Paper No. 211

Salinity Extent and its Management in Punjab

By

M. Azhar Javaid
Ch. Karamat Ali
Dr. Muhammad Javed

SALINITY EXTENT AND ITS MANAGEMENT IN PUNJAB

M. Azhar Javaid[1], Ch. Karamat Ali[1], Dr. Muhammad Javed[1]

ABSTRACT

Salinity as a major soil pollutant has badly affected the socio-economic condition of the farming community by making the environment unsuitable for crop production. With 2.84 m acres out of 23 m acres surveyed of the CCA of the Punjab currently affected by salinity, specific interventions are required to mitigate the problem. The policies and interventions require the foundation of statistics on the problem, which have been reported by different agencies in different ways (depending upon surveying technique followed). It is estimated that more than 100 thousand acres of good agricultural land run out of cultivation each year. Paper reviews fifteen years data (1981-1995) of the Irrigation and Power Department to show salinity increasing in CCA of Punjab. It is evident that Fordwah, Rangpur and Haveli Canal commanded areas are affected to a great extent. The rate of reclamation and soil deterioration are not compatible with each other. It may be anticipated that majority of the irrigated lands would go out of cultivation within next 70 to 80 years or so, if menaces were allowed to go unchecked at the present rate of soil deterioration. Allocation of extra canal water supplies (or reclamation shoots), use of chemical amendments, growing of salt tolerant crops with proper rotation involving pedo-bio-hydro-logical strategies may be some of the priorities to tackle salinity in irrigation commands.

INTRODUCTION

Soil salinity/ sodicity is one of the major soil pollutants that affects the crop yield and consequently the socio-economic conditions of the farming community. New techniques and scientific interventions are required to mitigate salinity and to have a suitable environment for crop production. Salinity and waterlogging are ongoing process not yet ended and more than 100 thousand hectares of good irrigated land go out of cultivation every year (JRCE, 1989). The problem has been reported to the extent of 5.6 m ha in irrigated agriculture (Qureshi and Rashid, 1988).

Salinity has devoured the potential of our agricultural lands. According to an estimate annual loss of Rs. 14,000 million has been reported in Pakistan (Qayyum and Malik 1988). The problem is becoming more acute with the expansion of irrigated areas. Today it has been estimated that 6.1 m ha are affected by salinity/ sodicity in Pakistan (Carrythers and Smith, 1990). Need is to realize the extent, magnitude, trend and gravity of the situation in its true perspectives.

The data based salinity surveys in that context may play a consequential role to understand gravity of the situation. Therefore, the collection of salinity statistics is an essential element for formulating soil management and reclamation strategies. Salinity monitoring, on the other hand, is generally based on visual salinity, chemical analysis of soil samples and instrumental measurements on EM-38 by electromagnetic induction (Raza et al., 1993). Each method has its own merits and demerits. Thus different authorities have reported different facts and figures, both at country and provincial level, for lands affected with salinity. However, it is an established fact that large tracts of

[1] Directorate of Land Reclamation Punjab, Irrigation and Power Department, Canal Bank Moghalpura, Lahore.

Table 1

Thur in different canal commands of the punjab for the year 1994-95

S.No.	Name of canal	Area surveyed. (acres)	Total *thur*[1] (acres)	% age under *thur*
1.	Upper Jehlum	572846	21236	3.70
2.	Lower Jehlum	1574440	275459	17.49
3.	Upper Chenab	1423070	211900	14.89
4.	Marala R.Link	175425	-	-
5.	B.R.B	72943	-	-
6.	Lower Chenab	3645360	468189	12.84
7.	Central B.D.	7030013	36072	5.13
8.	Lower B.D.	1733306	168230	9.70
9.	Depalpur.	1008123	133219	13.21
10.	Pakpattan.	1411063	109600	7.76
11.	Mailsi.	750977	82714	11.01
12.	Haveli.	1133461	282903	24.95
13.	Muzaffargarh.	851224	195709	23.26
14.	Thal.	2374799	16375	0.68
15.	Rangpur.	356739	99515	27.89
16.	D.G.Khan.	953881	123223	12.91
17.	Punjnad.	1507025	258842	17.17
18.	Abasia.	296027	22768	7.69
19.	Bahawal.	906204	35132	3.87
20.	Qaim.	45128	7086	1.57
21.	Sadiqia.	1228727	171906	13.99
22.	Fordwah.	464554	148851	32.04
23.	Small Dam.	32217	-	-
24.	Civil Canal.	13599	-	-
Total		23235051	2868929	12.35

1 *Thur* is a wide term used in Irrigation and Power Department for all categories of salt affected soils.
BD= Bari Doab

good agricultural lands are affected by salinity (Yasin and Rao, 1993) which require specific interventions to mitigate the problem.

The Irrigation and Power Department of the Punjab conducts the annual salinity surveys to pin point the exact locations, extent and severity of the problem in canal commands of the province. According to the latest salinity statistics about 12.35% of fertile area of the province is salt affected (Javed and Javaid, 1995). It is the right time to monitor the past and present salinity trends in the province in order to devise new ways and means together with modifying existing ones to manage an effective check over these menaces. The Irrigation and Power Department in that context has planned this data based review for the assessment and management of salinity in irrigation commands.

MATERIALS AND METHODS

Directorate of Land Reclamation of the Punjab Irrigation and Power Department collects the data with the collaborative efforts of Soil Scientists, Agronomists and Revenue Staff serving in various canal circles, divided into 50 canal divisions and 24 main canals (Table-1). The salinity surveys at the level of field or *Killa* (measuring 67m x 60m) are conducted each year. The salinity surveys are generally conducted during the winter months when salinity is visible on the soil surface. The soil samples are collected at random and analysed in the laboratories of the Department to support visual observations. The data are compiled by the *Thur* and *Sem* Statistics Division of the Irrigation and Power Department in coordination with the Executive Engineers, Superintending Engineers and other field staff of the Department.

