Chapter 10
Impact of Irrigation on Soil & Water Regime

CHAPTER 10

IMPACT OF IRRIGATION ON SOIL AND WATER REGIME

GENERAL BACKGROUND

Water resources development for irrigation especially in tropical areas has existed since ancient times. The use of ponds, tanks, wells, and small inundation canal has been practiced in India since very old times. It is a common human psychology to depend more and more on the development and exploitation of natural resources for satisfying the escalating energy demands. But, at the same time preserving the fragile environment is equally important. Unfortunately in the developing countries like India the impact of irrigation on environment has been given secondary importance.

The basic purpose of water resources development is to provide improved condition for the livelihood of people both at the present time and near future. The improved conditions are the combination of:

- Satisfaction of Social Needs.
- Economic Benefits.
- Improvement of Man's Environment.

Every human activity, which enriches the society, has an impact on the existing environment and ecosystem in one way or other. The environmental impacts of the water resources projects can be classified viz., (I) Air Environment, (II) Water Environment, (III) Noise Environment, (IV) Biological Environment, (V) Cultural Environment and (VI) Socio-economic Environment (Gupta and Singhal, 1997).

The irrigation project has both positive and negative impacts, its existence and severity vary from place to place depending upon the physiography, climate, soil characteristics, cropping pattern and irrigation management. It primarily affects the soil and water regime of irrigation command area. The positive impacts (environmental gain) such as irrigation, water supply, flood control, industrial development, etc. are indirect one and long term. Water resources project also causes significant negative impacts (environmental loss) such as waterlogging, deterioration of water quality, soil salinity, soil fertility socio-economic aspects etc.

IMPACT OF IRRIGATION IN MATAR COMMAND AREA

In the Mahi Right Bank Canal command the irrigation by utilization of canal water has increased from 891 ha in 1958-59 to 1,91,288 ha in 1998-99. Prior to introduction of canal, the farmers were mostly going for dry farming crops or the crops, which need minimum water. The main crops were Bajra, Cotton, Tobacco, and others of short duration. Owing to extended perennial irrigation facilities to the command area a drastic shift in cropping pattern, i. e. substantial increase in the cash and commercial crops (i. e. high water consumption crops) has been witnessed. This modification in landuse pattern has caused considerable impact on the water and soil regime of the Matar Command area also. Some of the problems, which have already reached to an alarming level, are (I) water level rise causing waterlogging, (II) groundwater salinity, and (III) soil degradation.

RISE IN WATER LEVEL

In the developing countries the excessive utilization of much cheaper canal water and poor management practices lead to increase in groundwater storage, which result in water table rise is very commonly observed phenomenon. The Mahi Right Bank Canal Command as a whole and the Matar Branch in particular have not remained exceptional from this problem. As it has already been discussed in the preceding chapter on water regime that over the period the Matar Command has witnessed sharp change in groundwater storage and significant rise in water levels. Resultantly large area of the irrigation command and in particular, the lower-middle command has fallen in the grip of waterlogging.

The study of Water table monitoring data of Matar command area since the introduction of canal irrigation has revealed continuous rise in water table. It is observed that during last four decades certain pockets of the command area shown average rise in the water table to the order of 0.47 m/year with an overall rise of 15-20 m. Also, the canal irrigation has significantly affected the seasonal fluctuation in the water level. Prior to the inception of canal irrigation the seasonal fluctuation used to be of 2-3 m. This has now reduced to almost 0-0.5 m. Similarly significant change in hydraulic gradient is also observed. The gradient, which is used to be steep (1:855), has now changed to gentle (1:1655).

Based on historical data on water level behaviour and authors own observation for three seasons, the author has prepared the hydro iso-bath maps for different periods i. e. pre-canal irrigation, achieved irrigation potential 100 % phase from 1976 to 1999 (at 05 years interval), for both pre- and post-monsoon seasons. The prepared hydro iso-bath maps (Fig. 10.1 and 10.2) thus provide range of water levels and its respective spatial coverage. The quantitative estimates prepared for different period on range of water levels i. e. 0.00-1.50 m (waterlogged), 1.50 - 3.00 m (prone to waterlogged), 3.00- 6.00 m (rise in water level) and more than 6.00 m (deep water level) are given in Table 10.1.

Table 10.1 Hydro Iso-Bath Estimates of Matar Branch Command Area.

Depth (m)	Year of Observation											
	1976		1980		1985		1990		1995		1999	
	Aerial Extent (ha) & Percentage											
	Ha	%	ha	%	Ha	%	ha	%	ha	%	ha	%
Pre-monsoon												
0-1.5	0	0	0	0	0	0	0	0	2821.58	12.46	550.81	2.43
1.5-3.0	2255.22	9.96	590.22	2.61	3987.37	17.61	3538.37	15.63	5687.24	25.12	7945.98	35.1
3.0-6.0	6954.55	30.72	18458.38	81.53	16716.54	73.84	14074.76	62.17	11741.85	51.86	13349.9	58.97
> 6.0	13430.24	59.32	3591.41	15.86	1935.92	8.55	5026.92	22.2	2389.31	10.55	793.36	3.5
Post-monsoon												
0-1.5	5690.92	25.14	5044.59	22.28	3161.71	13.97	5619.34	24.82	4757.95	21.02	6123.26	27.05
1.5-3.0	5503.32	24.31	12220.3	53.98	6451.92	28.5	6629.32	29.28	9518.01	42.04	10708.87	47.3
3.0-6.0	4291.99	18.96	4807.62	21.24	11864.11	52.4	10391.34	45.9	7507.66	33.16	5806.12	25.65
> 6.0	7153.76	31.6	567.52	2.51	1162.25	5.13	0	0.00	856.4	3.78	1.76	0.01

The obtained estimates for the pre-monsoon season show almost 60 % of the area was having water table > 6.00 m in 1976; this has been reduced to mere 3.50 % in 1999. In a time span of 25 years almost 37.00 % of the command area has been fallen in the categories prone to waterlogged (35.00 %) and waterlogged (3.00 %). During the pre-monsoon season, the area with water table depth more than 3 m. has reduced to just 25% of the command. This implies that an additional 25 % area is waterlogged during the post-monsoon. Almost 75 % command area has now falling under the categories of prone to waterlogged (47.31 %) and waterlogged (27.50 %). The water table more than 6.00 m merely covers 1.00 % of the total command area. The prepared histogram (Fig. 10.3) with the help of hydro iso-bath data clearly establishes the above discussed facts.

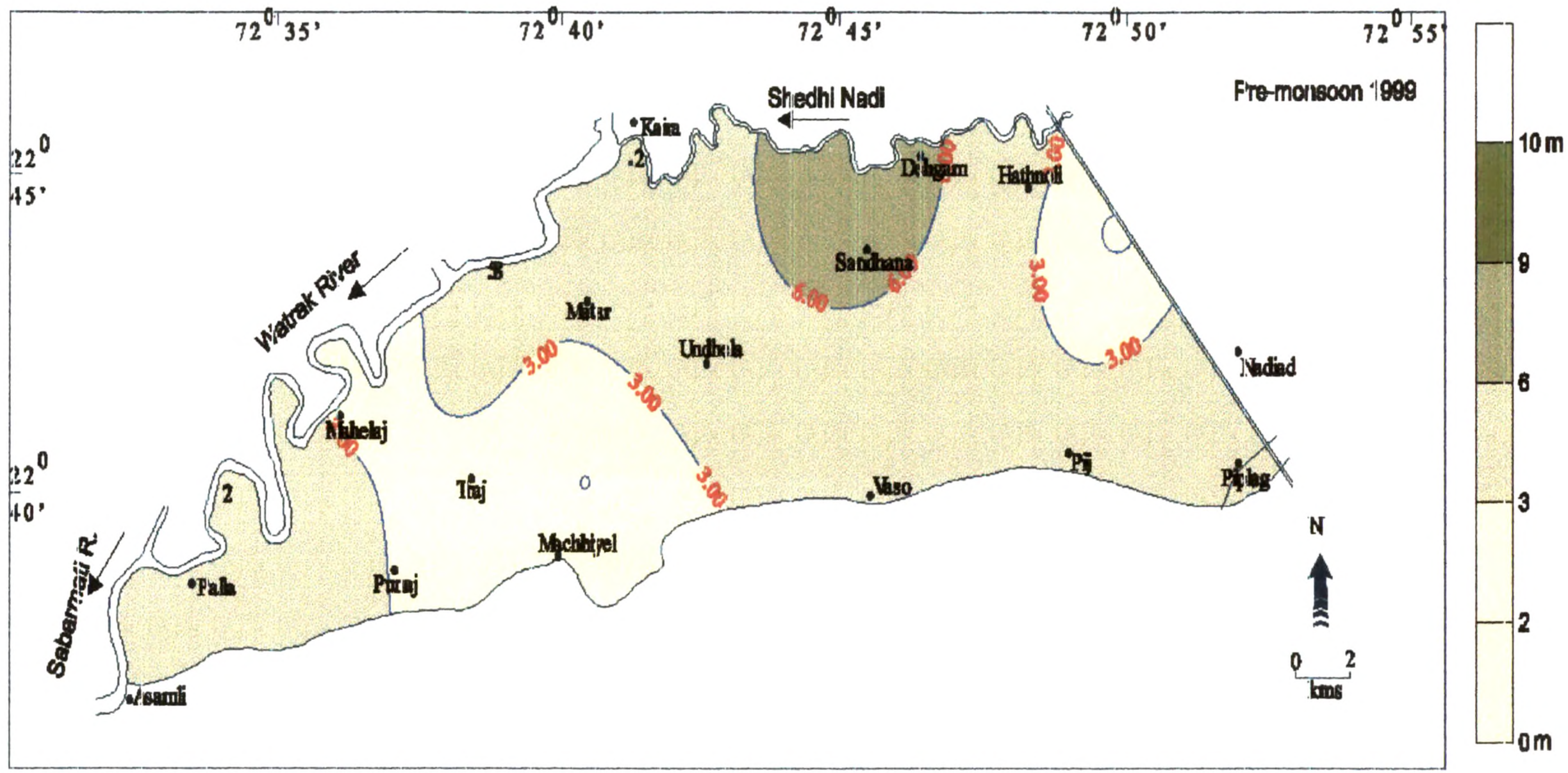


Fig. 10.1 Hydro Iso-bath Map of Matar Command Area. (Year: Pre-monsoon 1999)

