the ground truth survey. The extension of the study to microlevel was carried out, by fixing the enlarged 1:50,000 visually interpreted map of IRS-1A/LISS-II image successfully on the reduced cadastral map of Padra village with the plot along with the ownership details of appropriate survey numbers. Thus generated data yielded the plotwise degradation of land, which could be used for the farmers for better management of their plots. This kind of study was already attempted by using Landsat/TM data to identify wastelands and aerial plots in salt-affected lands. (Dutt et al 1986), latter using Landsat / TM image the salt affected plots were identified at the village Pariaj of Kheda district (Mothi Kumar and Bhagwat, 1990). Using the IRS-1A/LISS II data for waterlogging deduction in the village ecosystem of the Khambhat taluka had its own limitation, because of the resolution capacity of the sensors, to minimum mapable area and also the possibility of sight shifting of the plots during superimposing the cadastral map of the village on the enlarged 1:50,000 interpreted map was not completely ruled out.

Thus the result from the study of delineation and monitoring of waterlogged area, had given accurate results, which could be highly correlated with some accuracy information, by the fluctuation of ground water level, which increased from 11.62 m to 14.66 m from the year 1984 to 1987 in Kheda district shown by Gujarat Water Resources Board, and the Hydrological map of Khambhat taluka confirming the deterioration of the ground water as well as the land in the southern and central part of the taluka due to high water table and salinity, as reported in these study. Similar correlation was also made with hydroisobath and ground water table of the same season by Kalubarme et al (1983 with delineated waterlogged areas in their work carried out in MRBC command area and proved the potentiality of the satellite remote sensing for waterlogging delineation.

<u>VEGETATIONAL STATUS</u>

The temporal analysis of the vegetational status carried out in the study area from the remotely sensed data of 1983 to 1986, indicated the negative correlation with waterlogged areas. This was Wastelands due to the hazards of waterlogging and salinity prevailing in this area. Complete elimination of vegetation from the southern region in the year 1983 to 1986 revealed the total failure of the management in this taluka in reclamation and conservation efforts. This deterioration in coastal area was studied by Chaven et al(1984) through almost the entire taluka excepting the permanent waterlogged and severe salinity areas, showed the luxurient growth of vegetation, in post monsoon season due to the monsoonic activity the degradation of land was very evident in the premonsoon data due to scanty vegetation in the affected area. The increasing of dense vegetational cover from may 1983 to March 1986 in the quantified data was possible due to the prevalence of agricultural crops in the month of March as compared to May. Thus the vegetational cover could be considered as a yard stick in assessing the land degradation under stress conditions like Waterlogging and salinity, as these had a deleterious effect on the vegetation individually or combined together as proved by the earlier workers in stress Physiology. (Bernstein and Hayward, 1958, Gree way, 1973, Davies and Hillman, 1988, West and Taylor, 1980.). This delineation of vegetational status by visual interpretation in satellite remote sensing was higly correlated with the irrigability classification exhibited in the command area, which classified the land based on the suitablity of land for light perennials and Rice, for two seasonal, for seasonals only, suitable with improved agronomic practices and suitable with improved agronomic and drainage, which lies from eastern toward southern regions respectivily in the taluka.

DIGITAL ANALYSIS

The digital analysis supports a wide range of operations, in which the remotely sensed data are manipulated by different algorithms with the aid of a computer system. Since the CCT product of IRS-1A/LISS-II of 1989, used in this present study, covered only a 75% of the total area, just an attempt was made to find out the utility of Digital processin classification and enhance technique for easy interpretation of waterlogged areas. Waterlogged areas were identified clearly as the dark and light blue tone in the generated FCC (2,3,4) as it preferred by Saha et.al. (1990). Quantified assessment of waterlogged and vegetation, confirmed the deteriorating agricultural lands in this taluka. Among the various enhancement technique used, Soil Brightness Index, yielded a remarkable result, by discriminating saline and waterlogged areas. However ratioing technique using band 1 and 4, could not separate these two futures, might be due to the moist nature of the saline areas. The waterbodies were highlighted in simple and normalised ratio output. Simple Vegetation Index and the supervised classification based on greeness vegetation index indicated the absence of Dense and Moderate vegetation in most of the area. The affected saline and waterlogged areas with nil or sparse vegetation confirmed the degree of degradation of the agricultural areas in this taluka.