To counteract salinity, the reclamation programmes are prepared in each canal circle and approved with the name of reclamation supply (or reclamation shoots). Farmers are required to level their fields, construct levees in quarter acre plots, grow salt tolerant crops and use chemical amendments, if necessary. The area is kept under observation for more than three years or till reclaimed through cropping - leaching phenomena. Soil sampling is carried out before and after the reclamation operations to ascertain the difference in chemical composition of soil. Normally one cusec for 45 acres is supplied for leaching of the soluble salts.

The upto date record is maintained to monitor the salinity trend and keep an eye on the soil deterioration in irrigation commands. Since area surveyed varied from canal to canal, so for quick understanding the sharp trend of salinity the data were transformed into exact figure of 23 million acres. The graphics were added to illustrate the data, where necessary.

RESULTS AND DISCUSSION

Extent of salinity:

The soil salinity is categorized into primary and secondary salinity. The primary salinity is due to the presence of salts in soil at origin, while secondary is mainly due to waterlogging and the use of poor quality groundwater (Choudhri et al., 1978). In addition to the above mentioned facts, the soil salinity in irrigated areas of the Punjab is also associated with decreased water allowances to the fields. Decreased water allowance contributes a lot in increasing salinity status of the soils that is assessed by the Irrigation and Power Department from year to year (Javed and Javaid, 1995).

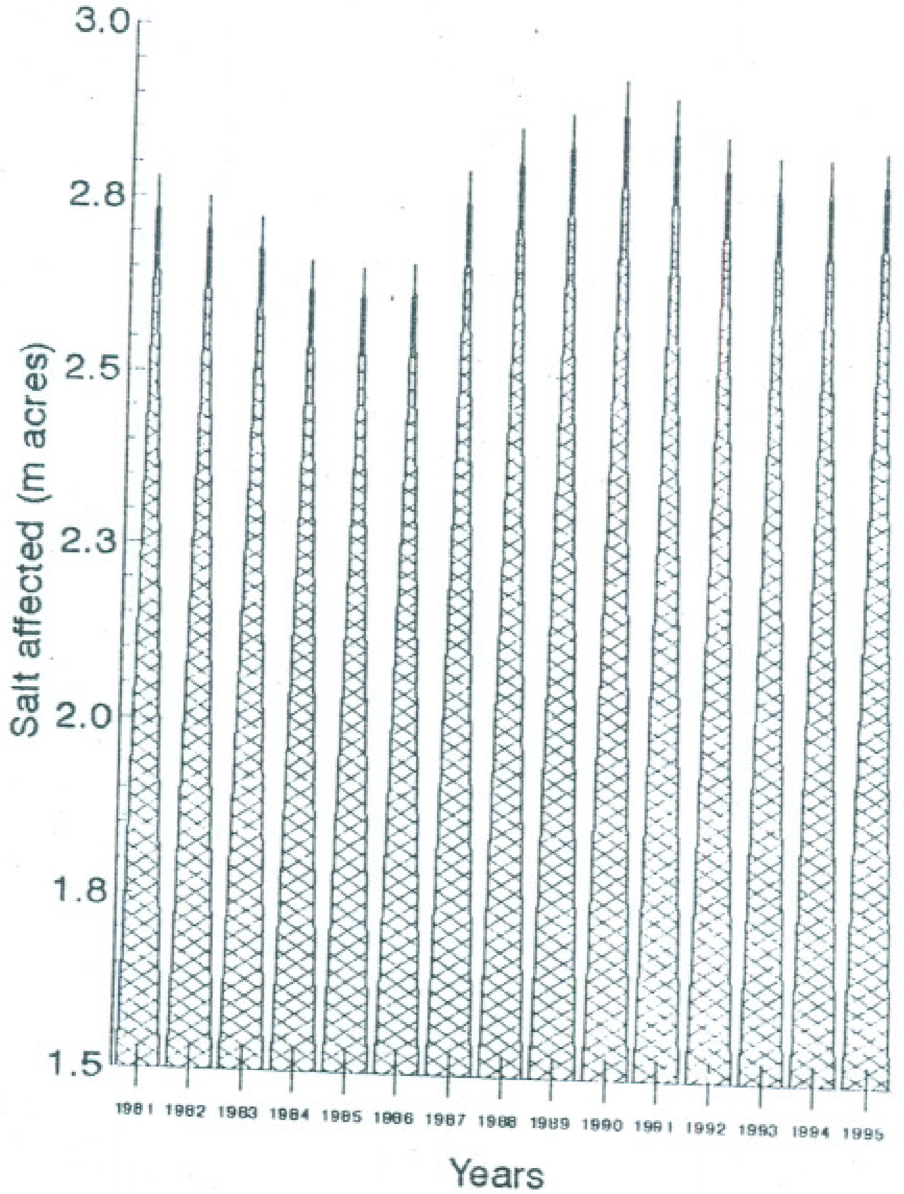


Fig. 1: Salinity trend in Punjab (out of 23 m acres surveyed)

