Chapter X

Soil Water Management Strategies

Irrigation has Great Potential for Development if it is Properly Managed (Rao, 2000).

SOIL AND WATER MANAGEMENT STRATEGIES

GENERAL BACKGROUND

One of the major processes degrading the soil quality in canal command is rising trends in groundwater table and the resultant accumulation of salts in excess, causing soil and water salinisation (Minhas and Singh, 1996). Introduction of surface irrigation induces additional recharge to the groundwater of irrigated areas due to seepage losses through conveyance systems and deep percolation from field application, which ultimately causes rise of the groundwater tables. Wherever the raised groundwater table approaches the root zone of crops, waterlogging interferes with the effective vegetative activity of the root zone of crops and the crop yield declines. In due course of time soils of the waterlogged areas develop salinity. The rate of water table rise primarily depends upon the conveyance and applied irrigation practices, rainfall, soil type and properties and aquifer nature and its disposition pattern with reference to the surface conditions.

Subba Rao (2000), has pointed out that irrigation is not only a science concerning with better use of water but it is an art of management. Therefore, better management should increase the output by irrigating more land with less water or by adopting various remedial measures to improve the productivity of land or soil.

It has already been discussed in preceding chapters that irrigation in the Kakrapar Left Bank Canal Command Area in general and the Chalthan Branch Canal Command Area in particular is being practiced for almost past four decades. Initially, the primary objective of irrigation was to bring the large area under irrigation in order to prevent crop failure. Rather than implementing a sustainable irrigation, the poor irrigation management has led to a productive irrigation. Resultantly a significant part of the command area has now become vulnerable to land degradation by waterlogging and soil salinity.

Taking in to account the inferences drawn from the preceding chapters on water regime, soil regime and the impact of irrigation on soil and water regimes of the Chalthan Branch Canal Command Area; the following interrelated constraints, which needs an appropriate remedies, and management practices have been identified:

- Rising trend in groundwater table - waterlogging,
- Deterioration in overall groundwater quality,
- Concentration of salts in soil and sub-soil horizons - soil salinity.

The aspects of soil and water management in irrigation command have been studied in great detail world over. In depth field studies have been carried out to identify the causes of soil and water resources degradation and for appropriate remedies, to restore the productivity of soils and optimum utilization of land and water resources. Studies carried out by Minhas and Singh (1996) has put forth various options through a flow chart for preventing the salt build up to level, which limit the productivity of soils, and control salt balances in the soil-water system as well as minimizing the damaging effects of salinity on crops at the field/plant level (Fig. 10.1).

Some important landmark studies referred by the author, for adopting an appropriate remedial measures in the present case are based on the work carried out by Agrawal and Gupta, 1968; Kumar and Arya, 1972; Garg and Singhal, 1982; Handa, 1983; Mahodaya et al, 1984; El-Ashry et. al., 1985; Gupta, 1985, 1987; Abrol, 1992; Miller and Dohahue, 1992; Varade, 1992; Apshankar and Kapre, 1996; Tygi, 1996; Minhas and Singh, 1996; Khare and Inamdar, 1996; Gupta and Gupta, 1997;

Marlet, et. Al., 1998; Tripathi, 1998; Singh et. al., 2000; Subba Rao, 2000; Silva, 2000; Barbiero et. al., 2001; Mondal et. al., 2001; Qadir et. al., 2001 and Tedeschi, et. al., 2001. In the light of above raised constraints in achieving the sustainable irrigation, following management strategies may be adopted in Chalthan Branch Canal Command Area.