PHYTOSOCIALOGICAL ANALYSIS OF KHAMBHAT TALUKA

Phytosocialogical analysis of plant communities of three sites, in the study area revealed the distinct influence of the waterlogging stress filled habitat niche caused by Waterlogging on vegetational characteristics. Out of the three communities, studied, the saturated surface moist soil, exerted a severe stress condition over the plant community, as compared to the flooded site and the normal site. This conclusion has been confirmed by the decreasing species richness index and species diversity index, that is accordence with the reports of Mac Arthur (1975). Even in the low diversity communities, some species possessed the ability to with stand high stress condition, which were considered to be a decisive factor for imparting stability to a system. (MC Naugton,1977). This has been proved in these three communities by the IVI value of the species. Some species like **Stemodia viscosa** Roxb,**Suaeda fruticosa** (Linn) Forsk,**Cressa cretica**L. etc. showed the maximum IVI value in the surface moist land, and **Typha angustata** Bony and chaub in flooded soils indicated their high adaptability under stress conditions. The reason for lesser number of species in the surface moist soil of study area could be due to low salinity prevelent in soil of persistant waterlogging exerting soil ionic stress, where as under flooded habitat the dilution of these ions due to the excessive water could dilute the stress creating a resultant luxurient growth of aquatic plants. Thus the high degree of stress in moist soil as compared to the flooded soil was also confirmed by the dominant diversity curves plotted using different important values. The steep curve of the community from the surface moist land was very well indicated the harshness of the environment and the curves presented in this study also fit best in the geometric series of Niche preemption model, where in the low diversity communities each species preempted Niche space with no overlapping, resulting in a steeper curve. Curves approximating geometric series were of fairly wide occurence and appeared for some communities that had rigorous environment with only a few species widely scattered along the logarithmic scale of relative importance (Whittaker, 1965). Low over all diversity with the steeper curves were in accordence with Odum (1971). In this present study the diversity of normal soil diversity of flooded soil diversity of surface moist soil, were observed as reviewed by Wittaker (1965, 1970, 1972).

Various indices of diversity was reviewed by Dickman (1968), Johnson and Coworkers (1968), Pielou (1969), Hurlbert (1971), Whittaker (1972), De Benedicts (1973) and many others. Among the various indices generated in this present study, the richness index and, evenness index indicated the degree of stress present in the respective environment. It decreased in the order of surface moist soil, flooded soil and normal site. The number of species that shared all the three different habitat were some species of Graminae. However, the increasing value of dissimilarity was found between the normal and the other two habitates. The increasing level of similarity index between the moist soil and flooded community indicated the existence of tolerant species either aquatic or terrestrial in these two communities. The vegetational survey showed the plants growing under these conditions were mostly Waterloving plants. The emergence of aquatic plants like **Ipomca aquatica**Forsk,**Ipomea carnea**Jacq.**Sagitaria sagitifolia**L. Chara sp were noticed in the flooded habitat as a contrast to the normal and moist lands. Similarly the extinction of some plants like **Vernonia cenerea**(L) Less**Tridax procumbens**L.**Trianthema portulacastrum**Linn.**Occimum** canum Sims, *Acalypha indica* L. etc. were observed from normal to flooded habitats, as dipicted by the low value of similarity index of normal site with the other sites. Though the two communities shared most of the species, the species which were located only in the moisture soil was found to be the tolerant variety of salinity for example **Aleoropus lagopoides**(Linn) Trin, **Suaeda fruticosa**(Linn) Forsk.**Alhagi pseudalhagi** (M. Bieb) Desv. etc. Thus total dissimilarity index indicated that under stress conditions,. there was a natural selection for some species, which could withstand the stress condition by their tolerant charcters. (Mac Arthur and Wilson, 1967).

The frequency pattern of Raunkier's classes, indicated very clearly, the absence of highly dominant species in the study area. The plant degradation further oblitrated, the presence of species having frequency classes between 60 to 80 % and also reduced the species greatly in the class 'c' under flooded condition. The increse in moisture content in the soil brought an increase in the class A (10 to 20 %). This situation was more evident under flooded condition with the parallel decrease in class B and C and the absence of class D. These findings are not line with the Simpson's Index of Dominance, where as they are confiring the Diversity index. While working with stressfil environment, one has to be very cautious not to employ the two indices of Simpson as both are related. It is also essential to generate data of the frequency pattern constancy etc along with the other indices to get a meaningful explanation of the different communities under various stress.