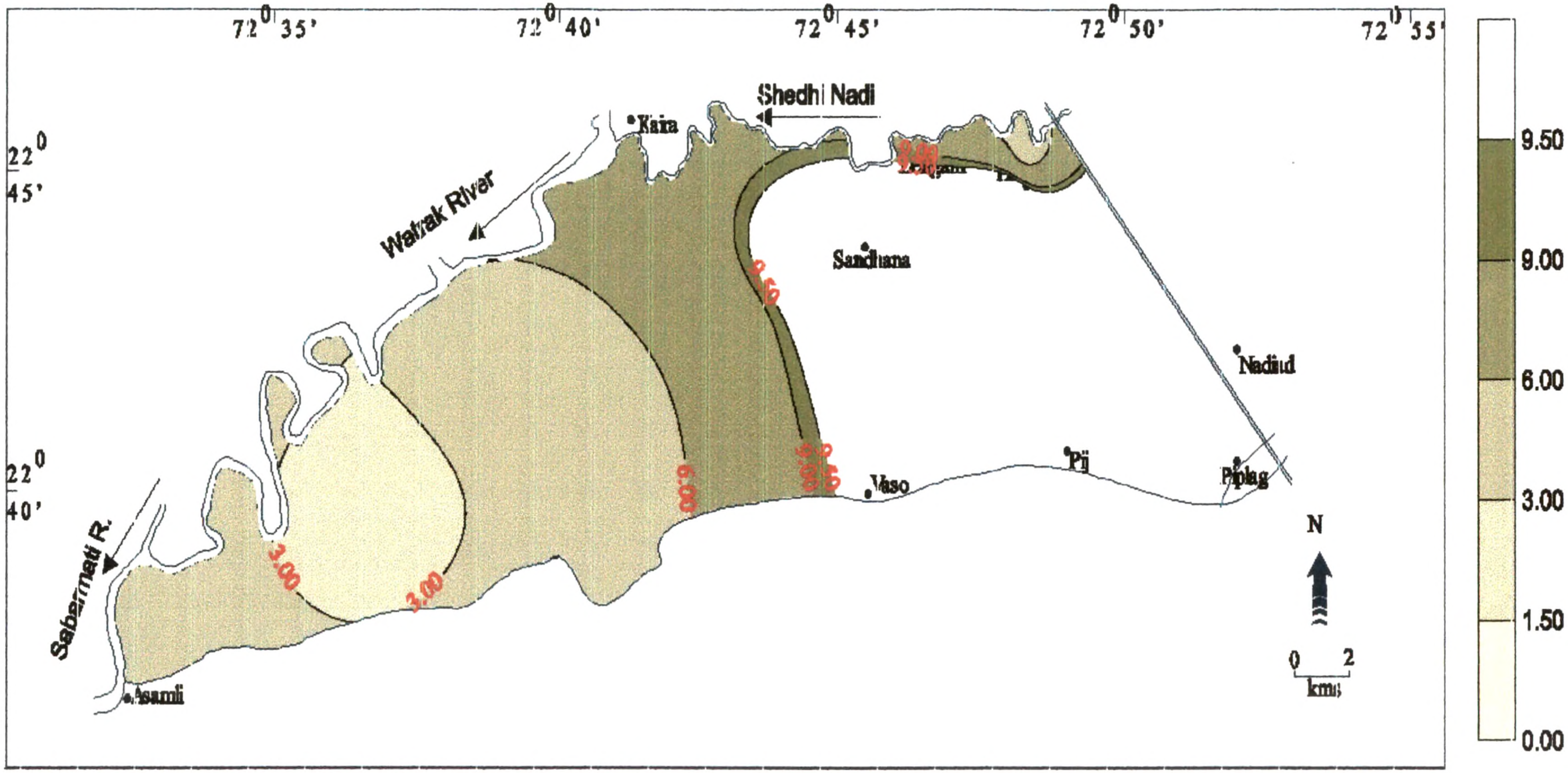


Fig. 10.2 Hydro Iso-bath Map of Matar Command Area. (Year: Pre-monsoon 1976)

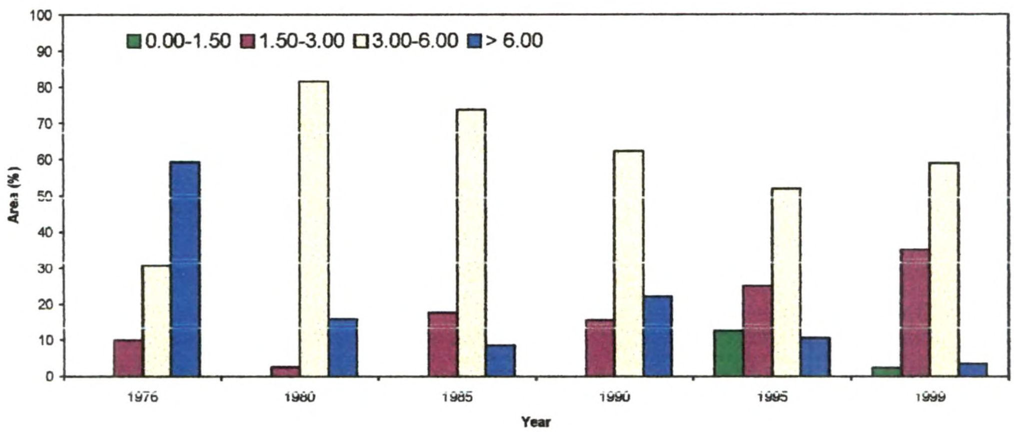


Fig. 10.3 Hydro Iso-Bath Trends in Matar Command Area

Waterlogging is caused by both natural as well as man-made factors. A noteworthy contribution on the waterlogging problems of irrigation projects has been made by the following workers viz., Todd, 1959; Mehta et. al., 1968; Walton, 1970; Arar, 1971; Framji, 1973; Gupta and Pandey, 1979; Agrawal and Malik, 1982; Bowender and Ravi, 1983; Gupta, 1985; Bhatnagar, 1986; Bowender et. al., 1987; Sodhi and Sharma, 1987; Bouwer et. al., 1990; Chitale, 1991; Varade, 1992; Abott, 1997; Finney, 1997; Gupta and Gupta 1997 b; Salama et. al.; 1999, Valenza, et. al., 2000; Vishwakarma et. al., 2000; Singh, 2000; Babu Rao, et. al., 2001; Sarwar et. al., 2001). Based on the review of above cited works, the main causes of waterlogging may be listed as under:

- Poor natural drainage as consequences of unfavorable topography and unfavorable sub-soil geology.
- Introduction of irrigation without considering the characteristics of soils and sub-soils.
- Heavy losses of water due to seepage from canal distributaries and watercourses.
- Development activities such as construction of road, bridges, railway lines and building resulting into choking of natural drainage.
- Poor maintenance of existing drainage system and outlets.
- Hydraulic pressure of water from upper irrigated areas resulting into seepage in low lying areas
- Excessive use of canal irrigation attributing high recharge as returned irrigation seepage.

- Non- utilization of groundwater resources and increase in groundwater recharge from rainfall.
- Poor land and water management practices.

However, in the Matar Command area the author has identified following factors, which ultimately led to the rise in water level thereby waterlogging problem.

i. Adverse physiographic features and lack of surface drainage *(Physiographic Factor)*.
ii. Lateral facies variations in aquifer material and the hydraulic characteristics *(Anisotropic Aquifer Characteristics)*.
iii. Annual recharge through rainfall and bare minimum utilization of groundwater *(Reduced Groundwater Utilization)*.
iv. Excessive use of canal water, leading to more recharge to the groundwater regime from canal seepage and returned irrigation seepage *(Excessive surface water Utilization)*.
v. Changes in cropping pattern vis-a-vis inherent soil characteristics *(Cropping Pattern)*.

Salient controls exercised by above-mentioned factors in causing the waterlogging phenomena are discussed as under:

i. Physiographic Factor:

It has already been discussed in the preceding chapter on the Terrain characteristics that the Matar command area is characterised by an almost flat terrain with altitudinal difference of only 12 m with and average gradient 1:3200 with intermittent depressions. The rivers Shedhi, Watrak and Sabarmati delimit the northern and northwestern boundaries of the command area. Baring these major trunk streams the study area lacks the lower order drainage, which generally act as surface runoff channels. The combination of featureless topography, lack of any significant surface drainage lead to higher rate of infiltration than the surface run-off. Also, the presence of numerous surficial depressions and rainwater fed ponds results in stagnation of water during the rainy season, contributing additional recharge to groundwater regime.

ii. Anisotropic Aquifer Characteristics:

Already discussed hydrogeological characteristics categorically point to inconsistent disposition pattern of the aquifer materials. The aquifer thickness tends to decrease from the east to west direction with hydraulic gradient, due southwest i.e. Gulf of Cambay. The abrupt truncation of aquifers with clay dominated sediments in the western extremity of the command area is seen responsible for sudden drop in hydraulic gradient, hydraulic continuity and groundwater storage capacity. The overall change in hydraulic gradient i. e. from steep to gentle prevents the movement of the groundwater causing stagnation of groundwater as well as the uprise in the water level particularly in lower reaches of the command area.

iii. Reduced Groundwater Utilization:

It is a known fact that in any irrigation command the groundwater has been given least or dam minimum utility. Prior to canal irrigation groundwater was the major resource for irrigation in the command area, but the introduction of the irrigation has resulted in an overall decrease in the groundwater utilization. Figure 10.4 clearly depicts that since last ten years the area irrigated by the groundwater is merely ranging between 25000 to 35000 ha, whereas the area irrigated by canal and pond irrigation shows continuous and sharp rise and has attained almost 80,000 ha mark.