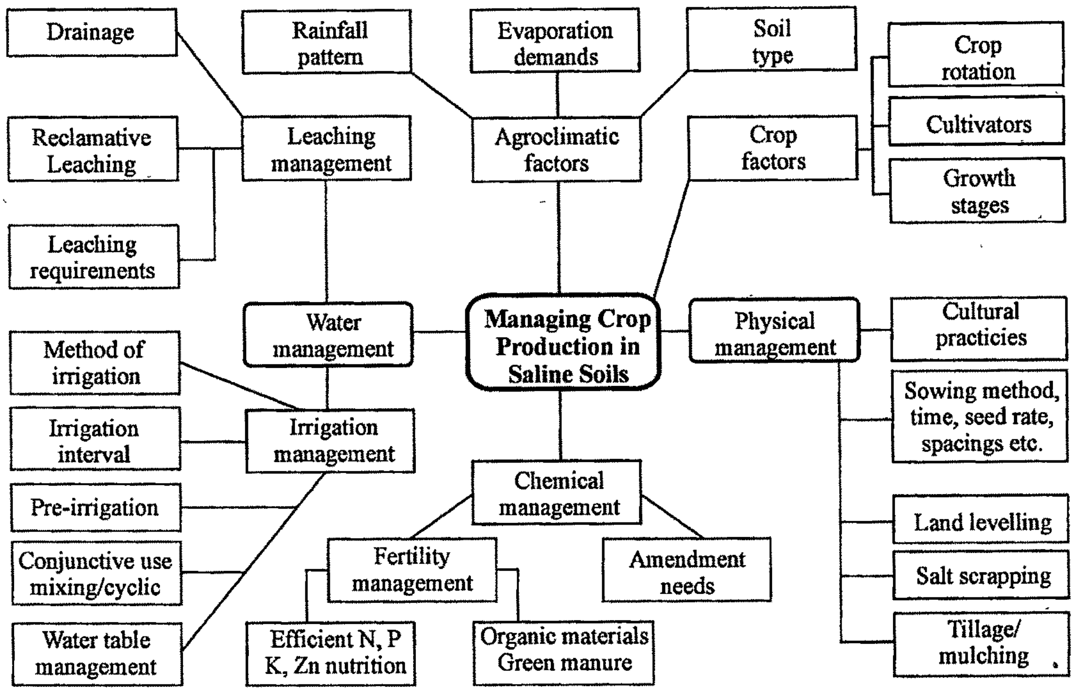

Table 10.1 Management Options for Crop Production in Waterlogged and Saline Soils (Minhas and Singh, 1996).

WATER MANAGEMENT PRACTICES

As it has been already discussed in preceding chapter i.e. impact of irrigation on soil and water regime, the study area is greatly affected by rising trend in water table i.e. waterlogging and brackish or saline groundwater quality. To prevent these adversities, no single strategy can provide fruitful results; therefore an integrated approach has to be devised, that can combat the earlier cited two fold problems. Accordingly, the following management strategies may be adopted for mitigating the command area problems.

(a) **Efficient Drainage System**: In order to reduce inflow of surplus water into sub soil strata all the important drains will have to be improved, additional drains in subsoil will have to be opened. A number of important drains in the command area which are already existing, it will be necessary to improve them in order to have better carrying capacity and suitable outfall conditions. An efficient surface and subsurface drainage system, which permits a quick flow of accumulated water, in short period helps to reduce the waterlogging (Fig. 10.2). Besides the deepening and widening of natural drainage (Fig. 10.3) and artificial drainage, proper maintenance is absolutely necessary for lowering of the water table in the command area.

