Chapter 11

Soil & Water Management Strategies

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SOIL AND WATER MANAGEMENT STRATEGIES

It is clearly discernible that the deterioration states of soil and water regime in Matar Command area is the manifestation of geo-environmental characteristics of the area as well as the adopted cropping pattern and irrigation practices. To arrest further deterioration, there is an acute need for adoption of adequate management strategies. Proper management of soil is of vital importance for crop production. Considering the ever increasing multiple demands of the fast increasing population and rapidly decreasing land to man ratio; one can simply not afford to lose the precious land, even it s degraded due to salinisation and alkalization. The salt affected soils are basically rich in potential nutrients. However, their availability to the plant is restricted due to unfavorable soil conditions. Such naturally occurring problem soils can be utilized for agricultural production particularly in the area where adequate irrigation facility with good quality water is available. Interestingly, the present study has highlighted the fact that benefits of irrigation have not reached the expected level of socially agreeable and environmentally harmonious dimensions. This is because soil salinity, sodicity and waterlogging in the area are the products of irrigation with poor management.

Irrigation in the MRBC in general and the Matar 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 now became vulnerable to land and soil degradation. Taking in to account the inference drawn from the preceding chapters on soil and water regime and the impact of irrigation on soil and water resources of the command area; the following interrelated constraints, which need an appropriate remedies, and management practices have been identified:

- Deterioration in overall groundwater quality.
- Waterlogging and the concentration of salts in soil and sub-soil horizons, particularly in the lower reaches of the command.
- Dilapidated state of water distribution system.

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 fertility of soils and optimum utilization of land and water. Some of the important landmark studies referred for adopting an appropriate remedial measures in the present case are based on the work carried out by Agrawal and Gupta, 1968; Handa, 1983; El-Ashry et. al., 1985; Abrol, 1992; Miller and Dohahue, 1992; Varade, 1992; Gupta and Gupta, 1997; Marlet, etl. Al., 1998; Tripathi, 1998; Roman, et. al., 1999; 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:

Irrigation and Water Management Practices:

As it has been enumerated that in the study area brackish and saline groundwater are associated with waterlogging conditions. The following management strategies might be helpful in mitigating these problems.

(A) Blending/Mixing:

In the study area the groundwater quality from the irrigation point of view by and large fall in Doubtful-Unsuitable categories (i.e based on the EC values Fig. 8.25). majority of groundwater shows specific conductance in the range of 2000-3000 mmhos/cm; whereas the canal water it is merely 180 mmhos/cm (refer Table 4.3). therefore it is possible to mix the inferior quality groundwater with fresh surface (canal) water in adequate volumetric proportions, so as to match requisite quality standards for irrigation. Considering an average EC values of 2500 mmhos/cm for entire groundwater resources (i. e. 2340 MCM) of the study are and EC value of 200 mmhos/cm for canal water; the blending of this water would be meet requisite quality standards as per following ratios-

Canal water:Groundwater Blending	Resultant EC mmhos/cm	Obtained Quality
1:2	1735	Permissible
1:1	1350	Permissible
2:1	966	Permissible
3:1	775	Good
4:1	660	Good

Since mixing of 2 parts of groundwater with 1 part of canal water is very close to the threshold value of doubtful quality and using 2 or more parts of canal and 1 part of groundwater, although can considerable lower down the EC values but economically may not be viable. Hence, it would be most appropriate to blend the water at 1:1 ratio so as to obtain EC 1350 mmhos/cm, which is well within the permissible limit of irrigation water quality standards. Thus groundwater utilization coupled with canal water in the non-monsoon and dry season will cause a lowering of water table. During monsoon season, rainfall recharge will bring the water table back to the normal level. to achieve this normal cycling in groundwater storage changes; apart from blending of water, it would be essential to regulate the groundwater recharge from canal and returned irrigation seepage.