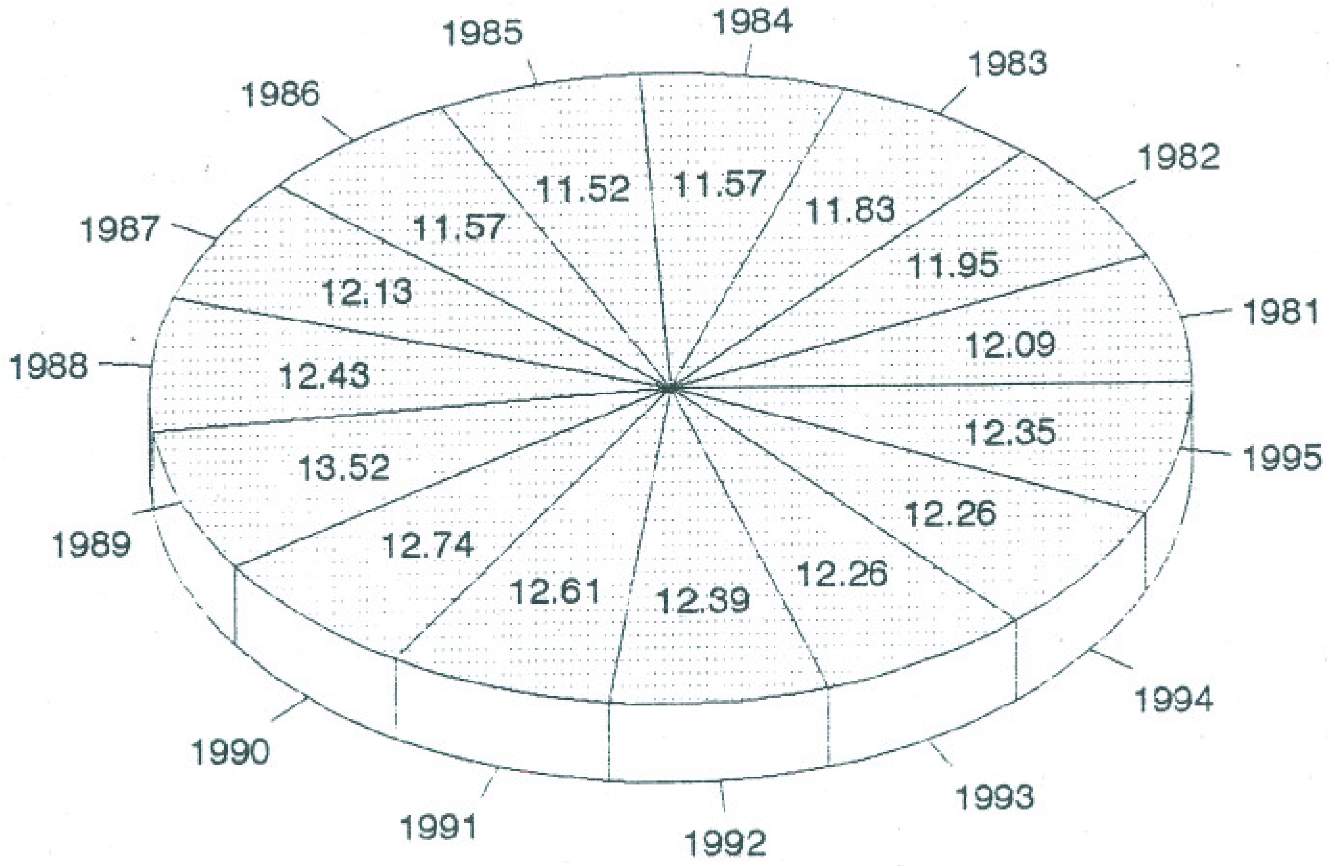
Table 2

Reclamation supply and area reclaimed during different year (1981 to 1995)

Years.	Reclamation supply actually utilised (cusecs)	Area operated (acres)	Area reclaimed during the year (acres)	Area reclaimed upto date (acres)
		Area reclaimed upto 1980:		**1069159**
1981	**1465.89**	**69806**	**22575**	**1091734**
1982	**1216.36**	**62383**	**15465**	**1107199**
1983	**1037.82**	**55682**	**25284**	**1132483**
1984	**823.40**	**39505**	**18451**	**1150934**
1985	**805.80**	**37944**	**10092**	**1161026**
1986	**860.12**	**42738**	**8514**	**1169540**
1987	**1015.16**	**48866**	**16362**	**1185902**
1988	**1118.62**	**51992**	**14007**	**1199409**
1989	**984.96**	**47170**	**17219**	**1217128**
1990	**1074.63**	**46270**	**16424**	**1233552**
1991	**973.96**	**45774**	**12998**	**1246550**
1992	**1011.82**	**48090**	**15613**	**1262163**
1993	**900.68**	**42332**	**13655**	**1275818**
1994	**567.49**	**26105**	**9096**	**1284914**
1995	**330.14**	**14856**	**4952**	**1294010**

(Source: Ali, 1995)

Fig. 2 Pie graph showing year wise % distribution of salinity in Punjab (out of 23 m acres surveyed)



The data on salinity for the last fifteen years (1981-1995) depict a clear picture of post and present trends of salinity in Punjab (Fig.1). In 1981 about 2.8 million acres out of 23 million acres surveyed were affected badly with salinity. Soil management and reclamation strategies were included in irrigated farming that resulted a decline in the rate of soil deterioration (about 2.5 m acres upto 1980). The main reason was application of liberal reclamation supply that on an average amounted to 2136 cusecs for the period starting from 1977 to 1980. The results of this supply appeared in the subsequent years (1982-86) in the form of land reclamation by leaching of the soluble salts into deep soil layers (Ali, 1995).

It is evident from the graphical representation that after 1986, the salinity trend began to elevate till 1990 and it again touched to the terrible figure of 2.9 m acres that was even higher than the year 1981. The apparent reason may be decreased water allowances accompanied by reclamation supply available for leaching of soluble salts. During 1981 to 1986, the reclamation supply was reduced to about 1035 cusec against 2136 (1977 to 1980). The favourable results obtained during 1981 to 1986 as a result of liberal reclamation supply during 1977 to 1980, again were formidable upto 1990 due to decreased water application during 1981 to 1986. The results of reclamation shoots appear in three to four years after it is included in reclamation programme. So the formidable results in 1990 were the consequence of contraction in reclamation supply during 1981 to 1986.