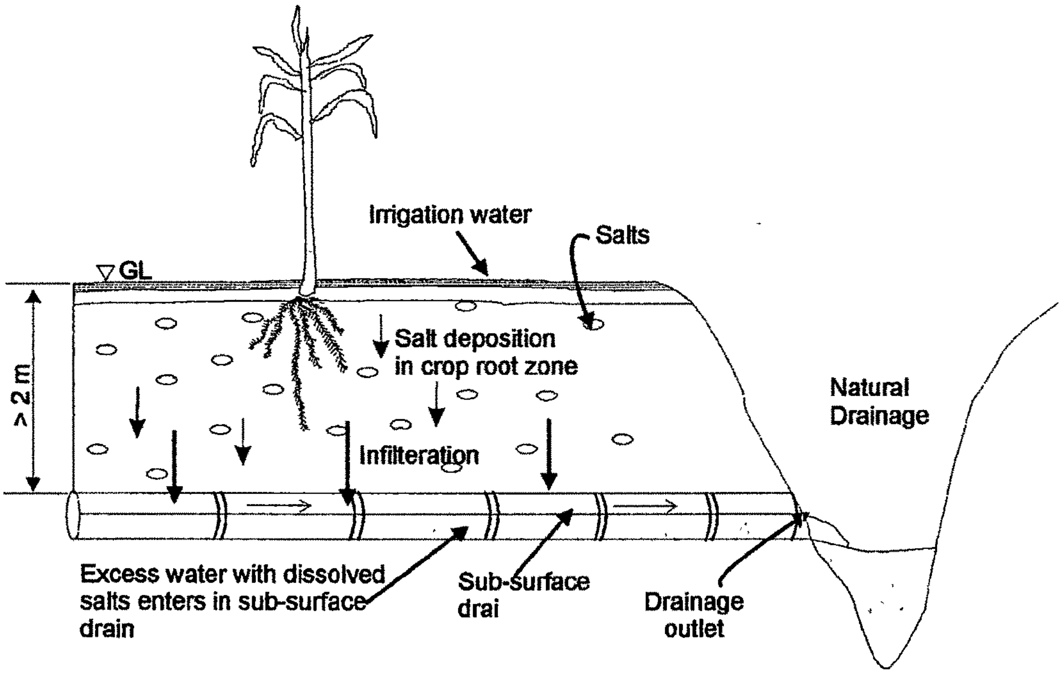

Fig. 10.2 Schematic Sketch Illustrating the Role of Subsurface Drainage in Controlling Waterlogging and Salt Accumulation.

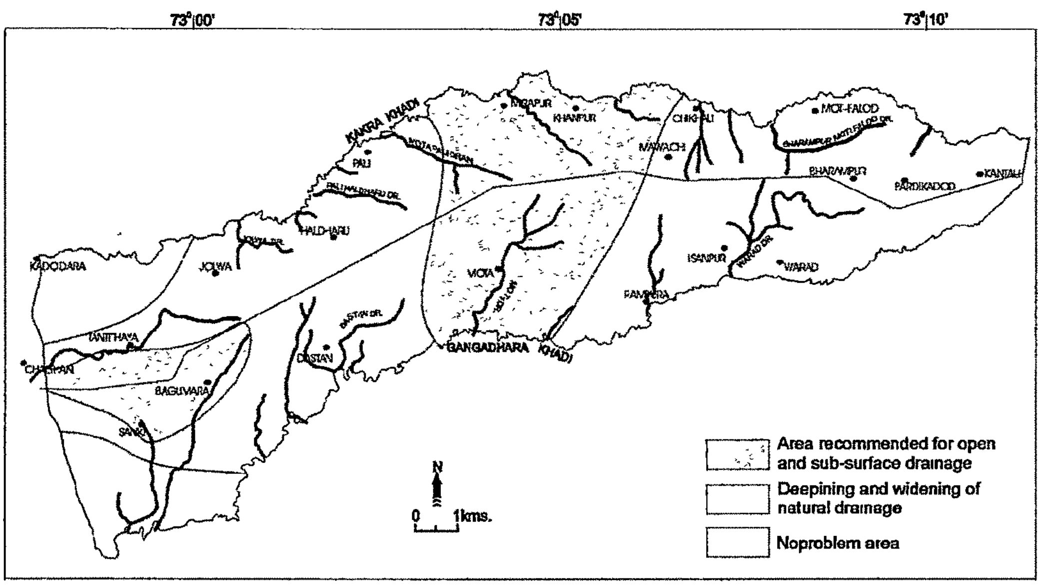

Fig. 10.3 Command Area Demarcated for the Improvement of Surface and Sub-surface Drainage for Controlling Waterlogged Conditions.

Experimental pilot studies carried out by the Command Area Authority with the assistance of World Bank funding has amply proved the efficacy of such measures. Also, it has been observed that there is considerable increase in the crop yield, where in sugarcane crop has recorded an overall 44% increase in crop production (Table 10.1) in comparison to those areas where such measures have not been inducted (Raman, 1994).

Table 10.1 Effects of Surface Drainage on Sugarcane Crop Yields (Pilot Area 60 ha).

Year	Yield (t/ha)		% improved over un-drained area
	Drained area	Un-drained area	
1985-86	98.0	73.0	34.2
1987-88	79.7	64.5	23.6
1989-90	107.6	63.4	69.7
1990-91	100.1	75.2	33.1
1991-92	104.8	63.9	64.0
Mean	98.0	68.0	44.0

(b) **Reduction in Percolation from Canals and Irrigation Channels**: As it has been already discussed that an observation well located at Mavachhi in proximity of Branch canal shows almost 4 m difference in water level between operational and non-operational periods of canal. To prevent this seepage or percolation from canal, the canal section must be strengthened with proper earthwork and with the provision of lining. The problematic length of the canal should be lined to make it impervious. Realizing this very fact, the Command Authority had recently taken up the task of carrying out canal lining of all branch canal network of entire Kakrapar Canal Command Area. The effect of this measure will discernible in near future. The following measures should be taken to prevent seepage from canal or irrigation channels.