(B) Augmentation Well Pumping

Water balance studies has revealed that in addition to the monsoon recharge, almost 50% (1521 MCM) of the total recharge to the groundwater storage is contributed during the kharif season (refer Table 9.1) whereas the total groundwater draft through different modes stands at 19.30 MCM. Therefore the balanced storage of 1500 MCM if utilised through augmentation well pumping and its blending with canal water (i. e. 1500 + 1500 = 3000 MCM), it would create more than the actual irrigation requirement during the rabi and hot seasons i. e. 2327 MCM. Thereby almost 830 MCM would be the net saving of surface water resources plus 673 MCM would be surplus from blending. Also the statistical analysis of the water balance studies using regression equations (Pl. refer Table 9.3) has clearly pointed out that the annual water table rise can be reduced by 0.5 m if the annual canal supply is reduced by 40 MCM.

In addition to that aquifer in the Matar command tends to pinch out in west and become discontinuous after the village Undhela (Pl refer Fig. 8.3 and 8.4). Since, the area comprises the close network of well system and canals, the pumping of the groundwater from the wells near Undhela and its distribution to the lower command are through already existing canal network will be not only helpful in reduction of the water table in the upper command area but also in improving the groundwater quality.

(C) Irrigation Through Tanks and Ponds:

The success of any irrigation project depends upon the efficient use of water, which depends upon the conservation of rainwater during monsoon and its utilization in dry season. Also in coastal areas where chances of groundwater salinity is a very commonly observed problem; the ponds are not only serves an important source of potable water but also due to incipient recharge which create groundwater mound pushes away the saline water (Islam, 1986). Irrigation tanks and ponds, when used conjunctively with canal irrigation function as storage reservoir in to which surplus water could be diverted. The command area consists of number of such ponds, constructed across the remnants of paleochannel courses (Pl. see Table 4.1).

Inspite of the existence of large number of ponds their effective utilization is reported to be poor. Problems of waterlogging have been attributed to the major cause of low utilization of tanks because these tanks are mainly located in LIC III, IV and V. The main constraint of these soils is its drainability. Poor drainability of soils in the tank's command area and over irrigation through canal supply has led to the waterlogging problem. Therefore, efficient use of ponds in irrigation coupled with adequate provision of surface drainage would certainly minimize the waterlogging and soil salinity hazards.

(D) Reduction in Non-Beneficial Consumptive use:

In the study area except the branch canal network, the entire canal system is unlined in nature. Further the poor maintenance, excessive anthropogenic interference have made these structures vulnerable to cause very high seepage losses, particularly from the distributory, minors and field outlets. The water balance studies carried out by the author clearly show that almost 480 MCM annual seepage losses, contributed to the groundwater storage (Pl. see Table 9.1). Even thickly grown weeds (Plate XI 1) in the canal beds cause stagnation of the water. Therefore regular maintenance of the canal network and the lining of the lower level of the canal network will certainly reduce the seepage losses and thereby contribution to the groundwater storage.

SOIL MANAGEMENT

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 ubiquitously seen as soil salinity and sodicity. The various measures may be adopted for the restoration of these saline and sodic soils are discussed here under:

SALINE SOILS

In Matar command saline soils area confined to waterlogged zones encompassing about 200 ha. land. They are fine grained and show development of white crust. This condition has reduced the movement of irrigation water downward. As a result, it is difficult to leach the salts to the desired depth, i. e. below the plants root zone. 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. The following management practices may be adopted to regenerate the saline soils.

Drainage and Leaching:

Good drainage is the prerequisites of any reclamation and management program of salt affected soils. In the study area, there is enough water available to leach the excess salts out of the soil. Therefore, by using an open trenches it would be possible to remove the water before it reaches the groundwater table (Gajja et. al., 1994). The open trench drainage system needs to be adopted by farmers as a co-operative exercise. The study area comprises the artificial drains in the lower command area. The drains are of different dimensions but the depth of the drains hardly exceed the depth of 1.5 m. Few farmers have also tried the boulder drain at the selected drain depth in the area. However, these measures have helped in improving the situation partially.

As the waterlogging problem is mainly confined to lower command area, the probable hazards attributed to the waterlogging can be overcome by

1. Deepening of the existing drainage up to the 2.00 m so as to drain out the returned irrigation seepage from the irrigation fields.
2. Periodic cleaning of the existing drainage system especially in the downstream parts of the command area.
3. Reconditioning of the drains as a regular process, to avoid excessive growth of weeds.