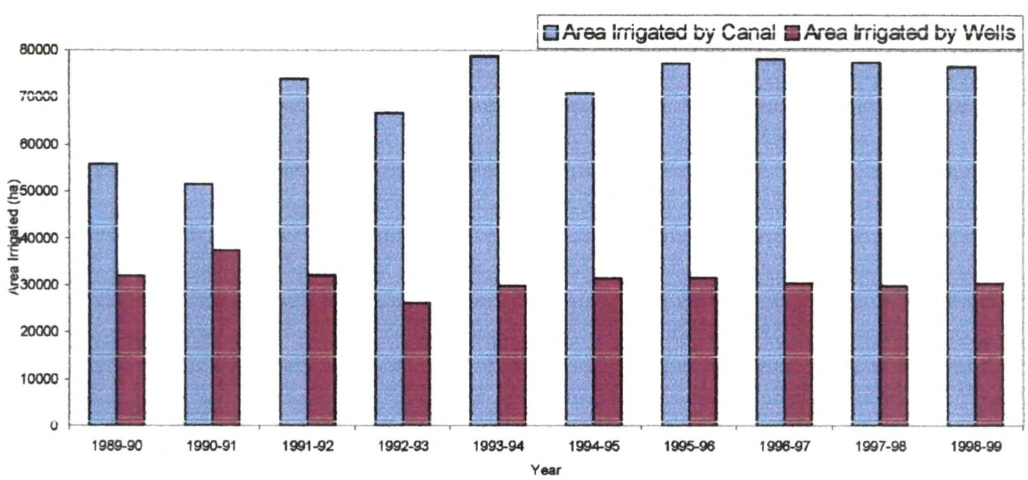


Fig. 10.4 Yearwise Area Irrigated from Different Sources in Matar Command Area.

The slight reduction in the area irrigated by the canal water particularly in the year 1992-93 and 1994-95 is attributed to limited as well as non-supply of water due to deficit rainfall and closure of canal for maintenance respectively. Also the groundwater draft 1860 MCM/ycar constitutcs barc 38.21 % of total volumc of canal watcr i. c. 4869 MCM/year made available for irrigation; clearly points to continual addition in groundwater storage.

iv. Excessive Surface Water Utilization:

As it has already been eluded that the irrigation potential for the entire MRBC command area has been created in the year 1976-77. Although the canal water supplied as per the created irrigation potential, still the actual irrigation yet to be achieved. The plotted histogram (Fig. 10.5) for year wise achieved irrigation potential and created potential clearly depicts this gap. This difference in created and achieved irrigation potential may be attributed to the excessive or unauthorized irrigation practices in the upper command area and excessive seepage from the canal system.

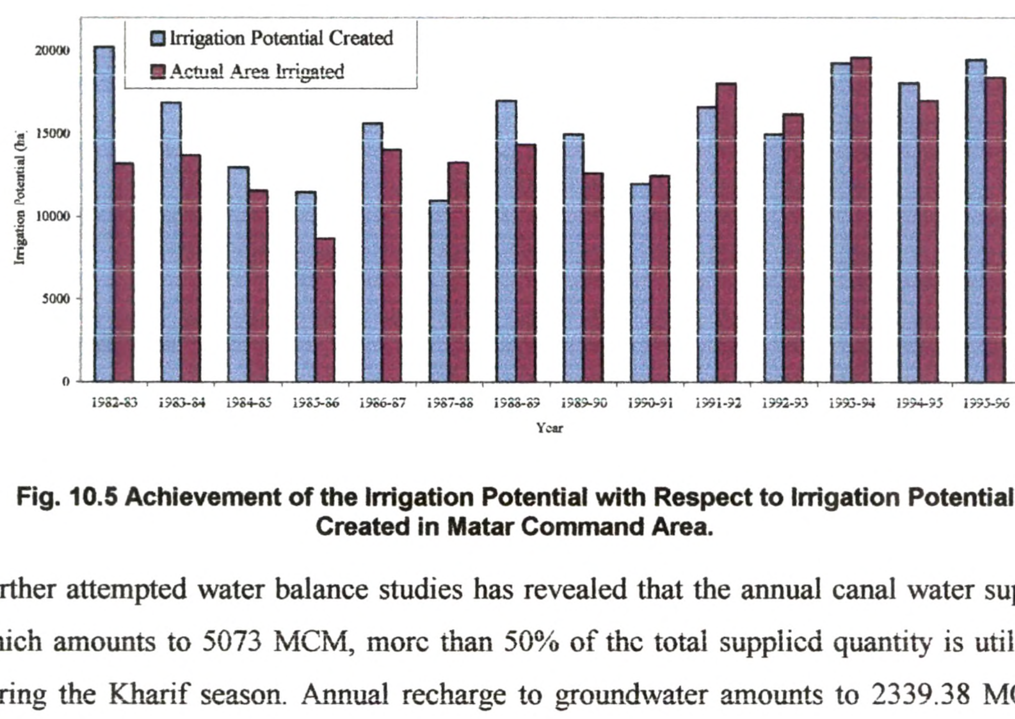


Fig. 10.5 Achievement of the Irrigation Potential with Respect to Irrigation Potential Created in Matar Command Area.

Further attempted water balance studies has revealed that the annual canal water supply which amounts to 5073 MCM, morc than 50% of thc total supplicd quantity is utiliscd during the Kharif season. Annual recharge to groundwater amounts to 2339.38 MCM, which constitutes almost 33.51 % of the total water input (viz., rainfall, and irrigation from canal seepage). The total recharge from canal water supply amounts to 1999.14 MCM i.c. 39.41 % of total watcr supplicd. Statistical analysis on rccharge to groundwatcr point to this very fact that significant contribution to groundwater storage is from canal and the return irrigation seepage ($R^2 = 0.98$) than recharge from the rainfall ($R^2 = 0.34$).

v. Cropping pattern

Taking in to account the cropping pattern of the Mahi Irrigation command as a whole which in turn also reflect the study area, prior to the inception of canal irrigation Bajra was the major crop (40% of command) and paddy and wheat were the minor crops (30% of command area). The introduction of canal has brought a gradual change in cropping pattern. Now there exists vast difference in suggested cropping pattern (on the basis of soil-water-crop relationship) and the actual practiced cropping pattern adopted by the farmers in the command area (Table 10.2). The crops grown are similar to the suggested pattern but irrespective to land irrigability classes and season.

Table 10.2 Suggested and Practiced Cropping Pattern in MRBC Command Area (ha)

[Source: Taluka Panchayat & MIC, Nadiad)

Crop	Cropping Pattern	
	Suggested	Practiced (1998-99)
Perennial	7711 (3.60)	13258 (8.80)
Rice	45772 (21.50)	75074 (49.60)
Jowar, Bajra, and Other Kharif*	39233 (18.50)	14013 (7.10)
Wheat	52249 (24.60)	10734 (7.10)
Tobacco	13077 (6.10)	24673 (16.30)
Cotton	13077 (6.10)	-
Jowar and Bajra**	15421 (7.30)	765 (0.50)
Groundnut	-	3721 (2.50)
Miscellaneous ***	26154 (13.70)	9237 (6.00)
Total	212694 (100.00)	151475 (100.00)

* Includes Tobacco and cotton ** only fodder crops

*** Includes Rabi Jowar, gram and other fodder crops

As it has been already stated that the area is dominated by the soils falling under the land irrigability class II, III and IV, characterised by higher MHC, moderately slow permeability and moderately fine texture. Generally the soils under the land irrigability class III are suitable for cultivating two season crops like, Bajra, Jowar etc. whereas the soils belonging to the land irrigability class IV are suitable for cultivating the single season crops. At places even in the soils of the land irrigability class V (which are practically unsuitable) rice cultivation is carried out (Gajja et. al., 1994). This deviation and non-adoption of the suggested cropping pattern violates the sustainability of irrigation project. As a result of this change in cropping pattern, the water requirement has also increased manifold which ultimately make an additional contribution to groundwater storage as returned irrigation seepage. Thus the diversification from the suggested pattern, (especially in the soils of land irrigability class III, IV and V with water table less than 3 m.) may lead to the development of the problems of waterlogging and salinisation of soils.

The land productivity in terms of the per hectare output of Rice, Wheat, Bajra (Kharif), Bajra (summer), Tobacco and Groundnut showed decline in crop yields owing to soil degradation (Table 10.3). The crop yield in general is declined with increase in the normal soil comprising land irrigability class I and minimum under severally degraded soils in land irrigability classes V and IV.

Table 10.3 Production Performance (q/ha) of Different Crops under Different Land Irrigability Classes and Soil Degradation Levels.