Thus the phytosociological study of Khambhat taluka had an immense value to identify or assess the land degradation, as it was explained by Myur (1968) that the plants were found to be the best indicators of the degraded lands, for example the appearence of **Suaeda fruticosa**(Linn) Forsk **Aeluropus lagopoides** (Linn) Trin. **Cressa critica** L., **Stemodia viscosa**Roxb, **Tridax procumbens** L. **Scirpus litterolis** gave an indication to the saturation of the surface moist soil. However, the first three species were found to be specific to saline soil, showing luxurient growth with the salt encrustation on the ground (Plates 35,36) as it proved to be salt-tolerent plants in the earlier study in the same area. Since the salinity was caused by the evoporation of the high water table in Khambhat taluka, the saline land was generally associated with surface moisture of the soil in the above area.

AMELIORATIVE STUDIES:

Intensive irrigation in the absence of adeqnate drainage causes the water table to rise up in the soil and the capillary fring to reach root-zone. This condition is hastened by cultivating crops like Rice, sugar cane which need high irrigation. Such waterlogged soils results in the virtual exclusion of oxygen from the soil and the prevailing anaerobic condition modifies the normal soil-chemical processes, hampering the healthy activities found in the soil. (Ponnamperuma,1972, Grable, 1966, Waldren. et al 1987). In this present study, though the emergence of radicle was not affected adversely by root zone

Plate 35 Suaeda fruticosa Luxurient growth under severe saline condition

Plate 36 Cressa critica growing with salt encrustation

waterlogging in pearlmillet, the growth of both coleoptile and radicle of peartmillet was affected adversly. This crop had been mostly used under dry farming and perhaps most suitable to grow in soils permanently waterlogged due to the rising of ground water level, as the crops needing high irrigation would degrade the soil further. The important factor here was the survival of the cultivar under experimentation in the stress condition. The peart millet seemed to be a good choice, as the emergence of the radicle was not affected by waterlogging though the further growth was affected. The quick emergence of summer crop seeds during germination was also observed in the study of Kono et al (1987) under flooded condition. During germination, the rate of inhibition due to waterlogging was more in case of root than shoot and also the complete absence of root hairs, was noticed under waterlogged condition, as it was observed in the absence of ethylene. Though ethylene considered as a environmental pollutant its role as a growth promoter in waterlogged plants initiated interesting line of research. The inhibition of root growth, and lack of root hairs under flooded condition could be due to the inhibition of ethylene production in complete flooded condition, prevailed in experiments, since the convertion of ethylene from its precursor ACC (I-aminocyclopropane-1-carboxylic acid) needs oxygen.

The results of the experiments using the cultivars of pearlmillet and Brassica confirmed the adverse effect of waterlogging on the shoot growth of the plants. The studies on other crops like cotton, maize, peas, corn,garlic, sorghum, wheat, mungbean etc.had indicated adverse effect of waterlogging on their growth. (Hodgson and Macleod, 1988; Lee, 1980 Davis and Hillman, 1988). The effect on the shoot growth accompanied by depressed accumulation of fresh & dry matter of the shoot system with a decreased leaf area index (LAI) and net assimilation rate (NAR) under waterlogged condition which were in line with studies on other crops. The net assimilation rate of Bk-560, under waterlogging condition was increased at the earlier stage, parelled with the study of Musgrave and Vanoy (1989), on mungbean, where, the NAR was increased during stressed condition. The cultivars GHB-32 and MH-179, also showed the reduced growth rate, which was indicated by the reduced RGR under waterlogged conditions. Generally, the chlorophyll content was considered as a reliable source to reveal the assimilatory capacity of leaves leading to the growth of plant and their biomass production (Kvet *et al.*,1971). Waterlogging had a severe effects on the pigment levels of the cultivars of pearlmillet at all the stages of growth, as in the earlier study of cotton, (EL Beltagy and Soliman, 1985). Its depression was found to be an indicator of the suppression of growth, through the reduction in net assimilation rate, RGR ultimately in reduction of drymatter accumulation under waterlogged stress. Though the depression of shoot growth was not significant in the cultivars of pearlmillet, the results from the yield study confirmed that the root zone waterlogging had a deleterious effect on the yield of pearlmillet (**Pennesitum typhoides**(Burmf) Stapf & Hubb). The biological yield was considerably reduced due to the effect of waterlogging treatment than the controls, where the water was freely drained. The differences in the biological yield was not significant between the two cultivars of pearlmillet GHB-32 and MH-179 as indicated by the Factorial analysis. However, the main effect of waterlogging on the crop was found to be highly significant (P 0.01). the reduction of the yield due to waterlogging was also reported in other agricultural crops like Maize, Sorghun, Peas, Garlic, Wheat etc. (Belford et al., 1980, Singh Room and Ghildyal , 1980; Lee, 1980; Hodgson and Macleod, 1987; Davies and Hillman, 1988). Reproductive parts of crops were affected severely by the waterlogging treatments. Date of flowering was also delayed about 15 to 20 days under stress. Length of ear, girth of ear, number of florets and number of grains per spike were also significantly reduced by the stress produced by water logging treatment. Though there was considerable significant differences in percentage of sterility and length of the ear among the waterlogged and the control plants, their 'F' values of interaction was not significant. Oshima and Bennett (1979) also reported similar situation and they pointed out that the contrasts did not require a statistical significance as a prerequisite and could be applied regardless of the result of overall ANOVA. Though there was no consistant interaction between cultivars on waterlogging effect, by computing the biological and economical yield , the cultivar GHB-32 was considered to be the tolerant variety among three cultivars of pearl millet . Brassica juncca, found to be not suitable for cultivation in waterlogged area, due to its inability to survive, because of the severe adverse effect on the shoot by prolonged waterlogging.