Crop selection:

Proper Crop selection is equally important to combat water and soil salinity problems. Selection of suitable crops to be cultivated on saline or sodic soil is a subject of practical importance, as different crops have different reactions to salinity and sodicity. 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 condition
- Value of the crop in the individual farming activity
- Quality and quantity of water available
- Yield and the monetary returns

In view of the above criteria, proper selection of crop will help in achieving optimum production under the saline conditions. For example Wheat, bajra, jawar can be easily grown in the area where salinity is ranging from 5000-10000 mmhos/cm. On the other hand sugarcane, maize, and sunflower are semi tolerant crops, which can tolerate salinity in the range of 3000-5000 mmhos/cm (Singh et. al, 1998). It has been observed in some parts of the area, that farmers are growing bajra, jawar, sugarcane, maize, wheat and onion etc. However, Alfalfa (Medicego sativa L.,) is the backbone of salinity reclamation. Alfalfa is long-lived perennial legume, which can fix its own nitrogen when properly inoculated. It has a deep tap root system, once established, it provides excellent production for many years. Management of salt affected soils has significant relevance to cultivation of medicinal and aromatic crops(Patra et. al., 1996; Prasad & Singh, 2000; Prasad et. al., 2001). Several crops particularly aromatic grasses (Cymbopogon sp.) withstand soil salinity and sodicity to a higher level compared to common agriculture crops. At least on an experimental basis the plantation of such salt tolerant medicinal plants should be attempted and monitored for their efficacy in eradicating the soil salinity.

As it has already been discussed in the previous chapter on the impact of Irrigation on Soil and Water Regime that the violation of the cropping pattern is one of the foremost reasons for development of the twin hazards of the waterlogging and soil salinisation/alkalisation in the Matār command. The salt affected soils found at the localities Garmala, Heranj, Kathoda, the EC of the soil solution extract is higher than 20 mmhos/cm. Therefore, the reclamation of such soils can be by growing the salt tolerant crops like Wheat, Bajra, and Jawar. Where as the soils at the localities Pij, Sandhana etc. which are characterized by moderate salinity; the cropping of the semi-tolerant crops will help to reclaim the soils (Singh et. al., 1993). Besides this, depending upon the characteristics and nature of the soil, following crops can be proposed to reclaim the soil salinity.

Soil Type	Arable Crops	Horticultural Crops	Fuelwood/Timber	Fodder Species
Traj	Paddy-Safflower Paddy- Mustard Paddy-Wheat Paddy-Bajra		Cauarina equisetifolia Acasia nilotica Prosopis Julifora (Mesquite)	Leptochloa fusca Cressa Cretia Kochia Prostrata
Shekhupur	-do-	Annona Squamosa Grewia subsinequalis Achras zapota Citrus ausantifolia Carica papaya Mangifera indica Psidium guajava	Acacia nilotica Azadirchta indica Casuarina equisetifolia (Saru) Eucalyptus species Prosopis cieraria (Khejri)	
Sokhda	Phoenic clactulifera Zizyphus mauritiana Punica granatum			

Other than this there are many tree species viz., Acasia, nilotica, Prosopis juliflora, Prosopis chilensis, Zizyphus sp., Terminalia arjuna, Tamatrix aphylla etc., which can grow well in saline conditions (Abrol, 1991). Similarly, grass species like Diplachne fusca (karnel grass), Brachiaria mutic (Para grass), Chloris gayana (Rhodes grass) and Cynodon maritima can grow efficiently under saline conditions.

SODIC SOILS

Sodic soils are characterized by the occurrence of excess sodium (Na) to levels that can adversely affect soil structure and availability of some nutrients. Deterioration of these soils occurs through changes in the proportions of soil solution and exchangeable ions, soil reactions (pH) as well as osmotic and specific ion effects. Structural problems in sodic soils created by certain physical processes (viz., slacking, swelling and dispersion of clay minerals) and specific conditions (viz., surface crusting and hardsetting) may affect water and air movement, plant-available water holding capacity, root penetration, seedling emergence, runoff, erosion and tillage and sowing operations (Shainberg and Letey, 1984; Gupta and Abrol, 1990; Naidu and Rengasamy, 1993; Summer, 1993; Oster et. Al., 1999). Sodic soil amelioration needs replacement of excess exchangeable Na by more favorable calcium (Ca). The replaced Na is leached from the root zone and through excessive irrigation. Amelioration of sodic soils involves increase in Ca on the cation exchange sites at the expense of Na. The replaced Na together with excess soluble salts, if present, removed from the root zone through infiltrating water as a result of excessive irrigation.