The bar information (Fig.1) considered together with data of Table-2 (reclamation supply actually utilized) shows that after 1990 to the running years, the salinity again began to decrease as a result of 1059 cusecs (average) sanctioned during 1988-1989 against the very previous one (1035 cusecs). This fall in salinity trend after 1990 to 1995 still did not match the salinity magnitude of the year 1981. So, the pivotal role of water in reclamation of the lands cannot be denied.

The pie graph (Fig.2) shows the percentage of the area affected with salinity each year (from 1981 to 1995). The data associated with the pie indicate that on the average more than 12.2% of the 23 million acres surveyed were affected with salinity. This is a big figure challenging the hydro-technologists and general scientists. In 1981, 12.09% of the 23 m acres surveyed were affected with the salinity and figures dropped to 11.57% during 1986. After 1986 to 1989, the salinity trend elevated to a maximum value of 13.52%. A considerable area of different canals in the Punjab is severely affected with salinity problem. Canal commanded area of Fordwah, Haveli and Rangpur are affected to a great extent (Table-1).

Salinity in Punjab shows an increasing trend at an alarming rate and same is the case with the whole country. The trend has been highlighted by different agencies that have reported different figures (based on different surveying methods). Soil survey of Pakistan have reported that in Punjab out of 19.5 m acres CCA, 20.4% is salt affected (Choudhri et al, 1978). According to WAPDA (1981) on the basis of soil salinity classification the extent of soil salinity (from 4.0 to 12.0 dS m^{-1}) in the Punjab mounted to the figure of 3.25 m acres out of total salt affected area of the country (10.42 m acres). So salinity trend is increasing at alarming rate and needs to be checked with the effective scientific interventions from the actors involved in irrigation management.

It is also evident that salinity at tails is spreading rapidly. As it has been earlier pointed out that one of the reason of salinity spread up in the canal irrigated area of the Punjab is associated with decreased water allowances. Eighty years before, to start with, the water supply factor on the basis of one cusec for 350 acres (on an average) with crop intensity of 25% in *kharif* and 50% during *rabi* appeared adequate under those conditions when pressure on land was not so high (Hussain and Nishat, 1963). The soil characteristics and crops' yields are very poor at tails compared with those at head of a distributory. This is because the total water applied per unit area is too inadequate to keep the trend of salt movement downward.

Strategies for the management of salinity in canal circles

The reclamation strategies can be classified under broad reclamation categories i.e. PHYSICAL RECLAMATION (Salt Scraping, hard pan breaking to facilitate leaching), CHEMICAL RECLAMATION (use of chemicals), BIOLOGICAL RECLAMATION (growing of salt tolerant plant species for their root activities etc), HYDROTECHNICAL RECLAMATION (water use technology) and SYNERGISTIC APPROACH (combination of different methods). The methods are briefed in the following text:

1. USE OF CHEMICAL AMENDMENTS: The saline soils are reclaimable by the application of good quality irrigation water through salt leaching in a well-drained soil. The reclamation of saline sodic or sodic soils usually requires the application of some chemical amendments to replace exchangeable sodium by calcium. Different amendments used in soil reclamation alongwith their properties are grouped in Table-3. Calcium chloride and sulphuric acid (quick acting amendments) are soluble amendments that can be applied through water. Acids are used in calcareous soils (Pakistan's saline sodic soils contain 1-20% insoluble $CaCO_3$) for dissolution of precipitated $CaCO_3$. Before planning the use of acids, the economic analysis compared to gypsum should be carried out in addition to their adverse effects on crystal lattice and enhanced micronutrients solubility (to toxic limits).

2. FLUSHING OF THE SALTS: Visible crusts of salts on the soil surface have some times lead to attempts to reclaim soil by surface flushing i.e. passing the water over the soil and wasting the run-off. Salts from deep layers cannot be removed with this technique (depending upon soil characteristics).

3. REMOVAL OF SURFACE DEPOSITS: The soil scraping normally consists of a mixture of sodium chloride and sodium sulphate. This method may be useful if salt exists only within the top soil. The salt encrustation of the surface if once removed, is re-formed very soon due to upward movement of salts from the whole soil profile.

4. CULTIVATION OF SALT TOLERANT PLANT SPECIES: Reclaiming saline soils by removing salts taken up by plants (that can withstand the salt stress) is not practical. However, reclamation can be enhanced by the presence of plants resistant to salts. This is probably due to the physical action of plants roots, the addition of organic matter, dissolution of insoluble $CaCO_3$ in the presence of CO_2 evolved from plants roots and decomposition of organic matter in the soil. According to Richards (1954) among the field crops, sugarbeet, rape and cotton are highly salt tolerant to the rootzone salinity extent of 10-16 dS m^{-1}.

5. ADDITION OF ORGANIC MATTER AND GREEN MANURES: Sodic soils can be improved by organic matter and green manures of various types but this step is not sufficient and can only be a helper in reclamation of such soils by some complete process.

TABLE: 3

CHEMICAL PROPERTIES OF VARIOUS AMENDMENTS FOR RECLAIMING SODIC SOILS.