A variety of phenomena may be operative in the growth of plants in waterlogged soil.Due to the inadequate gas diffusion and the development of anaerobic conditions the chemical dynamisms of the soil may change completely. The main electrochemical and chemical changes that affect fertility include decrease in redox potential(Eh), changes in both soil and flood water pH, changes in electrical conductivity (EC) denitrification, accumulation of NH4 N fixation, reduction of Mn, Fe, and SO_4^{2-} ,changes in the availability of N, P, K, S, B, Cu, Fe, Mn, Mo and Zn, and production of CO_2 ,organic acid and H_2S(Ponnamperuma, 1984 a, 1984 b, Trough and Drew, 1980, Gambrell and Patrik,1978). Since many of the workers proved that in addition to the toxic production, there was a deficiency of nitrates and other essential elements,for the growth of the plants was found to occur in soils subjected to waterlogging stress. Many attempts have been carried out to ameliorate the ill effects of waterlogging by using different nitrogen sources like KNO_3 ,Urea,Nitrite and other elements like Calcium, Posphate, Magnesium etc.(Khera and Singh,1975,Lee,1979, Hodgson and Macleod,1988, Biswas and Mahapatra, 1980). In this present work also two types of nitrogen sources were used as an ameliorative measures, for the waterlogged soil.The results from the work confirmed the results of earlier workers, that the application of humus is a good source of nitrogen to the waterlogged soil,which had considerable ameliorative effect on the waterlogging stressed plants. Soil humuns brought about distinct partial ameliorating effect on the waterlooging stress throughout the different stages of growth. In cultivar GHB-32, under normal conditions, the IIIrd stage of growth was an active vegetative growth phase. Under the influence of increased soil humus, this phase seemed to have shifted to the second phase of growth.The influence of humus on NAR and Leaf Area index was also found to be indicator of the partial ameliorative effect of waterlogging. Biological yield, grain yield and Harvest index were found to be partially but singnificantly (P= 0.01) increased by increasing the organic matter of the waterlogged soil.This amelioration effect observed here could be due to the addition of some essential elements like Potassium or Phosphorus through the addition of Humus to the soil as indicated by Jones(1975), who observed the exchangeable postassium to be higher in the waterlogged soil profile at all sites, corresponding with the increasing organic content. Alternatively Jones(1973) discovered that high organic content under waterlogging condition could release toxic levels of iron and manganese and thus affecting the plant adversly. There findings would make it very important to know the critical level of humus to be added in the waterlogged soil for each crop. Moreover, the amelioration indicated by humus application never exceeded the non-humus applied control, and the percentage of inhibition calculated on the basis of the humus applied non-waterlogged soil was almost the same as that of the non humus applied soil.

Another source of nitrogen applied in microlevels to the plant in the form of polyamine spray did not show any significant ameliorative effect on waterlogging injury. Though the amount spread was too small to serve as a nitrogen source, its regulatory role on plant growth and development cannot be over ruled (Altman et al ., 1981 and Rupnaik and Paul 1978). Though, Spermidine and Spermine gave a negative result, the diamine Putrascine spray,improved the chlorophyll content and grain yield of the waterlogged plants. The prevention of cholorophyll loss by the exogenous application of polyamine was reported earlier(Alt man et al 1981).