Lowering of Full Supply Level of Irrigation Canals: If the full supply level of irrigation canal is reduced, there will be lesser seepage loss from embankment. The effective head between full supply level and field will also reduce and therefore, chances of a wastefull use of water are avoided.

Intercepting Seepage Drains and Shallow Tubewells: Waterlogging can be reduced considerably by providing intercepting drains or a row of shallow tube wells along the canal to collect part of seepage water. However, till recently no method was available to determine the seepage discharge into and assess the extent of lowering the free surface by intercepting drains. Therefore, a study was taken up at U.P. Irrigation Research Institute, Roorkee, which aimed at finding out an analytical solution to determine the extent of reduction in waterlogging as a result of providing intercepting drains or a row of shallow tube wells along the canal and also at evolving some suitable criteria to design such drains and wells. Some important conclusions of this study are:

i. The discharge to the intercepting drain increase with increase in bed width of the channel and diameter of intercepting drain, whereas, it decreases with increase in distance between the canal and the intercepting drain. As the drain is brought closer to the canal, the rate of increase of seepage into the drain increases. The effect of drain diameter in intercepting seepage, discharge is more, pronounced at deeper setting of the drain.

ii. The effect of lowering of phreatic surface by provision of intercepting drain extends to considerable distance on either side of the drain. The deeper setting of the drain results in greater lowering of water table. The location of the drain further away from the canal results in greater lowering of free surface beyond the drain although this results in slight rise in the elevation of phreatic surface between the canal and the drain.

(c) **Conjunctive Use of Water**: The conjunctive use is a planned and coordinated harnessing of ground and surface water resources. In other words, it is an integration of hydrologic, geologic, agronomic and economic components and social factors so as to optimize agricultural production and to achieve sustainable irrigation (Bhamrah, 1996). In waterlogged areas, the replacement of canal irrigation by tube-well irrigation is a very effective antiwaterlogging measures. Not only this, conjunctive use of surface and groundwater can also be resorted to lower the water table.

According to Gajja and Sharma (1994) the conjunctive use of canal and tube well water will increase crop output and farm income at a rapid rate and at the same time the problem of waterlogging can be prevented. The amount of water pumped is the net subtraction from the groundwater reservoir and is, therefore, very effective in lowering the water table. So, the farmers should be encouraged to use canal water in combination with groundwater either by mixing the water supplies or by cyclic use of canal and groundwater.

(d) **On Farm Water Management**: Good irrigation management lies in the efficient use of the irrigation water once it reaches the field head. It is reported that as much as 50 percent of the water delivered at the field head goes as deep percolation losses (Joshi and Agnihotri, 1984). To use this water through surface irrigation methods with minimum of losses, on farm water management technology should include efficient land leveling and shaping, efficient design and layout of the irrigation and crop planning for optimum yield per unit of water applied with minimum loss of soil and plant nutrients.

Fragmental land holdings with irregular field boundaries area a common feature of the study area. A scattered field with irregular boundaries increases greatly the energy requirement in farming operations. These also require longer length of watercourses and a series of branch water courses to convey water to the different fields. Converting the existing land into the rectangular plots and their consideration on ownership basis through suitable exchanges between different owners are desirable features of an efficient water management practices.

Fig. 10.4 shows a case example of example of efficient water management in the study area. Fig. 10.4a indicate the present layout of land holdings in the command area while Fig. 10.4b represent the suggested scheme of rectangular of the fields, keeping the area of each filed same as before and with less disturbances in the location of the holdings of the different farmers. From this it may be seen that proposed rectangulation scheme reduces the length of the water cources required for the outlet command hence there will be less seepage.

(e) **Regularized Canal Water Supply**: Because of unassured water supply, there is a tendency of the farmers to over irrigate their crops, which causes waterlogging problem. For mitigating this problem, irrigation authority should make an arrangement for assured water supply through adoption of warabandhi or formation of water cooperatives/societies or farmers participatory irrigation management systems. In all the systems, farmers' participation is a mush. In order to achieve this there is a need to educate the farmers about irrigated agriculture and scientific water management. This will automatically change the farmer's tendency, of over irrigating their crops and ultimately, the misuse of irrigation water can be brought down to its minimum level. Area with high water table may be allowed only for kharif irrigation and, during rabi and hot the cultivators may irrigate from open well or tube wells (Raman and Patil, 2000).