Amendment	Chemical Composition.	Physical description.	Solubility in Cold water kg m^{-3}	Amount Equivalent to 1 Kg of pure gypsum (kg).
Gypsum	$CaSO_4.2H_2O$	White mineral	2.4	1.0
Sulphur.	S_8	Yellow element	0	0.2
Sulphuric acid.	H_2SO_4	Corrosiro liquid	very high	0.6
Lime Sulphur	9% Ca+24% S	Yellow brown solution	very high	0.8
Calcium Carbonate	$CaCO_3$	White mineral.	0.014	0.6
Calcium Chloride	$CaCl_2.2H_2O$	White salt.	977	0.9
Ferrous Sulphate	$FeSO_4.7H_2O$	Blue green salt	156	1.6
Pyrite	FeS_2	Yellow black mineral	0.005	0.5
Ferric Sulphate	$Fe_2(SO_4)_8.9H_2O$	Yellow brown salt	4400	0.6
Aluminium.	$Al(SO_4)_3.18H_2O$	Corrosive granular material.	869	1.3

(Source: Hoffman, 1986)

6. SALT LEACHING WITH CANAL WATER THROUGH INCREASING WATER ALLOWANCES:

Of the previously explained technologies the only measure on which these technologies are dependent and which has been successful in removing salts from the soil is the use of excessive quantity of water to leach down the soluble salts. Leaching accompanied by some amendments when sodicity shares the salinity has proven more effective. To reclaim farmer's land, Irrigation and Power Department provides additional canal water for leaching of salts during the summer season @ 1 cusec for 45 acres in prennial channels and 60 acres on non prennial channels. This is 4 to 6 times the normal allowance of water for cultivated land.

The cultivators are required to level the field, construct levees for holding water in quarter acre plots, use soil amendment if necessary and apply water to start downward movement of salts and lower the surface salt concentration. Generally rice and *janter* (high water delta crops) as a reclamation crop is grown. The increased water allowance to the fields causes the soil to deplete in salts from the top soil layers that are deposited at lower soil depths as a result of leaching during three years reclamation programme or cycle.

The progress of general reclamation in cultivated area of the Punjab is given in Fig.3. The line curve indicates the area reclaimed during each year with the reclamation supply available. The crusts and trough of the curve show an increase or decrease in reclaimed area during different years that can be attributed to the increase or decrease in reclamation supplies. The bars, however, point out the total area reclaimed upto the date (1995), including the one before 1981.

The average lines of Fig.4 indicate that on the average due to decreasing reclamation supply (reclamation shoots), the area operated and area reclaimed during each year subjected to downfall. The sub fig. (fig.4) gives the regression analysis of the reclamation supply vis. area reclaimed in different years. It is evident from regression analysis that reclamation supply is significantly correlated ($r=0.74^{**}$) with the area reclaimed. The regression equation was of the type:

$$Y = 675.5 + 14.84X$$

where: Y = Area reclaimed in acres.
X = Reclamation supply in cusec.

The equation helps to predict the area that can be reclaimed with a given reclamation supply and it is applicable over a data range 300 to 1500 cusecs.

The area if left unreclaimed, the higher salinity trends would not be uncommon (Fig.5), but we have to confess that due to some limitations the rate of land reclamation is not compatible with the rate of soil deterioration. It is high time to revise polices to overcome these limitation so that salinity can be tackled in an effective way.

Besides the above explained approaches, deep ploughing, dry farming, ridge sowing and sub soiling are also important measures that need to be included as an important element in reclamation strategies.