Root zone waterlogging and salinity often occured together in irrigated agriculture, particularly in the present study area of Khambhat taluka due to the evoporation of ground water level. Hence the attempt to grow the pearl millet cuv. GHB-32 ,in this combined stress conditions, revealed that the adverse effects were higher in plants growing under the combined stress, than the individual one. However, the waterlogging was proved to be more injurious to the plant growth than the salinity. Contrarily, Vetiveria lowsoni showed a better significant growth under waterlogging, salinity and combined stress conditions over their control. Though the adverse effect was seen in its growth attributes like drymatter accumulation and level of pigment content at the early stages, it recovered later. Thus this plant showed the high degree of resistance to waterlogging and combined stress of waterlogging and salinity.The results of the severe effect of the combind stress on the pearlmillet GHB32, was aligning in with the finding of West and Taylor(1980) and John *et al*(1976) who reported that the effect of salinity is more under waterlogged conditions because the increasing rate of uptake of Na^{+} and Cl^{-} observed in the stagnant waterlogged root-zone.

Among the plants stuided for possible introduction in waterlogged areas, *Veteveria lowsoni* revealed an impressive growth under waterlogging conditions and pearl millet cultivar GHB-32, MH-179, BK-560 showed favorable ameliorative capacity under waterlogged conditons with high soil humus content. Similarly the diamine putrascine could also favour the cultivation in waterlogged soils. The different morphological changes brought by cultivars of *Pennisetum typhoides* during their growth under waterlogged conditons, favoured these findings. Lacking of root hair in the developing roots during their germination, and blackening of the roots during their growth of plant, under waterlogged condition were noticed (Plate-37,38). The suppression of root hair formation and death of part or all the original root system because of the build up in the products of anaerobic condition, lack of ATP, oxidation of the rhizosphere soil round the roots shown by the deposites of red ferric hydroxide was already reviewed. (Hook and Brown,1973, Crawford,1974, Hook and Crawford 1978, Hasuin and Sheikh,1978, Philipson and Coutts,1978, Hook and Scholtens ,1978 Armstrong ,1967). Besides these adverse morphological changes, some tolerant changes were also noticed in this present study. Formation of adventitious roots from the nodal region, have been observed under waterlogged conditions, as it was seen in wheat(Trought and Drew,1980) (Plate - 39,40). However the

Plate37,38 Blackening of roots and the formation adventitious roots from the nodal region of Pearlmillet under waterlogging condition.

Plate 37

Plate 38

increasing photosynthetic leaf area leeding to wider leaves as in Zea was observed in the plants treated with putrascine spray under waterlogged conditions (Hoehler et al,1976).

REFLECTANCE STUDY :

The spectral response of crop growth was already reviewed by Thomas et al, (1967), Stanhill et al ,(1973), Tucker et al (1979) Ayyangar et al.,(1980) and many others.The reflectance study in this present investigation also confirmed the various stress effect of the growth of the plant. The decreasing trend in value of ND and 1R/R ratio in stress condition correlated positively with the Leaf area index and Biomass, indicated the ability of reflectance study to monitor stress condition. The cholorophyll content was considered as a reliable source to reveal the assimilatory capacity of leaves, the depression of its content found to be an indicator of the suppression of growth and its dry matter accumulation. (Kvet.et al ,1971. The partial recovery from the stress also indicated by the percentage of reflectance of the plants in red and infrared region of the electro magnetic spectrum. The same spectral response(expresed as 1R/R) of the crop during growth for rice, sugar cane and finger millet, Maize showed similar trends.(Ayyangar et al ,1980, Nagraja Rao et al, 1987).

Thus the over all results of the ameliorative studies confirming the adverse effect of waterlogging on the plant growth and the possibility of the partial recovery from the stress effect by the addition of nitrogen sources like application of humus to improving the soil fertility, and spraying the growth promoter to the shoot system. It was also confirmed the role of tolerant plants like Vetiveria lawsoni . in ameliorating the ill effect of waterlogging and greening the waterlogged lands.