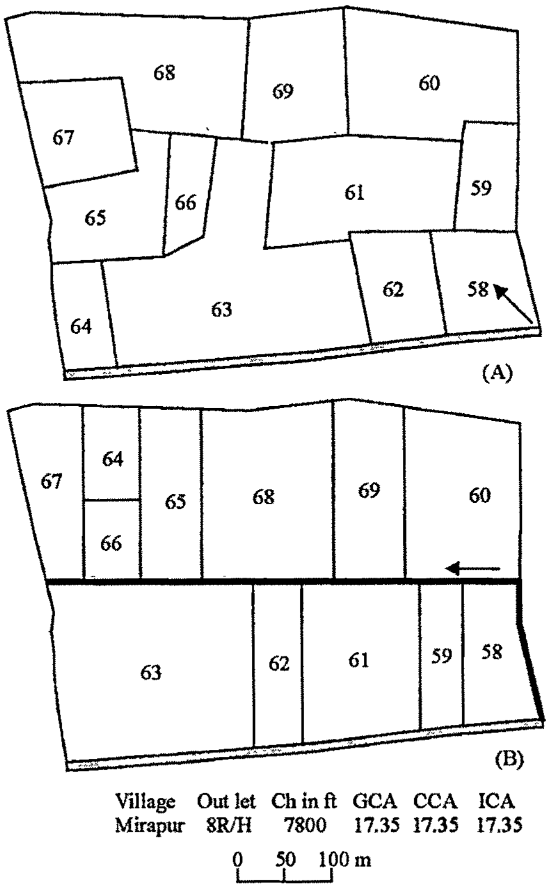

Fig. 10.4 Distribution of Land Holdings in the Chalthan Command Area of Outlet No. 8R/H.

(f) **Groundwater utilization:** To lower down the existing water table, groundwater should be utilized for irrigation directly or could be mixed with canal water if the quality is not good. This could be done through (i) Shallow well pumping - water is pumped out from top aquifers to depress the water table. This water may be utilized for irrigation in some other area and (ii) Deep well pumping - the water is pumped out from several water bearing strata and this discharge should be used for irrigation purpose. Lift irrigation and well irrigation in study area should be promoted.

Recently for the purpose of providing lining to Chalthan Branch Canal system, canal was kept non-operational for about four months during post monsoon period of year 2000. During this period farmers have been advised to use the groundwater for their irrigation purpose. The effect of 04 months groundwater utilization and almost negligible recharge due to seepage from canal system; has been of considerable significance. The water level monitoring data of this season and its comparison with previous year records, categorically points to significant lowering of water levels (Table 10.2).

Table 10.2 Static Water Levels in Chalthan Branch Canal Command Area.

Village	Post monsoon 1999 (m)	Post monsoon 2000* (m)	Difference (m)
Vihan	1.75	8.80	7.05
Chikhli	2.00	5.70	3.70
Haldharu	1.70	8.05	6.35
Bharampur	3.30	4.25	0.95
Khoj Pardi	3.70	6.80	3.10
Mota	0.30	4.50	4.20
Isanpur	3.40	4.40	1.00
Tantithaiya	0.75	4.60	3.85
Sanki	2.20	2.55	0.35

* - January, 2001

In order to demarcate the change in groundwater level fluctuation for post monsoon 1999 and post monsoon 2000, author has prepared spatial hydrographic profiles (Fig. 10.5) along Karan - Kantali (A-A') transact. The profile shows a marked decline in water levels from post monsoon 1999 to post monsoon 2000.