Records of the century old of sodic soil amelioration research and practice reveal that several site-specific methods have been used to ameliorate a variety of sodic soils (De Sigmond, 1924; Kelley and Brown, 1934; Puri and Anand, 1936; Agrawal et. Al., 1979; Gupta and Abrol, 1990; Oster et. Al., 1999). These methods include (1) leaching without amendment application, generally applicable to ameliorate gypsiferous soils, (2) application of high electrolyte water containing divalent cations, high-salt-water dilution (Gapon, 1933; Eaton and Sokoloff, 1935; Reeve and Bower, 1960), (3) use of chemical amendments, both inorganic and organic, (4) soil profile modification through tillage, (5) horizontal flushing after amendment application to ameliorate low permeability sodic soils where vertical leaching is not efficient, (6) Electromelioration consisting of passing electrical current through the soils (Puri and Anand, 1936; Gibbs, 1966; Vadyunina, 1968; Acar et. al., 1990; Ahmad et. al., 1997) and (7) phytoremediation dealing with cultivation of certain plant species, tolerant to ambient soil salinity and sodicity levels, without the application of an amendment (Robbins, 1986a; Chaudhary and Abaidullah, 1988; Ahmad et. al., 1990; Qadir et. al., 1996a, 2001; Ilyas et. al., 1997). Salient characteristics management of sodic soils by adopting an individual or combination of the above mittigatory methods is given in ensuing table.

Method	Site condition required for its application
Leaching without Amendments	▪ Applicable to Gypsiferous Soils
Application of high electrolyte water with divalent cations	▪ Soil should be of higher Smectite type clay mineral. ▪ Low hydraulic conductivity of soils. ▪ May create hazardous concentration of divalent cations. ▪ Subsequent disposal of the reclaimed water should be done.
Horizontal flushing after amend application	▪ Practical basis of its application (Trial and error). ▪ Presence of near by drain should be required.
Electrodialysis	▪ Undefined need of electrical supply, which makes it uneconomical. ▪ Risk to human and animal life.
Phytoremediation	▪ Very slow process of reclamation ▪ Required high cost amendments for application.

After a careful examination of basic geochemical characteristics of the study areas' degenerated soils; the author has found following methods adequate for combating the sodic soils and possible regeneration.

(A) Chemical Amendments:

Chemical amendments have long been recognized for their benefits in amelioration of sodic soils. Such materials produce Ca in sodic soils, directly or indirectly, through chemical and/or microbial actions. The amendments used as direct Ca sour are either soluble salts such as calcium chloride, mined gypsum, phosphogypsum, fuel gas desulphurization gypsum, or relatively much less soluble ground lime. Some polymers have also been used for the amendments of sodic soils (Wallace et. al., 1986; Nawar and Petch, 1987; Aly and Letey, 1990) several other amendments and by products of certain industries e. g. pressmud from the sugar industry (Hoffman, 1986) can also be used successfully. Addition of organic matter like farm manure, slaughter-house wasters, poultry excreta and green manure can ameliorate sodic soils but at a slow rate (Chand et. al., 1990). Some chemical fertilizers such as calcium nitrate and single superphosphate can supply some Ca. However, addition of such fertilizer in the usual economical doses does not reduce the soil sodicity to a great extent. When an amendment is incorporated in to the soil, the exchange complex acts as an effective sink for Ca, which replaces excess exchangeable Na, until both the dissolution and the exchange reaction, reaches equilibrium (Oster, 1982). The application of amendment not only reduces the soil sodicity but also improves the soil physical properties such as infiltration rate and hydraulic conductivity.