Soil Degradation Level	Land Irrigability Classes					
	I	II	III	IV	V	Average
Rice						
Normal	42.60	34.65	-	-	-	42.60
Marginal	-	26.64	17.90	-	-	20.47
Moderate	-	18.30	12.55	10.27	9.30	13.29
Severe	-	15.15	9.70	7.33	6.80	7.93
Average	42.60	22.08	12.43	8.54	8.54	17.09
Wheat						
Normal	21.70	16.15	14.17	-	-	20.61
Marginal	-	-	11.04	-	-	11.04
Moderate	-	10.76	8.26	4.64	3.47	6.64
Severe	-	-	6.44	3.97	2.95	4.95
Average	21.70	11.25	8.56	4.28	3.21	5.34
Bajra (Kharif)						
Normal	17.91	14.45	-	-	-	17.45
Marginal	-	11.85	-	-	-	11.85
Moderate	-	-	7.84	6.25	4.12	5.61
Severe	-	7.59	-	-	-	7.95
Average	17.91	1.86	7.84	6.25	4.12	13.99
Bajra (Summer)						
Normal	21.90	18.07	-	-	-	20.91
Moderate	-	14.04	11.40	9.88	-	12.47
Severe	-	11.90	10.73	6.69	-	9.87
Average	21.90	15.79	11.13	8.29	-	17.95
Tobacco						
Normal	19.67	12.80	13.68	-	-	18.90
Marginal	-	10.85	7.62	-	-	8.13
Moderate	-	8.35	5.91	-	-	7.58
Severe	-	6.14	-	-	-	6.14
Average	19.67	8.79	9.53	-	-	16.37
Groundnut						
Normal	17.08	14.51	11.58	-	-	16.01
Marginal	-	-	9.80	-	-	9.80
Moderate	-	8.56	7.48	3.86	-	7.41
Severe	-	6.39	5.09	3.01	-	4.27
Average	17.08	4.49	8.64	3.29	-	10.57

(Source: Gajja et. al., 1994)

GROUNDWATER SALINITY

Water has been considered as the 'Universal Solvent'. The quality of groundwater is of great importance in determining the suitability of water for a specific use. Water quality is governed by the extent and composition of the solids dissolved in it. Excessive concentration of dissolved ions, may make water injurious to irrigation and drinking use. In the irrigation command excessive use of water, inconsistent with the basic soil characteristics vis-à-vis cropping pattern make water highly vulnerable to deteriorate in its quality.

In an irrigation system a portion of water supplied is lost by evapotranspiration (consumed) and it is essentially salt free. The water percolating under surface irrigation and/or return flow through the soil profile, contain the majority of salts left behind by water returned to atmosphere i. e. evaporation and transpiration (Concentration effect). As the water moves through the soil profile it may pick up additional salts by dissolution i. e. pick-up salts. In addition some salt may be precipitated in the soil and there will be an exchange between salts present in water and soil. Thus water either as return flow from field or through soil profile, expected to undergo variety of changes in quality (Yaron, 1988) viz.,

1. Considerable increase in dissolved solids concentration.
2. Anisotropic distribution of various cation and anion.
3. Increased Nitrate content.
4. Little or no Phosphorus content.
5. Reduction of pathogenic organisms and colliform bacteria.

Groundwater Salinisation

It has already discussed in the previous chapters that after the introduction of canal irrigation there is considerable reduction in use from other modes of water resources viz., ponds and wells. Resultantly, the percentage of a area under saline water influence rose from mere 5% during pre-canal irrigation to 47 % at present. The secular changes observed on EC and pH parameters with respect to water table depth and relative aerial coverage (Table 10.4 & 5) proves this fact beyond any doubt.

Table 10.4 Temporal Aerial Distribution Pattern of Electrical Conductance in Matar Command Area

E. C. mhos/cm	Year of Observation											
	1976		1980		1985		1990		1995		1999	
	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	ha
	Aerial Extent (ha) & Percentile Value											
	Pre-monsoon											
0-1000	0.00	0.00	0.00	0.00	0.13	30.51	0.64	145.08	1.76	397.84	0.00	0.00
1000-2000	6.10	1380.65	5.10	1155.66	4.44	1005.90	4.75	1075.31	29.66	6714.36	6.10	1380.65
2000-3000	46.66	10564.36	20.66	4677.14	27.01	6115.18	23.09	5228.42	34.43	7794.10	46.66	10564.36
> 3000	47.24	10694.99	74.24	16807.21	68.41	15477.47	71.52	16191.23	34.16	7733.71	47.24	10694.99
	Post-monsoon											
0-1000	6.73	1522.60	0.01	1.92	0.00	0.00	8.83	1999.69	1.35	306.48	0.00	0.00
1000-2000	41.93	9492.14	19.24	4356.05	6.52	1475.39	24.30	5500.69	31.57	7146.59	10.15	2298.33
2000-3000	24.00	5434.31	36.67	8302.92	22.95	5196.91	23.88	5406.95	34.41	7791.09	45.79	10367.50
> 3000	27.35	6191.00	44.08	9979.15	70.53	15967.71	42.99	9732.67	32.67	7395.83	44.06	9974.18

Table 10.5 Temporal Aerial Distribution Pattern of pH in Matar Command Area

pH	Year of Observation											
	1976		1980		1985		1990		**1995**		**1999**	
	Aerial Extent (ha) & Percentile Value											
	%	Ha	%	Ha	%	Ha	%	ha	%	Ha	%	Ha
	Pre-monsoon											
< 7.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5-8.5	67.25	15225.69	59.71	13517.29	65.93	14925.58	94.67	21432.88	98.82	22370.71	100	22640
> 8.5	32.75	7414.31	40.29	9122.71	17.04	3857.22	5.33	1207.15	1.19	269.27	0.00	0.00
	Post-monsoon											
< 7.5	0.00	0.00	0.00	0.00	1.03	233.83	8.85	2003.48	15.06	3409.72	21.75	4923.17
7.5-8.5	54.15	12258.46	100	22640	97.93	22172.36	82.30	18633.08	69.88	15820.55	78.25	17716.84
> 8.5	45.85	10381.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The salinisation is found to be progressive in nature with time and can be realized by the increasing aerial extent of the water quality deterioration. It is an established fact that as the salinity of water increases, the proportions of sodium, magnesium and calcium salts also increases. At higher level of salinity, the proportion of magnesium salt increases over calcium salts (Skogerboe and Walker, 1988; Gupta and Gupta, 1997 a). The groundwater salinisation adversely effects (I) the physical properties of soil, (II) Reduction in crop yields, (III) Corrosion of plumbing fixtures, industrial barriers and house hold appliances (El-Ashry et. al., 1985).

GEOCHEMICAL DIVERSITY AND REACTION

Study of geochemical reactions is important in understanding the sources and pathways of dissolved ions. For discerning the nature of geochemical interaction in the study area, the author has evaluated ionic ratio of different chemical constituents such as Na/Ca, Ca/Mg, Na/Cl and Scholler Index (SI). Study of these ionic ratios is helpful in identifying the relative contribution of ions from natural and anthropogenic sources. A detailed quantitative data on various ionic rations as Na/Ca, Ca/Mg and Na/Cl obtained from groundwater from various locations and different seasons are given in Table 10.5.

The Na/Ca of the groundwater varies from 2 to 25 (pre-monsoon) and 2 to 50 (post-monsoon). This points to the weathering of plagioclase is the chief source of these constituents (Mathess, 1988). Spatial variations in Na/Ca exhibits lower values in the upper command and higher values in the lower command groundwaters. This possibly indicates enrichment in Na concentration due to evaporation and precipitation of Ca as $CaCO_3$ in the lower zone (Chhabra, 1995). These brought out conclusions are in conformation with the Gibb's Plot where in the wells for each season fall in the field of evaporation and rock dominance (Fig. 10.6) (Gibbs, 1970).

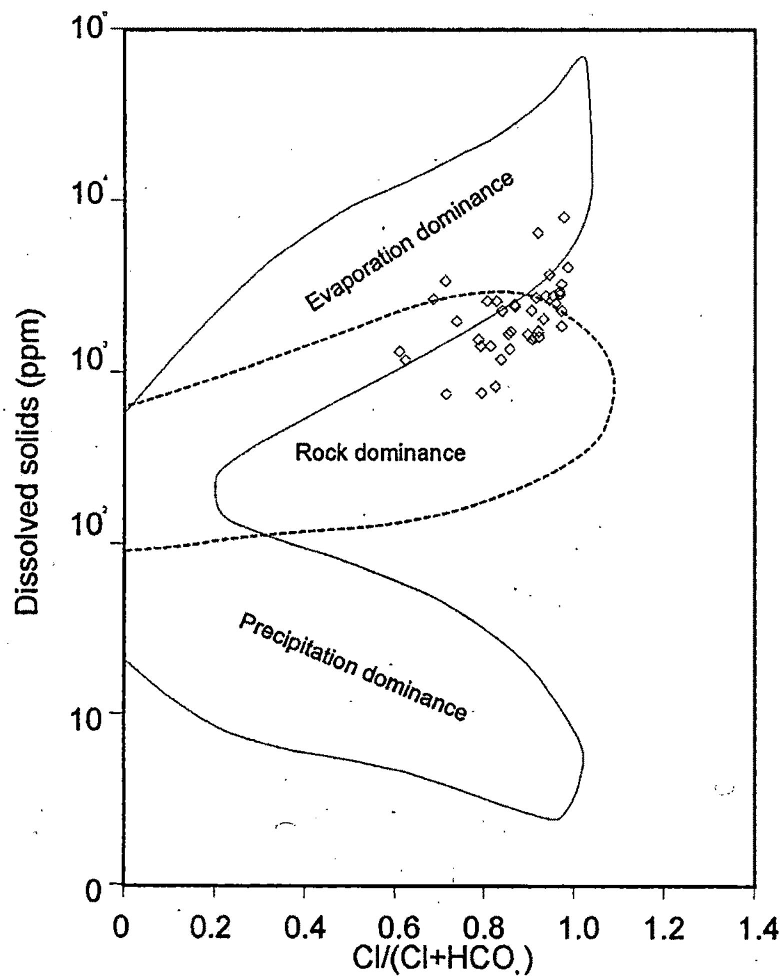


Fig. 10.6 Gibb's Plot Showing Evaporation Characteristics of Groundwater in Matar Command Area.

Further the pre-monsoon season by and large the values of the Ca/Mg ratio (Table 10.5) are > 1 and in the post-monsoon season it is < 1, indicating the contribution of magnesium ion from both the groundwater and anthropogenic activity (Astaraei and Chauhan, 1995). The higher values of the Ca/Mg ratio indicate the dominance of the decomposition whereas the lower values indicate that contribution is more from the agricultural practices.