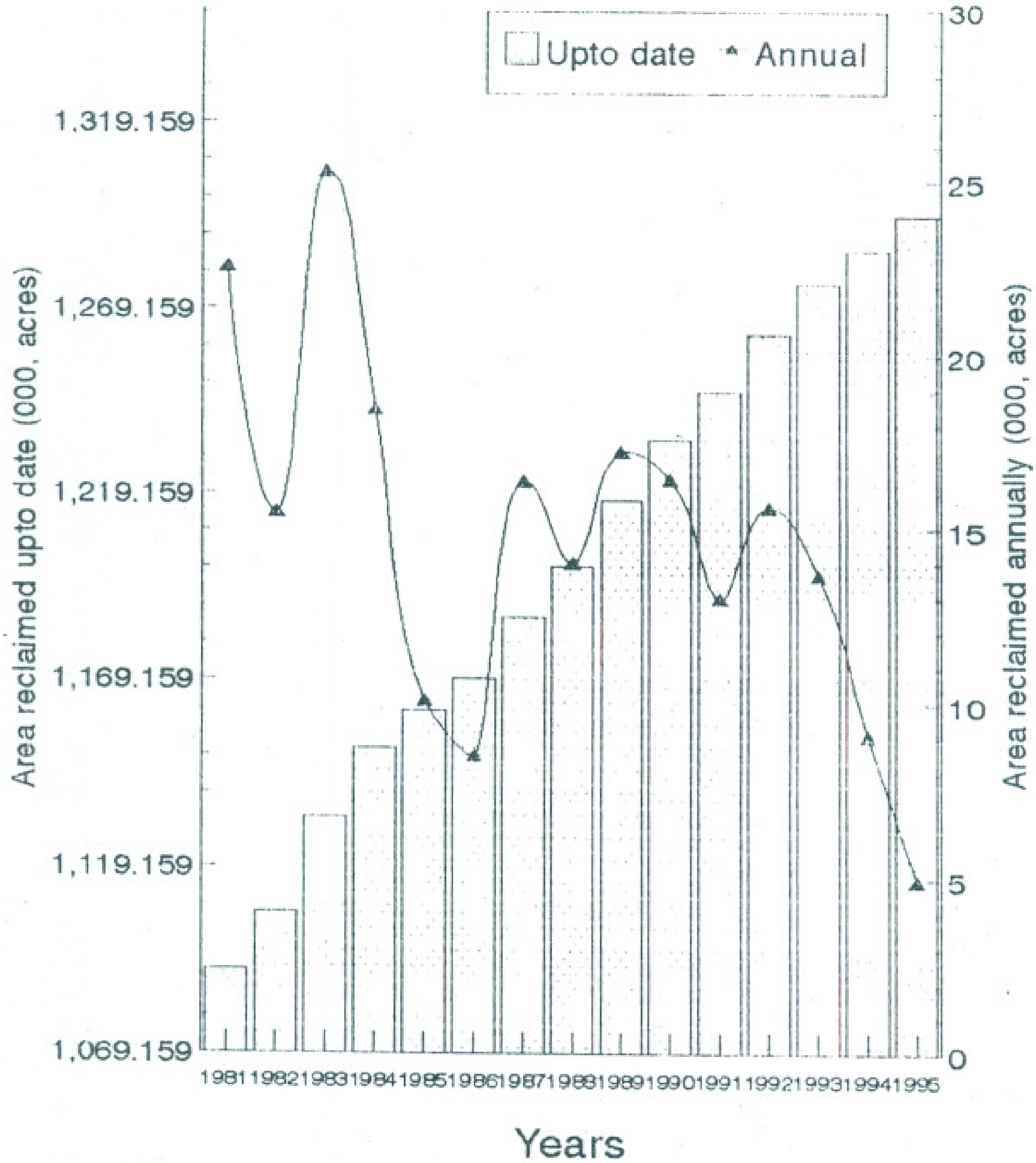


Fig. 3: Area reclaimed upto 1995 by Directorate of Land Reclamation Punjab

7. SYNERGISTIC APPROACH: Sometimes different reclamation technologies are applied simultaneously to reclaim a soil.

Other management operations for leaching:

It has been determined that the major cause of the accumulation of salts in the rootzone is the upward movement of water through capillary action and absence of adequate drainage. However, if fresh irrigation water is available these salts can be leached down expediently, provided no sodicity is present. But these efforts can only bear fruit if soil is properly tilled keeping in view.

1) LAND LEVELING AND OPTIMIZER: For uniform leaching, the precision land leveling is the pre-requisite. If land leveling is not carried out prior to leaching, the higher areas of the field will not receive adequate water for leaching, while the lower will be flooded. Due to this imbalanced water application, the salinity is likely to persist in patches (raised spots), decreasing the overall productivity potential of the concerned field. Land leveling if done to precision is likely to keep the fertility and productivity of the field uniform and thus making the achievement of optimum crop yield possible.

2) DEEP PLOUGHING IN SOIL RECLAMATION: On numerous occasions, salinity and waterlogging have been observed to be caused by suspended or hanging watertables. These watertables are formed because of the development of an impervious layer (hard pan) below the surface of the soil that hinders or completely stops the infiltration of water added through rain or irrigation. In addition to this, these layers when present near the surface, interfere with the normal growth of crop roots, bringing a significant reduction in yield. So deep ploughing (chiesling/subsoiling) may be the most appropriate remedial measure.

Drainage for reclamation of waterlogged saline lands

The salts are brought in by the rivers and their tributaries. The total salt load entering Punjab is about 15.8 m tonnes. This implies that, annually, an average of one ton of salt is added to each hectare of irrigated land (Bhutta and Wolters, 1997), which invites our attention toward drainage and leaching. In areas where hydrodynamic equilibrium of groundwater is disturbed through seepage, we should aim at reducing the drainable surplus or the recharge to groundwater. This includes lining of watercourses, lining of canals and interceptor drains.

For the leaching to be effective, surface and subsurface drainage systems are normally practiced. Surface drainage consists of open drains while subsurface drainage constitutes vertical drainage (through tubewells) and the horizontal drainage involving engineering structures laid horizontally parallel to ground (pipe-sump assembly). Government of Pakistan has now planned to launch NDP for effective control of waterlogging and waterlogged saline lands. The project is designed as sector investment project (SIP) which consists of some complementary components with estimated total costs of US $ 785 million (Haq et al, 1997).

Bio-sline approach to drainage: This approach may include the growing of salt tolerant and high water delta crops and trees. The saline agriculture approach may be complementary to the engineering approach to drain and reclaim saline lands. For tree plantation the saline drainage effluent can be used.