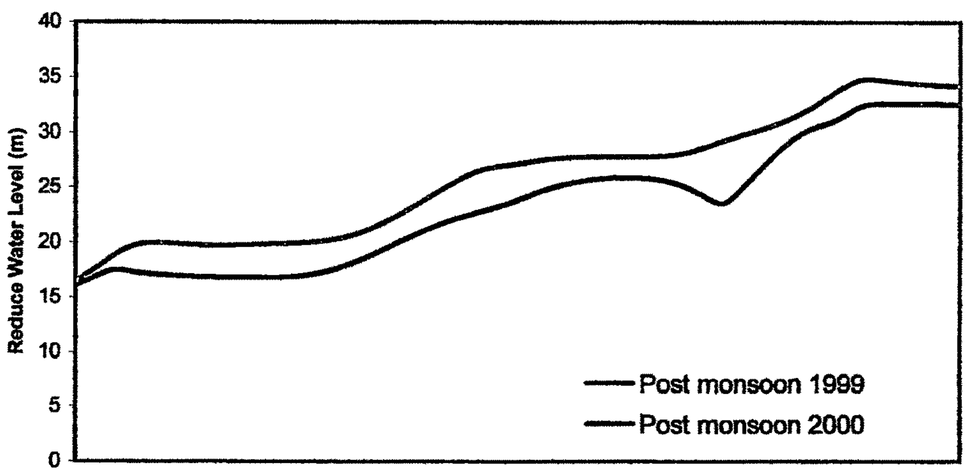

Fig. 10.5 Spatial Hydrographic Profiles Along Karan - Kantali (A-A') Transact in Chalthan Command Area, Depicting Decline Water Levels due to Groundwater Utilization During Canals' Non-operational Period.

This amply proves the efficacy of this strategy in proper management of canal command area.

(g) **Increase in Irrigation Charges:** In comparison to the cost of groundwater, surface water is cheaply available. These also promote the farmers for misusing the irrigation water. This can be curtailed to some extent by increasing the charges of irrigation water. Of course, the rise in charges should be such that finally it should be economical to the farmers. This will vary with the cropping pattern being recommended in the command areas (Raman and Patil, 2000).

(h) **Blending of Surface Water with Groundwater:** A study carried out by Sharma et al (1994) that with the use of saline water (EC = 12.5 mmhos/cm) with non-saline canal water (EC = 0.4 mmhos/cm) in various cyclic treatments, 88 to 94% of wheat yield could be obtained without any serious soil degradation. In study area as well as Kakrapar Left Bank Canal Command Area some of the well water shows high salinity in groundwater, which is not suitable for irrigation. However such quality of groundwater can be used by blending with canal water in such a proportion that ultimate blended quality of irrigation water is within useable limits for irrigation.

A few laboratory experiments have been carried out to study the proportion in which saline groundwater could be blended with surface water. Groundwater samples from open well and surface water samples from nearby canal were collected and analyzed. The EC in case of groundwater sample was 4.1 mmhos/cm. and that in canal water it was 0.65 mmhos/cm. different sets of blends were prepared in varying proportions, i.e. saline groundwater was mixed in 10, 20, 30, 40 and 50 % with the canal water.

Table 10.3shows the chemical characteristics of groundwater, canal water and blended water. The hydrochemical results of blended water clearly suggest that with the blending of well water and the canal water there is considerable change in cation and anion content. Also both water's at mixing ratio 1:1 i.e. 50% of well and canal water, there is considerable reduction in chemical content i.e. almost 50% reduction in Na, HCO_3, Cl and SO_4 while Mg and Ca does not shows much effect of blending at this ratio.

Table 10.3 Chemical Analysis of Saline Groundwater, Canal Water and Blended Water.

Well water (%)	Canal water (%)	EC (mmhos/cm)	pH	TDS (mg/l)	Ca	Mg	Na	HCO_3	Cl	SO_4
					meq/l					
100	00	4.10	8.20	2624	0.75	2.47	38.11	17.00	20.76	3.62
00	100	0.65	7.80	416	1.50	1.23	0.96	2.80	0.90	0.00
10	90	0.96	7.80	614	1.25	1.48	4.65	4.20	2.93	0.25
20	80	1.30	7.80	832	1.25	1.48	8.27	5.61	4.74	0.71
30	70	1.70	7.80	1088	1.25	1.73	12.01	7.00	6.77	1.21
40	60	2.20	8.00	1408	1.00	1.97	15.83	8.59	8.80	1.44
50	50	2.50	8.00	1600	1.00	2.22	18.71	9.60	10.38	1.92

Classification of irrigation water of blended water is given in Table 10.4 It is clearly seen from the table that if blending of well and canal water is of 20:80 than this water is highly suitable for irrigation water, but if the blending is of 30:70 of well and canal than this water is marginally suitable for irrigation, while the proportion is more than this then the blended water is not suitable for the irrigation.

Table 10.4 Irrigation Water Quality of Saline Groundwater, Canal Water and Blended Water.