The ratio of the Na/Cl ranges between 0.40 to 1.20 in pre-monsoon and 0.99 to 1.50 during the post-monsoon. The higher values of the ratio indicates that the concentration effect of the sodium dominating over the chloride and decomposition of the sodium bearing minerals (plagioclase feldspars) in the soils as the main source (Sarin et. al., 1992). Further the values of Na/Cl ratio higher than unity indicates higher sodium concentration may be either due to decomposition of sodium bearing mineral or due to the exchange reaction between the calcium and magnesium with sodium. The lower values of the ratio during the pre-monsoon season are indicative of the non-availability of chloride ions during summer as the rainwater recharge source ceases to be exists during the summer.

For studying the significance of ion exchange process in the groundwater, Scholler Index (SI) was used (Schoeller, 1951, 1962). The SI values in the Matar command area found to be positive with the time. As discussed in the previous chapter on the Water Regime the obtained SI values for the major part of the command show negative values thereby cation-anion exchange type of reaction i.e. chloro-alkaline disequilibrium. However, the lower part of the area depicts the positive values of the SI indicating base exchange reaction i.e. chloro-alkaline equilibrium. This implies that sodium and potassium in the water exchanged with the calcium and magnesium (Raju and Goud, 1990). Further, the analytical data shows HCO_3 > Ca + Mg indicating the sodium ion have exchange with the calcium and magnesium alkaline earth (Chhabra, 1995).

Statistical analysis of geochemical data (Table 10.6) indicates that both in pre- and post-monsoon season the upper bound of the EC remains almost same. Whereas the lower bound shows almost 75 % increase in EC during the post-monsoon period. This phenomenon can be attributed to increase in TDS in groundwater (Jain and Sharma, 2000). Increase in TDS is also reflected by increase in the mean values of Hardness (125.8 %) Calcium (292 %), Chloride (116.35 %) and Sodium (138.6 %). In case of the other elements the mean value decreases due to monsoon recharge. The higher values of the alkalinity indicate the action of carbonate ions upon the basic mineral of the soil.

Further the higher concentration of the calcium, magnesium and sodium indicates the hard nature of the groundwater, which is generally unsuitable for domestic purpose, and higher sodium content makes it unsuitable for irrigation purpose (Mathess, 1988).

Table 10.6 Statistical data on Ionic content of Groundwater in Matar Command
(Pre-monsoon and Post monsoon Seasons)

Parameter	Pre-monsoon			Post-monsoon		
	Range	Mean	Std. Dev.	Range	Mean	Std. Dev.
pH	7.18-8.60	7.76	0.28	7.68-8.59	8.16	0.23
EC □mhos/cm	1200-12900	3815.05	2251.30	2060-12860	3731.50	2295.83
Alkalinity meq/lt	1.28-10.48	4.08	1.95	1.06-6.60	3.35	1.14
Hardness meq/lt	99.98-2439.04	512.12	455.18	50.04-3069.58	537.62	614.64
Chloride meq/lt	3.50-242.04	37.53	41.89	1.52-281.62	49.71	62.38
Sulphate meq/lt	0.21-4.37	1.51	0.96	0.29-44.21	7.72	9.49
Sodium meq/lt	3.54-205.61	37.46	35.28	2.95-285.02	47.76	57.41
Potassium meq/lt	0.01-4.50	0.25	0.72	0.00-0.79	0.13	0.16
Calcium meq/lt	0.36-6.44	2.89	1.56	0.80-18.80	3.68	3.70
Magnesium meq/lt	1.12-43.06	7.35	8.45	0.00-42.58	7.07	9.15

The systematic calculation of correlation coefficient among water quality variables provides an indirect measure of rapid monitoring of water quality. The correlation matrix for different groundwater quality variables of the Matar command area is given in Table 10.7. It is evident from the data that

(I) EC exhibits a positive correlation with Na and Cl (R= 0.80).

(II) Hardness with MG (R = 0.99), Cl (R = 0.88 and Na (R = 0.81).

(III) Chloride with Na (R = 0.98 and Mg (R = 0.86).

Table 10.7 Correlation Matrix among Different Water Quality Variables

	EC	ALK	HAR	CL	SO4	Na	K	Ca	Mg
EC	1.00								
ALK	0.39	1.00							
HAR	0.68	0.24	1.00						
CL	0.79	0.34	0.88	1.00					
SO_4	0.09	0.13	0.05	0.00	1.00				
Na	0.80	0.36	0.81	0.98	-0.02	1.00			
K	0.09	-0.19	0.00	-0.02	0.26	-0.04	1.00		
Ca	0.53	0.26	0.49	0.49	0.20	0.49	-0.11	1.00	
Mg	0.64	0.21	0.99	0.86	0.01	0.78	0.02	0.34	1.00

ALK = Alkalinity; HAR = Hardness (Level of Significance = 5%)

A positive high correlation between the sodium and chloride is an indicative of mineralisation is more in the form of sodium chloride. A good relation of hardness exists with the chloride, sodium, and magnesium. This observation indicates that hardness of groundwater is mainly in the form of chlorides of sodium ($NaCl$) and magnesium ($MgCl_2$) and to lesser extent with calcium ($CaCl_2$). The presence of magnesium chloride may be due to its inherent property, high degree of solubility and low degree of precipitation properties of the magnesium ion (Matthes, 1982).

The regression analysis shown that there is a statistically significant relation at of Chloride (R^2 = 0.90), Sodium (R^2 = 0.92) and Alkalinity (R^2 = 0.86) with Electrical Conductance. Where as the Magnesium (R^2 = 0.82) and Hardness (R^2 = 0.82) shows the good relation with Electrical Conductance.

SOIL DEGRADATION

Soils' response to excessive irrigation and adopted cropping pattern is manifested in terms of alteration in basic soil characteristics thereby soil degradation. Based on detailed characterization of soil regime of the study area in preceding chapter, the author has made the assessment on level of soil degradation. The soils of Matar command show characteristics variation ranging from sandy loam to clay and the clay content tend to increase with depth as well as from upper to lower command. Further soils in the upper command area has higher permeability and infiltration rate, lower moisture holding capacity, higher wetting front movement (both lateral and vertical), makes the soil for proper drainage of the water. Whereas the soils in the lower command area are characterised by the lower permeability, lower infiltration rate, higher moisture holding capacity and lower wetting front movement (vertical) thereby making the soil poorly drained.

The phenomena of rise in water table, waterlogging, groundwater salinity and other anthropogenic factors grossly modify the basic soil characteristics. Abundance of water and dissolved salt content ultimately make the soil highly vulnerable to rapid degradation. The major yardstick indicating soil degradation is salinisation or alkalinisation, salt balance, soil nutrient and organic activities.

Soil salinization is a time and space dynamic degradation process conventionally observed in semi-arid regions. The presence of excess soluble salts in the soil indicates occurrence of salinity (Velayutham, 1999). Soil salinisation does not mean simple increase in amount of salts in the soil but it also entails catastrophic changes in soil properties, which renders the soil useless for agriculture (Khan et. al., 1991). It is a well-established fact that excessive and non-planned irrigation of non-saline soil, the first change is the increase in the soil salinity, which may be permanent or temporary. The soil salinisation in an irrigation command may be attributed to the deposition of dissolved salts, non-utilization of groundwater, and anthropogenic activity (Salama et. al. 1999). The principal salinity constituents are sulphate, chloride, and bicarbonates of calcium, magnesium and sodium. The degradation of soil is the result of combination of climatic factors, soil properties, groundwater characteristics, irrigation scheduling, and anthropogenic activities (Sehgal and Abrol, 1994).

Some of the important works illustrating the process of soil and water salinization and referred by the author for understanding the aspects of soil degradation of his study area are Satyanarayan et. al., 1967; Agrawal and Gupta, 1968; Abrol and Bhumbla, 1971; Zende, 1972; Paliwal and Gandhi, 1973; Gupta and Pandey, 1979; Tyagi, 1982; Edmonds et. al. 1985; Gupta, 1985; Hem, 1991; Gupta and Gupta, 1997, Tickell 1997; Hopkins and Richardson, 1999; Salama et. al., 1999; Cruz and Silva, 2000; Mehta et. al., 2000; Singh, 2000; Valenza, et. al., 2000; Way and Cheng, 2000; Babu Rao, et. al., 2001; and Pariente, 2001.

As it has already been eluded in the preceding chapter on soil and sub-soil characteristics that using pH, EC and ESP of saturation extract soils of study area can be classified in to normal, saline, sodic and saline-sodic soils. The term "Saline Soil" is used for those soils having the conductivity more than 4 mmhos/cm. exchangeable-sodium-percentage is less than 15 and pH is less than 8.5 (Richards, 1954). Saline soils are often recognized by the presence of white crusts of salts on the surface. In addition to the readily soluble salts, saline soils may also contain salts of low solubility, such as calcium sulfate (gypsum) and calcium and magnesium carbonates (lime).

In the Matar branch command area the important localities predominated by saline soils are Garmala, Pij, and Sandhana. Texturally these soils are of sandy clay nature. These saline soils are characterised by high EC (11.40 mmhos/cm), which tends to decrease with the depth to 2.0 mmhos/cm. The pH and ESP are in the range of 7.8-8.0% and 18-65 % respectively. The soil shows the Cation Exchange Capacity increasing with the depth, therefore indicating an increase in clay content. Similarly the geochemical data of the saline soils occurring around Heranj, Punaj and Machhiyel localities show high pH (8.0 8.3), EC (5.8 - 16.8 mmhos/cm), CEC (27 - 51 meq/100gm of soil) and ESP (0.47 - 17.05 %) thereby indicating highly saline nature.

Study of the soluble anions and cations from the soil extract indicates the dominance of Sodium among the cations whereas Chloride and Sulphate among the anions. The dominance of sodium may lead to the sodication of soils, by excess accumulation of Sodium Carbonate and Sodium Bicarbonate as well as increase in the exchangeable sodium content (Szabolcs, 1989). The soluble calcium content tend to increase with the depth at Pij, Garmala and Sandhana localities, whereas it is reverse in case of the Heranj, Punaj and Kharenti localities. Increase in soluble calcium content with the depth points to accumulation phenomena as Calcium Carbonate due to periodic wetting and drying cycles (Chhabra, 1995).