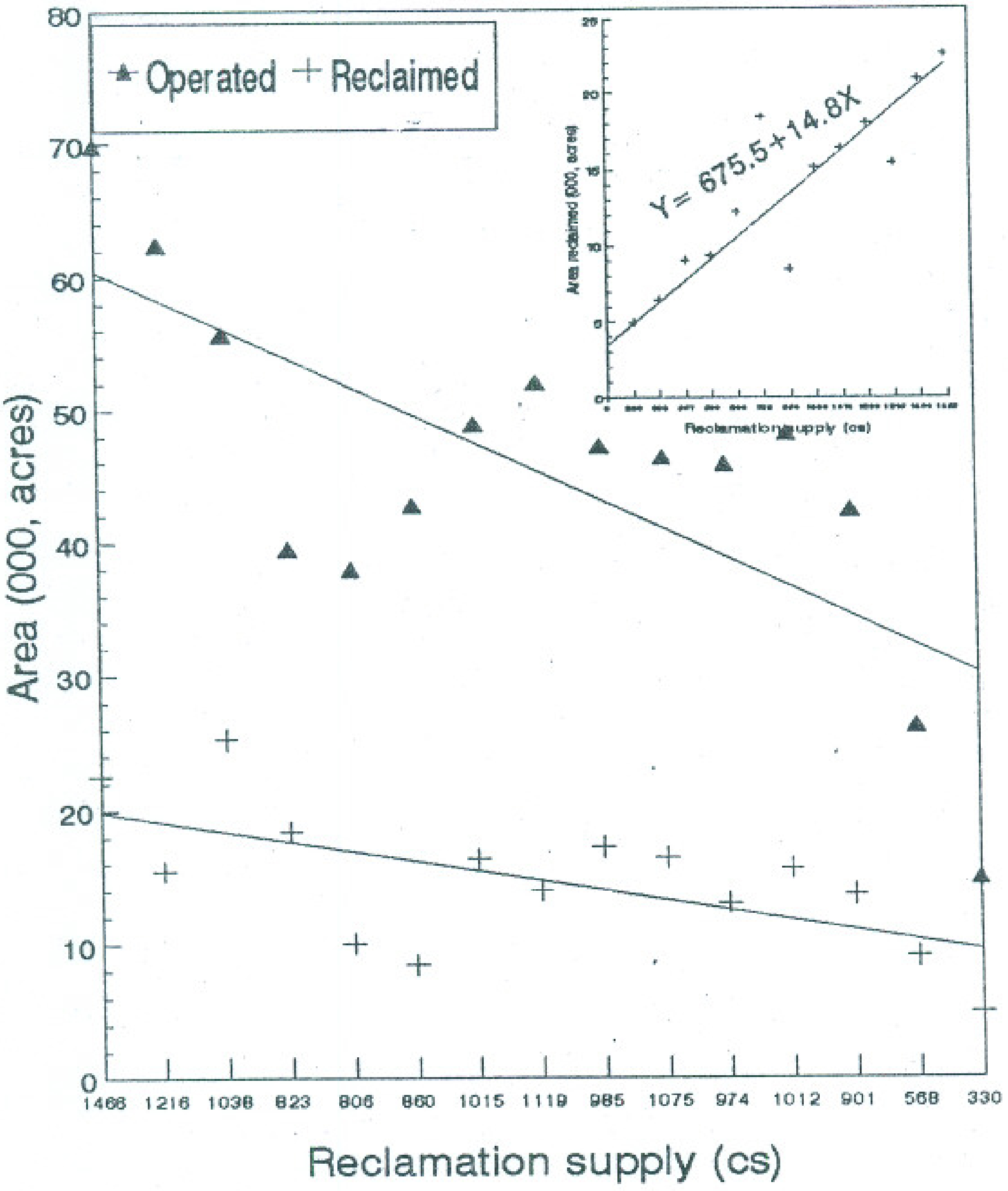


Fig. 4: Area reclaimed annually against the reclamation supply utilized from 1981-1995

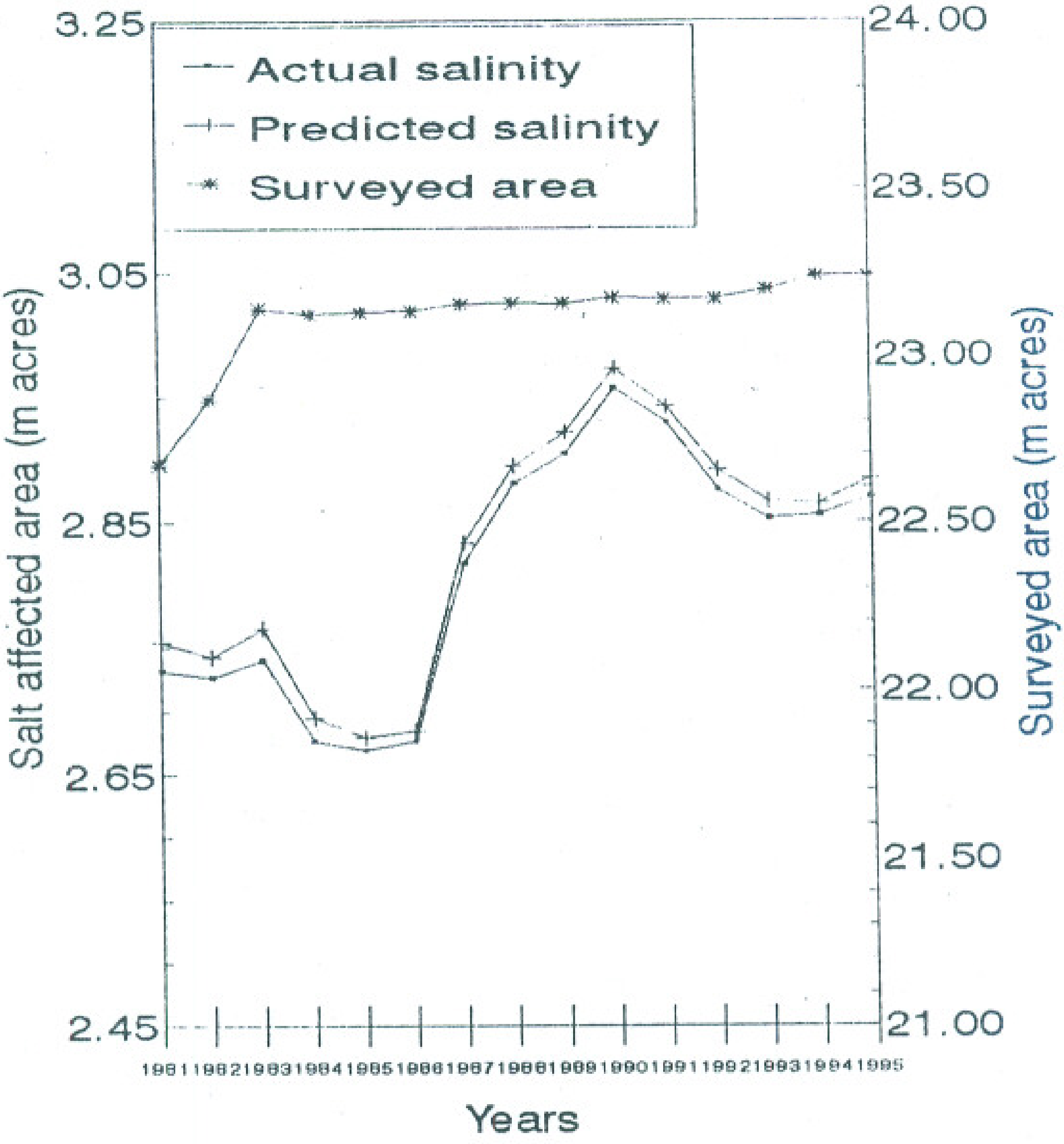


Fig. 5: Graph showing actual and predicted salinity trend in Punjab (out of surveyed area)

It can provide a good source of income for the farmers who otherwise cannot get much from their lands (Bhutta and Wolters, 1997).