Well water (%)	Canal water (%)	EC (mmhos/cm)	SAR %	SSP %	RSC	Water Class
100	00	4.10	30.04	92.21	13.78	C4S4
00	100	0.65	0.82	25.95	0.07	C2S1
10	90	0.96	3.98	63.04	1.47	C3S1
20	80	1.30	7.08	75.18	2.88	C3S2
30	70	1.70	9.84	80.14	4.02	C3S2
40	60	2.20	12.99	84.19	5.62	C3S3
50	50	2.50	14.74	85.31	6.38	C4S4

(i) **Method of Irrigation**: High energy pressurized irrigation methods such as sprinkler and drip are typically more efficient as the quantity of water to be applied can be adequately controlled but the initial investment and maintenance costs of such systems are high. A comparison of some irrigation methods with its drawbacks and advantages is summarized in Table 10.5 Experiments conducted at Hisar (Aggrawal and Khanna, 1983) for comparison of sprinkler with surface method using waters of different salinity have shown that application of highly saline (EC = 12 mmhos/cm) water through sprinkler to pearl millet and cotton is detrimental whereas it can be safely used for wheat and barely.

Table 10.5 Comparison of Various Irrigation Methods.

Variables	Traditional Irrigation	Drip irrigation	Exudation
Type irrigation	Flooding	Spot	Line
Minimum Pressure require	Large delivery by gravity	1-2 kg/sq.cm	From 0.2 kg/sq.cm.
Drawbacks	- Consideration evaporation - Water is dispersed over land - Loss by percolation - Excessive water consumption - Loss of nutrients through wash off - Labor needed to control flooding - Waterlogging and salinity problem	- Easily blocket - Not advisable to bury - Spot discharge of water - Constant maintenance - Awkward to remove and store	None
Advantages	No installation needed	- Low consumption - Localized application of fertilizers - Less evaporation than the previous	- No consumption - Localized application of fertilizers - Less evaporation than the previous - Uniform line irrigation - Reaches greater distance with less pressure - Easy to maintain - Long live - Can be buried

(j) **Crop Selection**: In order to get economical crop production under waterlogged conditions, appropriate selection of crop is a very important aspect. Table 10.6 shows the relative tolerance of a number of agricultural plants to waterlogging.

Table 10.6 Crops and Their Relative Tolerance to Waterlogging (Kovda et al, 1973).

Tolerant	Semi-tolerant	Sensitive
Sugarcane, Paddy, Jute, Dhaincha, Grasses, Palm, Coconut, Pear	Oat, Rye, Wheat, Cotton, Onion, Banana, Citrus, Sorghum, Wheat grass	Maize, Pea, Bean, Tobacco, Gram, Peach, Date Palm, Cherry, Potato, Tomato, Barely

(k) **Planting trees in Critical Areas**: Exotic plants can be grown in areas which are likely to help build up waterlogging. Some such areas are along the banks of the canals, distributaries and watercourses and along a seepage line from where inflow enters to the area. It is expected that such plantation will help reduces the seepage (Gupta, 1987).

SOIL MANAGEMENT PRACTICES

In any irrigation command, soils are the most vulnerable resources to face quality degradation. Over irrigation, inadequate cropping pattern and water table rise are the foremost factors causing adversities in soil stratum. In the study area manifestation of soil degradation are seen as soil salinity. As it has been already discussed that in Chalthan Branch Canal Command Area saline soils are restricted around Mota, Mavachhi and Bagumara villages. The efficacy of any soil management practice, in case of saline soils depends upon in achieving faster rate of water movement in sub soil horizon. In the present situation complete reclamation of saline soil seems to be difficult because of characteristics geo-environmental conditions. Some important measures, which may be adopted for the restoration of the saline soils are discussed as under:

(a) **Salt Leaching through Rain Water Management**: Once the salts have accumulated in the root zone, it is necessary to leach down the salts to a level that it does not adversely affect the crops as well as to take steps that helps in leaching and further build-up of soil salinity. In this case, a successful reclamation programme must aim at

i. Lowering of the water table to depth, which could be tolerated by the crops as well, as minimize the secondary salinisation.

ii. Reduction in the salt content of the root zone to a level, which could be tolerated by the crops, intended to be grown.

iii. Reduction in the sodium adsorption ratio of the soil solution below 15.

iv. Introduction of management options that establish favorable salt balance.

v. Management options that tend to dilute the saline groundwater (Gupta and Khosla, 1996).