Causes of Soil Salinisation:

Theoretically there are numerous factors influencing soil salinisation. However primarily it is irrigation, which leads to the formation of saline lands. In MRBC and Matar Branch command area a combination of various factors have contributed to the soil salinisation. A few important and identified factors which have grossly influenced the soil salinisation are climate, topography and micro-relief, ground water and soil factors (like texture, hardpan, impervious layers etc.), drains & roadside ditches and adopted faulty irrigation practices.

Climate

The study area constitutes a part of tropical terrain and characterised by semi-arid climatic conditions monsoon being the major and only source of water the non-monsoon months faces net saturation deficit where in evaporation exceeds rainfall. This loss of water from subsoil horizon under the influence of capillary rise and plants' transpiration; mobilize the soluble salts upward and deposit within the soils. The rate of salt build up is invariably high in those areas, which are characterised by shallow water table and medium textured (loamy) soils.

Topography and Microrelief

The topographic configuration and micro relief variation of the command area seems to be responsible for secondary salinisation of the soil. The soils at the head portion, eventhough fine to medium textured are well drained because of its higher elevation whereas at the tail end portion the soil are effected by secondary salinisation.

This is attributed to micro-relief variations manifesting local depressions, which made the soil to remain inundated. The soils around Matar, Cambay, Machhiyel, and Tranja typically represent a case of secondary salinisation where topographic configuration is one of the causative factors.

Ground Water Table Condition

Excessive application of canal irrigation has enhanced the groundwater recharge through the returned irrigation seepage, thereby rise in water table. As the rising groundwater always transfer salts from the deeper layers to the surface the soils become saline. In the study area this factor has played a major role in the process of soil salinisation.

Soil Factors

Basic Soil properties like texture, structure, saturated and unsaturated hydraulic conductivity, soluble salts content, and exchangeable cations, greatly influence the salinisation/alkalization processes. The medium textured soils are more prone to salinasation as compared to fine texture soils as the later has a very slow saturated conductivity. But in the study area the occurrence of the fine textured soils in a basinal low lying situations and availability of shallow saline water for longer duration has facilitated the widespread salinisation. Further presence of compact duricrust layers similar to hard pan obstructs the leaching of salts, which in turn get deposited on the surface.

Over Irrigation

Irrigation water is made available to farmers on warabandhi (on turn) basis and in proportion to land holding. In the absence of any prudent of water supply management system the farmers are in the habit of consuming water as long as the canal runs. As a result more recharge to the groundwater storage; even due to unlined and poorly maintained canal system (Plate 10.1) the roadside ditches and drains remain full with irrigation water making additional contribution to the groundwater regime thereby rise in salt laden water table causing soil salinisation.

Irrigation Practices

The selection of an irrigation method for applying water to the soil is one of the important factors that can be related to the problem of salinity. Therefore, application of irrigation method adopted in any area depends upon the number of conditions such as Cropping pattern, Climate, Topography, Soil characteristics, Salinity status of soil and Availability and quality of irrigation water (Gupta and Gupta, 1997).

The irrigation methods can be further classified in to four categories viz., Surface irrigation, Sub-surface irrigation, Spinkler irrigation, Drip irrigation; considering numerous factors like soil condition, crop type, climate, availability of water, capital expenses for laying the irrigation system etc.

Inadequate and/or lack of knowledge regarding crop-water requirement and financial constraint, the farmers have mainly adopted the surface irrigation method. Large-scale cultivation of paddy crop has encouraged the farmers to stick to traditional methods of irrigation i. e. surface irrigation. Excess use of water in this method lead to waterlogging and salinisation of soils and groundwater as well.

ALKALI SOILS

The soil, in which the exchange complex contains appreciable quantities of exchangeable sodium but may or may not contain excess salts, are called alkali or sodic soils and process leading to sodicity of soil is termed as sodiumization/alkalization (Richards, 1954, Chhabra, 1995, Daji, 1996). In this process the development of salts such as sodium bicarbonate and/or carbonate predominates. Resultantly the soil become dispersed and the available dissolved organic matter turn alkaline and gets deposited on the soil surface to give rise black alkali. Further, the dispersed clay transported downward through the soil profile and ultimately gets accumulated at lower levels. As a result, few inches of the surface soil are relatively coarse in texture and friable, the clayey layer developd below is of low permeability having columnar/ prismatic structure (Shainberg and Letey, 1984).

Sodiumization is considered as progressive step of salinization. In the light of some of the important studies dealing with the mechanism of the development of sodic soils and also suggesting an appropriate remedial measure for its management viz., Singh and Mishra, 1994; Brar and Bajwa, 1996; Tripathi, 1998; Sood et. al., 1998; Salama et. al., 1999; the author have made an attempt to investigate the process of sodiumization in the study area. The important parameters considered for characterization of sodic soils are pH, EC, and ESP.

In the Matar branch command the development of alkali soils have been observed around Jharol, Raghvanaj, Alindra, and Vaso villages. The soils at these localities are of the sandy loam and clayey loam nature. The geochemical data indicates following trends: EC 0.5 to 1.6 mmhos/cm for the surface soil and tend to increase with the depth to as high as 2.1 mmhos/cm; the pH of the soil at all the locations as well as through out the soil profile is > 8.5; and ESP for the sandy loam soils is as high as 29.41 and tend to decrease with the depth. In case of the clayey loam soils the ESP values are as high as 17 and tend to increase with the depth. Increase in the ESP makes the soil more dispersed and leading to surface soil become sodic (Richards, 1940).

ORIGIN OF SODIUMIZATION

The origin of sodiumization in the area is more or less similar to salinization process. The hydrochemical data of groundwater by and large reflect predominance of sodium followed by calcium or magnesium amongst cation. However the anions concentration is in the order of Chloride > Bicarbonate > Sulphate > Nitrate. These obtained trends in cation and anion concentration suggests that carbonate/bicarbonates saturated water is responsible in precipitation of calcium and leaving behind the magnesium in sodium rich solution developing sodicity in the soil. Also, the enhanced sodicity in the soils may be attributed to higher adsorption of sodium from the water having high Mg/Ca ratio (Paliwal and Gandhi, 1976). The prolonged irrigation by using water containing high Mg/Ca ratio and SAR also increases the Mg/Ca ratio and SAR of soil (Girdhar and Idnani, 1994). The geochemical data on soil and water establish this fact beyond any doubt and point to an important causative factor for developing sodicity in the soils of Matar Command.

MECHANISM OF SOIL AND GROUNDWATER SALINISATION

In an irrigation system it is desirable to have soil and water compatibility. However, if the compatibility between these two resources does not exists,, then adverse effects on the chemical and physical properties of soil and water resources are evident. Salinisation of soil and water is one such effect attributed to non-compatibility of soil and water characteristics. The process of salinisation involves complex factors. Although, the extent of salinisation depends upon the amount and nature of accumulated salts in the soil, these salts are carried along with water by many physical and chemical reactions. The geochemical process like adsorption and dispersion are the main physical transport processes, which are responsible for the transport of these dissolved salts from recharge to discharge areas. In addition to this, the chemical reactions such as dissolution and precipitation of minerals are also associated with mechanism of salinization (Miller and Donahue, 1995, Szabolcs, 1995, Salama et. al., 1999). Therefore, it is desirable to consider the geological, hydrogeological, hydrogeomorphological and environmental factors to understand the mechanism of salts migration and accumulation. The studies carried out by the workers viz., Beck et. al., 1984; El-Ashry, 1990; Hendry and Buckland, 1990; Toth, 1999; Salama et. al., 1999; Mehta et. al., 2000, Prasad and Singh 2000 and Prasad et. al., 2001 provide much insight on the mechanism of soil and water salinisation through the process of salt migration and accumulation.

NATURE OF SALTS

In the semi-arid and arid climatic regions normally the evaporation exceeds the rainfall. Evaporation coupled with the factors like topography and groundwater hydrology, are often responsible for the in-situ migration and accumulation of salts. In case of canal irrigation, the equilibrium between inflow and outflow is disturbed due to excessive seepage from canal network and contribution of excess water (through indiscriminate and unscientific irrigation practices) without taking in account the surface/subsurface drainage system. The surface drainage with adequate outfall is imperative for efficient disposal or accumulated salts and surplus water. The study area becomes highly vulnerable to salt accumulation due to lack of sufficient drainage network.

The chief ionic combination that gives rise to the formation of salt belongs to Ca, Mg, Na, Cl, SO_4, HCO_3, CO_3 ionic series. These elements depending on their geochemical mobility under variety of weathering processes, like hydrolysis, hydration, oxidation and carbonation, may be arranged in mobility sequence (Chhabra, 1995, Szabolcs, 1995):

- Practically non-leachable (Si in Quartz).
- Slightly leachable (Fe, Al, Si, P).
- Leachable (Si, P, Mn)

- Highly leachable (Ca, Na, K, Mg)
- Very highly leachable (Cl, B, I, S, C)

Salt formation is therefore expected to result from combination of the groups highly leachable and very highly leachable. Some of the important compound, which may be possibly, develop such as $MgSO_4$, $CaCl_2$, $CaSO_4$, Na_2CO_3, $NaHCO_3$, $MgCO_3$, and $CaCO_3$ (Richards, 1954, Chhabra, 1995, Szabolcs, 1995).