CAUSES AND REMEDIAL MEASURES:

With the introduction of irrigation in 1959 in the MRBC command , the naturally existing hydrologic balance was disturbed. Seepage from irrigation canals and watercourses, and the deep percolation from application of large doses of irrigation and the frequent cultivation of paddy crop. Under inadequate drainage condition, caused the ground water level to rise and ultimately lead to waterlogging of the lands. As it was reviewed by Kalubarmae et al(1983) . Problem of waterlogging is bound to occur under any canal system if attention is not paid to proper soil and water management.The development of successful irrigation involves not only supplying agricultural land with adequate supplies of irrigation water but it also requires from the very beginning measures to control waterlogging. To achive this one, by planners and administrators, it is essential to know the position of water table, at a perticular period in a particular season, extend of waterlogging land in the area without any loss of time in investigation. From our present study ,it can be recommended that the satellite remote sensing technique,is potentially most useful for the identification,delineation and monitoring of waterlogged land in the area,by its effecient technology adopted in synoptic veiwing, repetitive coverage, reliability of data products and cost effectiveness. The interpreted village level map at 1:50,000 scale was found to be very useful in easy location of the affected area to work out the remedial measures. By handling the different satellite data it can be understood the superiority of the Indian satellite data 1 IRS -1A/LISS -II by its improved spacial resolution and cost effectiveness to monitor the affacted area and help in the development reclamative measures frequently in short span of intervals without loss of time by a temporal ayanysis. The imformation about the nature and special distribution of the different categories of waterlogged land obtained from the computer analysis would help the planners and administrators to define the areas for large scale reclamation and utilization and the subsequent monitoring of these lands.

Though it is not possible to know the depth of water table or depth and thickness of saturated strata using the orbital remote sensing system operating in the optical region of the electro magnetic spectrum, surface soil conditions, many of which can be detected by remote sensors, are frequently indirect indicative of sub surface conditons. In addition, the natural vegetation of the area, can be used as indicators of soil properties.Thus the plants are frequently good indicators of conditions that occur below the soil surface, as it has confirmed by Myers ((1968) in saline areas.

To reclaim the already existing waterlogged areas of present study, to bring back the land to normal production and conserving the normal land from the extention of waterlogging to prevent the degradation of the normal productive land, can be achieved by the improved management system.For this planners and administrators can take up the recommendations summerised below,

i). It is necessary that existing ground water conditions must be established and the areas where problems of waterlogging must be indentified at the planning stage it self.

ii).Careful consideration has to be given in planning the irrigation system, to make a thorough investigation of the factors, such as topography, natural drainage, Geology and hydrogeology, soils, ground waters, outlet condition and sources and quantities of excess water, which can lead to the problem of waterlogging.

iii).Ideally the water table should be kept at a depth greater than or equal to 2 m to maintain a favorable ionic balance in root zone by using one or two methods of subsurface drainage, vertical drainage by means of tubewells and horizontal drainage by means of the open or file drains. The choice of method depends upon the possibility of using tubewell water for irrigation.

iv). Seepage losses from canals during conveyance and distribution can be prevented by bundh vegetation and use of on effective lining material.

v). Selection of a suitable cropping pattern that requires lesser applications of water can reduce the amount of water reaching the ground water table.

vi).Appropriate methods of irrigation among border method, furrow irrigation, drip irrigation, & sprinkler irrigation must be selected, keeping in mind the technical and economical constraints.Prevention of over irrigation by i) Lining of canals, Pre-irrigation soil surveys.'X' limits for perennial vegetaion, Block system, Volumetric supply, Adjustment of cropping pattern, varabandhi, conjunctive use of water resources can be help in reducing the damage to the soil as reported by Bapat.(1985).

vii).Afforestation can be carried out by cultivating the tree species, such as Casuarina obesa . C.equisetofolia Eucalyptus camatedulensis, Eucalyptus umbellata, Dalbergia sissoo etc. as recommended by Tomar and Gupta(1986).

viii).Cultivation of waterlogging plants like grass species which will be used as fodder, and other economical purposes like Vetevaria species.

ix).Improving the fertility of waterlogged soil by application of humus, and other waste products like green manure like leaves of Susbania Rice straw mollasses, press mud etc.

x). Nitrogen level of the waterlogged soil can be increased by growing Bio-fertilizers like bluegreen algae and **Susbania robstrum** etc .

xi). Aerial application of the nitrogen to the plants found to be useful than that of the soil application.

Implementation of many of these recommendations including rational water supply, crop planning, scheduling of irrigation, modernization of old systems, drainage and other aspects of supplemental irrgation, planning and research, there is thus need for the effective participation of Farmers, Agricultural officers, engineers, geologists, agronomists, economists scientists and administrators, together for achieving a high effeciency in reclamation and conservation efforts of the land, crop and soil management to boost the resources, which are regarded as the permanent assets in the service of mankind.