The overall climate of the area is sub-humid with mean annual rainfall of about 1200 mm. Inspite of an almost flat topography several depressions have developed in the study area. The runoff of the rain water accumulates in the depressions, and road side pits causing rise in groundwater table and reduces efficient leaching. It is therefore necessary to check runoff through bunding and land grading and thus allow efficient salt leaching in the field.

(b) **Growing Salt Tolerant Crops**: Crops and their varieties differ widely in their ability to tolerate salinity. Intergenic and intragenic differences can be exploited to manage root zone salinity. For this purpose, a crop and its variety is selected to suit the salinity of the root zone such that there is little depression in yield of the crop over its potential in a non-saline environment. Gupta and Gupta (1997) have suggested following criteria for choice of crops regarding the salt affected soils:

- Tolerance of salts,
- Adaptability of climate and soil conditions,
- Value of the crop in the individual farming activity,
- Quality and quantity of water available,
- Yield and the monetary returns.

A list of tolerant, semi-tolerant and sensitive crops in given in Table 10.7.

Table 10.7 Crops and Their Relative Tolerance to Salinity (Richards, 1954).

Tolerant	Semi-tolerant	Sensitive
Sugarcane, Date palm, Sugar beet, Barely, Cotton, Bermuda grass, Spinach	Paddy, Wheat, Oats, Sorghum, Maize, Rye, Cauliflower, Cucumber, Peas, Pomegranate, Soybean, Sunflower	Field beans, Green beans, Tomato, Onion, Radish, Carrot, Lemon, Potato

(c) **Mulching**: Mulching as a means to control evaporation and salinity build-up (Minhas and Singh, 1996). Mulches such as self-mulching (soil), organic matter and plastics, mulches have been used under experimental conditions and in depth studies are available in India and abroad. The self-mulching usually consists of ploughing of the land surface during the intervening period between the harvest crops to the sowing of the next crop. The tillage operation thus carried out will break the capillaries, reduce the evaporation from shallow groundwater table and thereby accumulation of salts in the root zone.

CROP MANAGEMENT PRACTICES

'X' Limit: In Maharashtra, the area of sugarcane is controlled by deciding the upper limit of the allowable percentage of sugarcane which is called 'X' limit. This mainly depends on the soil type and its draining characteristics. Therefore restriction on perennials crop such as sugarcane is necessary for protecting such lands from salinity and waterlogging hazards (Apshankar and Kapre, 1996).

'X' limit is fixed in order to restrict soil deterioration in that areas resulting from continuous heavy irrigation of crop like sugarcane. This is achieved by restricting sugarcane area on each outlet command. The damage to soils even after fixing 'X' limits, is improved by land drainage.

Following points are to be considered while fixing of 'X' limit

1. Damaged area: This is considered as unsuitable for sugarcane.
2. 400 m. Limit area of village: Sugarcane is not allowed 400 m. limit around village on environmental grounds.
3. 1.5 m Hydro-Iso-Bath zone: This can be shown after the observations of ground water levels in the existing wells in the command.
4. Not properly commanded area: All high portions of lands are excluded.

So far as Chalthan Branch Canal Command Area is concern, the area is affected by the perennial crop like sugarcane. The X-limit surveys for perennial cultivation have indicated that the concentration of sugarcane is permissible between 20 to 25%. This has exceeded the limits and has now increased upto 70 percent in the Chalthan Branch canal command area. It is, therefore necessary to restrict cultivation of perennial crops to the limit of defined X-limit. In the study area fixing of X-limit will provide an effective remedial measure for waterlogging and soil salinity. It has been already decided by the Command Area Authority i.e. 23% for the Chalthan Branch Canal Command Area shall be utilized for crop like sugarcane.

Based on the above discussion on soil-water management strategies, it would not be wrong to state that the immediate necessity and importance of thorough investigations regarding the characteristics of soil, water and crops; the existing and future developments of irrigation and drainage and their effects on the waterlogging and soil salinity, can not be ruled out. Arrangements are to be made to minimize the problems, by evolving the most efficient and economical drainage system, with due consideration as to where this drainage water will be disposed off, is to be planned and executed. The areas in which anti waterlogging and salinity measures may not be effective due to economic or other reasons, should be developed into pastures and forests. Since the disposal of drainage water is the major problem, it is suggested to create local tanks with high banks, to be filled up with drainage water for fish farming and flow irrigation of the nearby area.

The implementation of recommended water and soil management practices would certainly be helpful in improving the degenerating state of command and restoration of soil and crop yield.

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