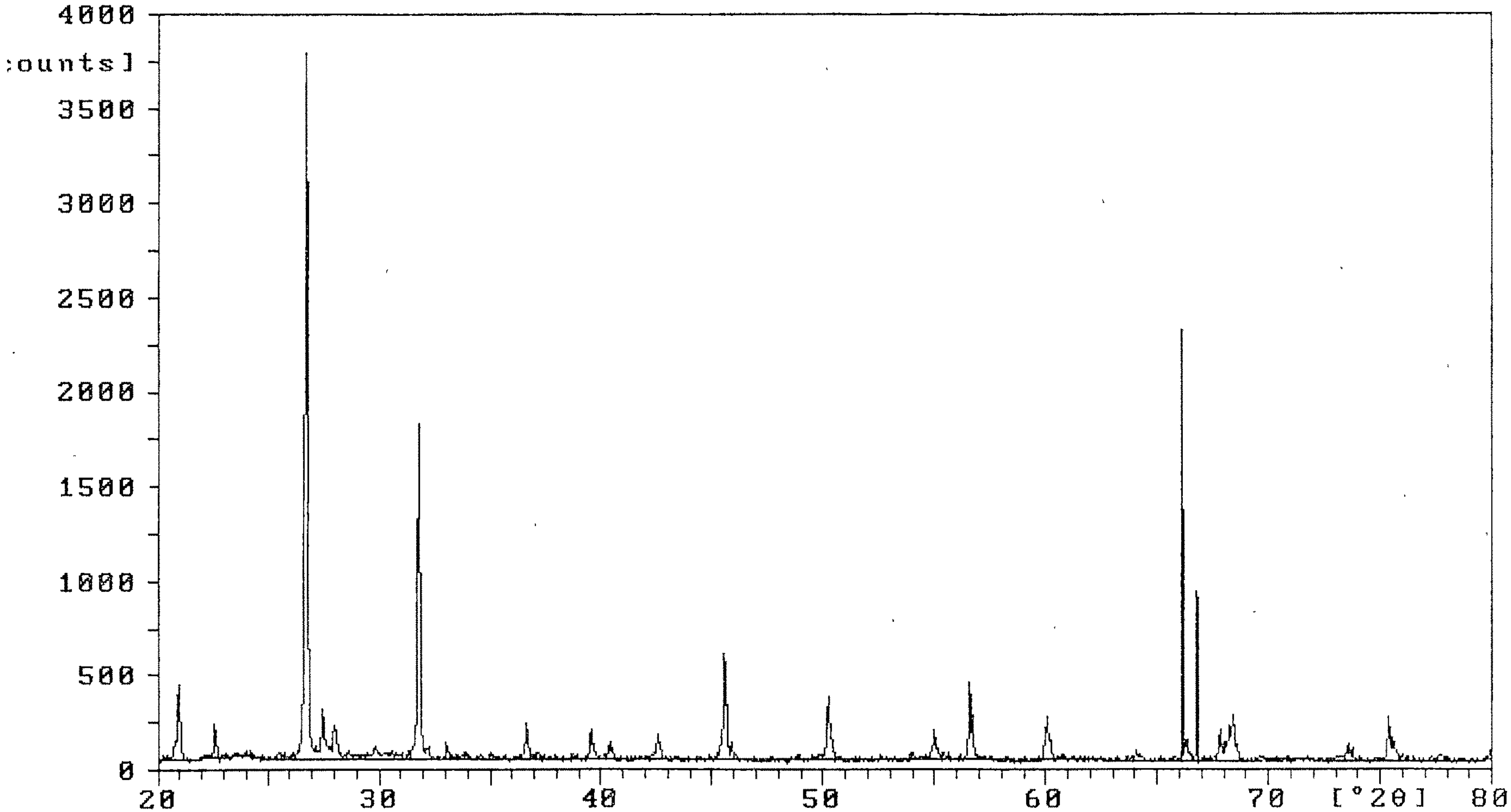
In order to determine the nature of soluble salt, the collected saline soil samples were analyzed for their soluble anions and cations. The obtained analytical data (Table 10.8) point to following order of predominance Na > Ca > Mg and Cl > SO_4 > HCO_3. The sodium which is as high as 80 meq/l, constitutes more than 50% of the total cations and anions. Considering the dominance of prevailing ionic concentration the possible nature of available salts may be of NaCl or $CaSO_4(OH)$.

In order to further confirm the presence of specific salts; the author has analyzed the typical samples using standard X-Ray Difractogram techniques (Pillips Analytical X-ray B. V., PW 1710, Cu K□). In all 03 samples from known location were analyzed and difractogram (Fig. 10.5 a, b and c) were qualitatively interpreted using the JSPDS cards (JSPDS, 1974).

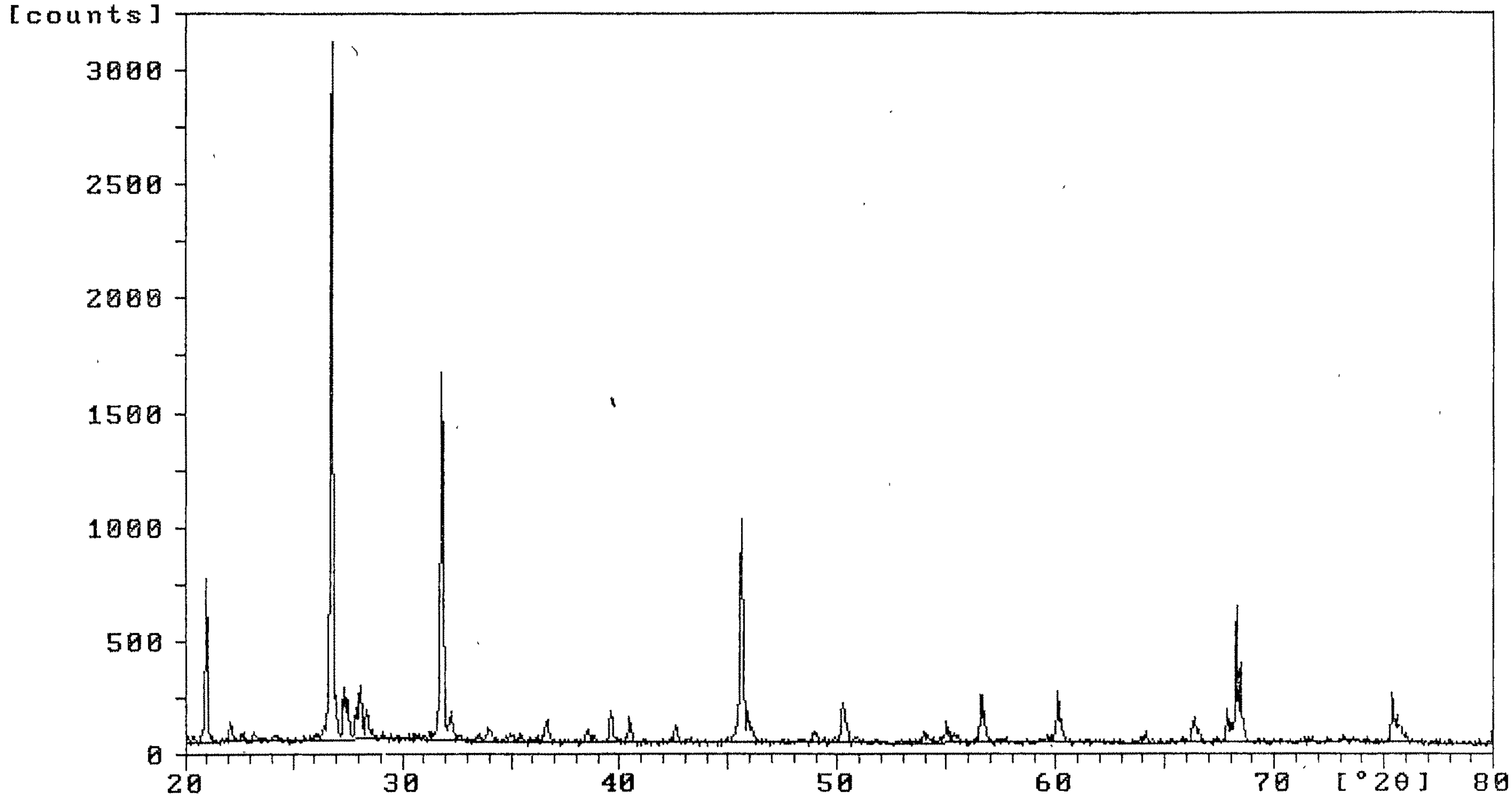
Qualitative interpretation of the obtained difractogram shows predominance of Halite NaCl (d = 2.82). The other defraction peaks constituting subordinate composition are Na_2SO_4 (d = 2.78) $CaSO_4(OH)$ (d = 2.87), Quartz (d =4.26), Orthoclase (d=3.33), and Muscovite (d =4.11). The relative abundance of available salts may be arranged as NaCl > Na_2SO_4 > $CaSO_4$; which is reliably in conformation with geochemical results.

EMPIRICAL MODELING FOR THE SOIL SALINISATION

It is imperative to know the composition of soil solution from the point of view of ameliorative measures, to be adopted for reclamation of salt affected soil. The soil rich in carbonates, bicarbonates and silicates of sodium normally requires acidifying amendments like gypsum and pyrites etc., while those rich in chlorides and sulphates require simple leaching coupled with drainage. Based on this author has made an attempt to work out empirical relationship between electrical conductance and different ionic concentration of soil saturation extract and groundwater quality.



X-ray Difractogram of Saline Soils of Matar Command Area. Location Pij



X-ray Difractogram of Saline Soils of Matar Command Area. Location Garmala

Four different empirical models were examined for predicting the ionic concentration as

$IC = (A \times EC) + B$ ....Linear Function

$IC = (A \times (\ln EC)) + B$ ....Logarithmic Function

$IC = B \times (e^{(A \times EC)})$ ....Exponential Function

$IC = B \times (EC^{A})$ ....Power Function

Where, IC = Ionic Concentration; EC = Electrical Conductance of Soil Saturation extract or Groundwater; A & B are empirical constant.

Using all the four models author has carried out the regression analysis for different ionic concentration and EC of both soil saturation extract and groundwater. Results have depicted that Linear Function model is found to be best fit in both the cases.