The choice of chemical amendments depends on its cost, availability, handling and application difficulties, relative effectiveness as from soil improvement and crop growth, and time consumption to react in soil and to replace the adsorbed Na (Rowell, 1994). Because comparatively low price, general availability, and easy application as compared to the other chemical amendments the gypsum is most commonly used as the external source of Ca. The electrolyte concentration of yielding solution after gypsum application depends on source of gypsum, particle size of gypsum, water flow velocity, depth of gypsum mixing and the soil characteristics. Some of the advantages of using gypsum as amendments are recorded by Swarup et. al. (1994) and Chhabra, 1995 as follows:

- It is good compromise between solubility and coats.
- It improves hydraulic conductivity of soils.
- It helps in reduction in pH
- It inhibits the leaching of P
- In general, it improves soil properties and hence the yield of crops.

The analytical data indicates that sodic soil in the area at localities viz., Vaso, Alindra and Raghvanaj are showing higher SAR and low SO_4 values. These variations in the ionic contents will enhance the process of exchange of Na by Ca (Ranji, 1969; Reddy et. al., 1980; Oster, 1982; Gupta and Abrol, 1990; Somwanshi, 1999). The quantity of gypsum required for sodic soil reclamation is referred to as gypsum requirement (GR). Cost of reclamation can be reduced by using locally available organic amendments (Chauhan et. al., 1986; Chhabra, 1995). Hence, the GR of sodic soils in the study area has been estimated between 9 and 20 t/ha.

(B) Tillage:

In sodic soils, tilth is very poor because of high pH and ESP. The soils are very hard and compact when dry and very sticky when wet. Therefore, it is necessary to till the soils very carefully at optimum moisture content. The effective root zone in sodic soil in the initial stage of reclamation is restricted to 10-15 cm depth (Qadir et. al., 2001).

Long-term amelioration of sodic soils requires not only increased macro-porosity, but also preservation and stabilization of the macro-pores. In addition to the general problems of soil sodicity, poor crop productivity in some sodic soils is often associated with low macro-porosity. Owing to fine texture, excess of silt, hard pan or stratification such sodic soils generally have restricted water infiltration. Water infiltration under certain condition may be improved through tillage that can help in increasing macro-porosity (Jawardane and Prathapar, 1992; Oster and Jayawardane, 1998). Where tillage results in loosening the soil, the bulk density decreases due to an increase in total porosity (Blackwell et. al., 1991) and plant available water (Oster and Jayawardane, 1998).

A number of tillage options can be used to create a rough and thoroughly disturbed soil surface. These options include deep ploughing, subsoiling, hauling and profile inversion (Qadir et. al., 2001). The aim of first three methods is to increase soil permeability directly, either by mixing fine- and coarse- textured layers to obtain a more uniform layer (deep ploughing), by breaking the impermeable layers (subsoiling), or by incorporating sand to a fine textured soil (sanding). Hauling with replacement of the sodic surface soil with a good soil, while profile inversion covers an undesirable soil layer with a better material from a lower layer.

Deep ploughing in this soil may further deteriorate the soil structure leading to reduce permeability of soil to water. Therefore, shallow tillage operation upto 10-15 cm depth that yields well in the sodic soils has been recommended. For this the field should be well leveled to affect uniform water distribution.

(C) Nutrient Management:

Sodic soils are generally poor organic matter and availability of nutrients particularly nitrogen, phosphorus, sulfur, and zinc is poor (Rai, 1995). Thus, such soils require the addition of manure and fertilizers (Chhabra, 1995, Singh et. al., 1998, Qadir et. al., 2001). In view of this, the management of nutrient is an important aspect of reclamation of sodic soils.

Amongst different forms of nitrogen fertilizers ammonium sulfate found to be the most suitable form of the nitrogen for all crops in sodic soils at high pH. This is due to it residual acidity. The sodic soils do not respond to P as there is a possibility of reaction between insoluble calcium phosphate and sodium carbonate to give soluble sodium Sulphate as:

$$Ca_3(PO_4)_2 + Na_2CO_3 \rightarrow Na_3PO_4 + 3CaCO_3$$

Therefore, when sodic soil leaches without gypsum, considerable loss of P occurs. However, reclamation of such soils by gypsum decreases the leaching of soluble P. In the present study, the available phosphorous is found to be low to very low in sodic soils (Pl. refer Table 7.15). Therefore, gypsum can be used successfully to reclaim such soils and then application of phosphorous can be practiced. The sodic soils in the area also have high to very high content of available potassium. Hence, application of potash fertilizers is not advisable for the reclamation of sodic soils.

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