RELATIONSHIP BETWEEN ELECTRICAL CONDUCTANCE AND DIFFERENT IONS OF SOIL SATURATION EXTRACT:

Various cations and anions influence the soil characteristics significantly and helps in deciding the reclamation policies. The relationship between different ions with EC is discussed below.

E. C. and Sodium: In the present investigation EC of the saline soils varied from 4.05 to 31.00 mmhos/cm. As the EC increases the sodium content of the soil also increases and it varied from 10 to 216 meq/l. The values of EC and Na are found to be significantly related ($R^2 = 0.97$) with the linear function. The best-fit line obtained for the relationship is

$$\mathbf{Na} = 10.3910 \times EC - 37.4160$$

E. C. and Chloride: The chloride content of saturation extract varied from 10 to 160 meq/l. Regression analysis has depicted that the chloride content and EC values are significantly related ($R^2 = 0.95$) with linear function. The best-fit line was resulted with an equation

$$\mathbf{Cl} = 9.1599 \times EC - 32.3750$$

E. C. and SAR: The EC and SAR has shown the positive relationship with $R^2 = 0.93$ with the linear function. The best-fit line obtained is

$$\mathbf{SAR} = 1.8829 \times EC - 0.4038$$

Thus it can be said from the above relationship that soil have dominance salt present in the form of sodium chloride and are linearly related with the electrical conductance. Thus it is dependable to predict the sodium chloride content from electrical conductance using the linear equations. It can also be seen that the sulphate is unevenly distributed and significant contribution of magnesium also helps to predict the concentration, using the linear equation and electrical conductance as parameter.

RELATIONSHIP BETWEEN ELECTRICAL CONDUCTANCE AND DIFFERENT IONS OF GROUNDWATER:

Groundwater below the saline field also found to be saline with electrical conductance ranging between 3.9 to 12.7 mmhos/cm. It has also been found that mineralisation of water increases with time.

E. C. and Sodium: In the present investigation as the EC increases the sodium content of the water also increases and it vary from 25.00 to 100 meq/l. The values of EC and Na are found to be significantly related ($R^2 = 0.90$) with the linear function. The best-fit line obtained for the relationship is

$$\mathbf{Na} = 0.0061 \text{ X EC} + 9.2123$$

E. C. and Chloride: The chloride content varied from 25 to 55 meq/l. The chloride content and EC values are significantly related ($R^2 = 0.89$) with linear relationship. The best-fit line was resulted with an equation

$$\mathbf{Cl} = 0.0073 \text{ X EC} + 10.454$$

Electrical Conductance and SAR: The EC and SAR has shown the positive relationship with $R^2 = 0.88$ with he linear function. The best-fit line obtained is

$$\mathbf{SAR} = 0.0011 \text{ X EC} + 11.4590$$

From the above discussion, it can be inferred that both groundwater as well as soil exhibits linear relationship between electrical conductance and sodium chloride content. Thus it can be said that soil salinisation has been resulted from groundwater i. e. higher degree if mineralisation of groundwater constitutes potential source of soil salinisation. Considering high degree of mineralisation of groundwater, there need a cautious approach in exploiting groundwater for conjunctive use for irrigation with good quality canal water.

WATERLOGGING AND SOIL SALINITY MAPPING: A REMOTE SENSING APPROACH

Remote sensing has become an important tool for natural resources management system. Advancement in technology has flourished the application of remote sensing interpretation and linked to the various streams. Recent advances in the application of remote sensing technology in mapping and monitoring degraded lands especially salt affected soil have shown great promises of enhanced speed, accuracy and cost effectiveness (Singh et. al., 1977; Venkatratnam, 1983; Singh and Dwivedi, 1989).

The nature and magnitude of problem, aerial extent and its spatial distribution of the problem area, both temporal and spatial, can be assessed through the available remotely sensed data. Majority of the scientist involved in remote sensing studies strongly believes that the LANDSAT and IRS 1A data provide signatures of salt affected soils with strong to moderate sodicity whereas the soils with low sodicity is difficult to identify (Rao et. al., 1991; Singh et. al., 1988). But, the salt affected soils, with different severity can be easily identified and possible to map it (Dwivedi et. al., 1989). Similarly it is easy to demarcate the boundaries of the waterlogged areas with MSS and FCC data (Sharma and Bhargava, 1987, 1988; Dwivedi and Deka, 1988; Sanjeevi et. al., 1990).

Author has attempted the delineation of salt affected soil and waterlogged area within the Matar Command using the LISS III FCC image of pre-monsoon (April, 1999) and post-monsoon (November, 1999) periods. Salt affected soils are expressed as bright white to dull white patches within the light brown background of normal soil on FCC. The wetness of varying degree during the summer period appearing as bluish or greenish blue patches on FCC. Upon changing the band the spectral behaviour found to change. The saline soils also develop pink color tone at places. Moderately saline-sodic soils, which are showing the dull white patches and have been confirmed with ground truth during the fieldwork to distinguish between the field applied with the gypsum.

Fig. 10.7 and 10.9 shows the waterlogged and saline area in Matar Branch Command area. The figure shows that the majority of the waterlogged area exists in the lower command area i. e. around Matar, Machhiyel, Sokhada, Traj, Kharenti. There exist small patches showing the waterlogged condition in and around Sandhana, and Pij in the upper command. The area has been calculated and quantified to 407.5 ha (1.8 % of Command), which is in confirmation with the area calculated on the basis of the contour plots.

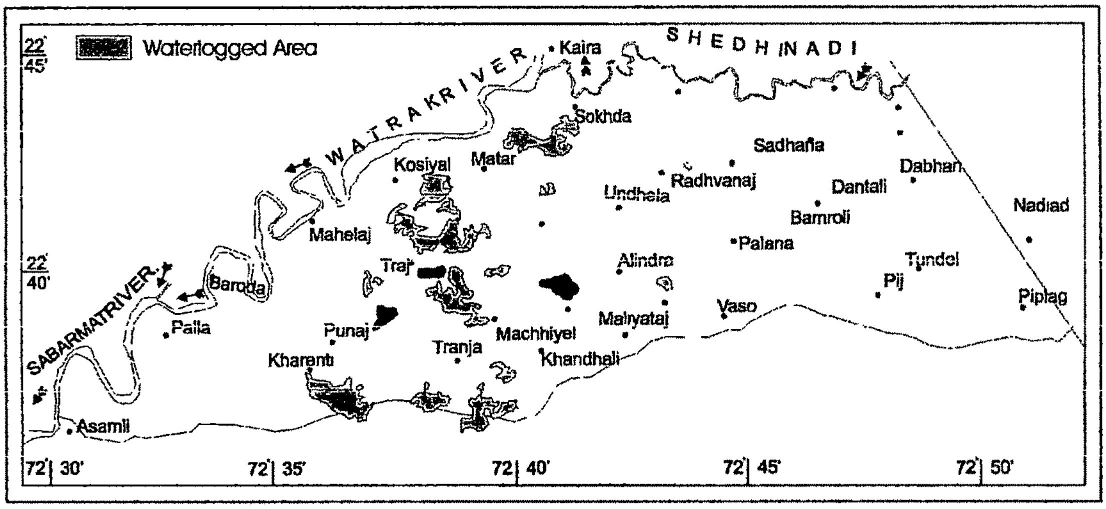


Fig. 10.7 Waterlogged Area as Delineated from the IRS 1A data.

The spectral response of salt affected soils is substantially higher than those of the normal soils (Rao et. al., 1995). Also the strongly saline-sodic soil have higher spectral response that the strongly salt affected soils. The salt affected soil is found to appear as bright white patches in the ground. At places the salt affected soils are found to be dull white with red background. As the area does not have saline-sodic soil, which usually appears dull white with bluish or pinkish background color. It is difficult to delineate the alkaline soils in the area, as it has not shown pronounced surface signature. The saline soils are demarcated in the area around the Kharenti, Machhiyel, Pij, Sandhana, Matar (Fig. 10.8) etc. The interpretation indicates the aerial coverage of 50 ha land under soil salinity.

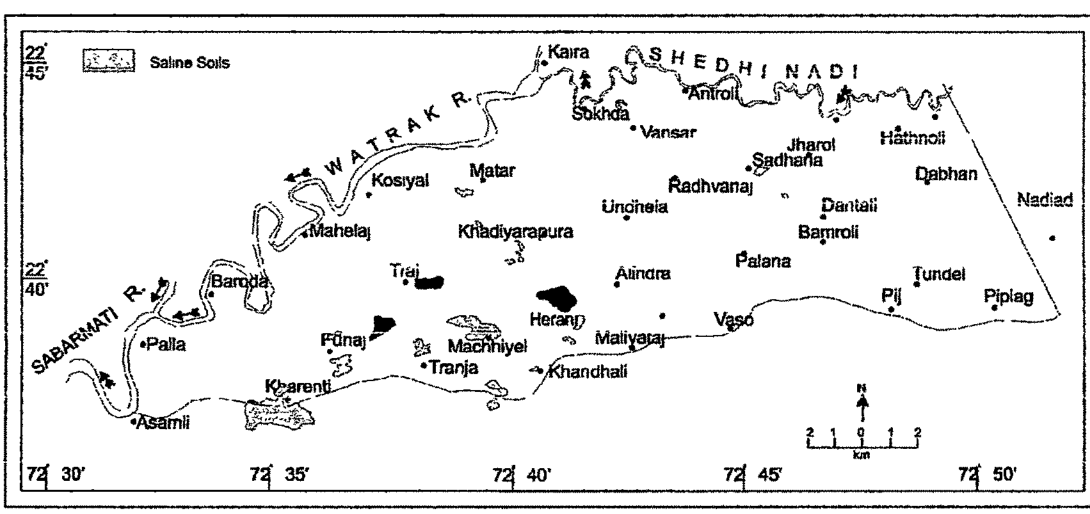


Fig. 10.8 Salt Affected Soils as Delineated from the IRS 1A data.