Restoration of soil fertility during reclamation operations

A considerable proportion of plant nutrients is leached alongwith salt as a result of excessive irrigation applied to reclaim the soils. Nitrogen is the nutrient that is affected to a great extent. Therefore, some green manuring crops e.g. *Sesbania aculeata*, guar (*Cyamopsis psoralioids*) etc should be included to replenish the nutrients in the exhausted soil. A proper crop rotation under different soil conditions needs to be observed not only to replenish the nutrient status of the soil but also to keep salt movement trends downward.

CONCLUSIONS AND RECOMMENDATIONS

The rate of reclamation is not compatible with the annual rate of soil deterioration. At present trend of soil deteriorations, it may be anticipated that the majority of irrigated lands would go out of cultivation within the next 70 to 80 years or so if the menaces were allowed to go unchecked.

The permanent assignments are to be made to increase the general water allowance from 350 acres per cusec to at least 120 acres from either groundwater or surface water supplies.

It is also advisable to make effective use of the surplus water available during the flood season by increasing water storage.

Pedo-bio-hydro-logical strategies should be effectively used to make hydrological strategy more and more effective on which all other reclamation measures depend.

In addition to adopting the curative measures to place check over the problem of salinity, preventive measures such as use of chemicals, increased water allowances, precision land leveling and proper land cultivation practices should be taken in to consideration.

Drainage programme for reclamation of waterlogged saline lands in irrigation commands involving leaching models, and salt tolerant limits of the crops should be viewed seriously.

The cost effective, realistic and optimal strategies need to be researched out as effective salinity control measures.

ACKNOWLEDGMENT

The authors are indebted to Muhammad Bashir Bhatti, Steno of this office for typing the manuscript.

REFERENCES

Ali, C.K. 1995. Salinity and Crop Management. Ann. Res. Report (1994-95). Directorate of Land Reclamation, Punjab, Irrigation and Power Dept., Lahore.

Bhatta, M.N. and Wolters, W. 1997. Waterlogging and salinity challenges in Pakistan and their viable remedial measures. Proc. Int. Symp. Water for 21st Century. June 17-19, Lahore. PP. 29-36.

Carruthers, I. and Smith, L. 1990. The economics of drainage. In Symposium on Land Drainage for Salinity Control in Arid and Semi Arid Regions. Feb. 25 to March 2, Cairo, Egypt. Vol. 1,151-170.

Choudhri, M.B., Mian, M.A. and Rafiq, M. 1978. Nature and magnitude of salinity and drainage problems in relation to agricultural development in Pakistan, The Pakistan J. Forestry. 28(2),70-92.

Haq, A., Shakir, A.S. and Shahid, B.A. 1997. National Drainage Programme (NDP) - Issues and Options. Proc. Int. Symp. Water for 21st Century. June 17-19, Lahore. PP. 521-536.

Hoffman, G.J. 1986. Guidelines for reclamation of Salt affected soils. App. Agri. Res. 1(2),65-72.

Hussain, M. and Nishat, H.A.. 1963. Review of Reclamation activities and methods and suggested measures for waterlogging and salinity control. Symp. Waterlogging & Salinity in West Pakistan. Engg. Cong. Lahore. PP. 179-202.

Javaid, M.A. 1997. Hydrodynamic nutrient and salt distribution under the existing on-farm salinity management operations. Unpub. information, Directorate of Land Reclamation, Moghalpura, Lahore.

Javed, M. and Javaid, M.A. 1995. Salinity - A threat. Ann. Res. Report (1995-96). Directorate of Land Reclamation Punjab, Irrigation and Power Dept., Lahore.

Journalists Resources Center for the Environment (JRCE). 1989. Pakistan Food Sheet Land, IUCN Pakistan, Dec. 1989.

Qayyum, M. A. and Malik, M.D. 1988. Farm production losses in salt affected soils: Research on management and reclamation of salt affected soils of Pakistan-present status. . Proc. first Nat. Cong. Soil Sci., Lahore: PP. 56-363.

Qureshi, R.H. and Rashid, M. 1988. p 173-184. Proc. first Nat. Cong. Soil Sci. , Lahore.

Richards (ed.). 1954. Diagnosis and Improvement of Saline and Alkali soils. USDA. Handbook No. 60. Washington, D.C.

Raza, Z. I., Beekma, J., Chaudhry, M.R. and Bores, T.M.. 1993. Electromagnetic induction to monitor soil salinity for assessment of agricultural and environmental development Proc. Internl. Symp. on environmental assessment and management of irrigation and drainage projects CEWRE; Univ. Engin & Technol., Lahore. April, 1993:PP.34-47.

WAPDA. 1981. Soil Salinity Survey. Vol. 2 Organizations Planning Division (WAPDA), Lahore.

Table 1: *Thur* in different canal commands of the punjab for the year 1994-95

S.No.	Name of canal	Area surveyed. (acres)	Total *thur*[1] (acres)	% age under *thur*
1.	Upper Jehlum	572846	21236	3.70
2.	Lower Jehlum	1574440	275459	17.49
3.	Upper Chenab	1423070	211900	14.89
4.	Marala R.Link	175425	-	-
5.	B.R.B	72943	-	-
6.	Lower Chenab	3645360	468189	12.84
7.	Central B.D.	7030013	36072	5.13
8.	Lower B.D.	1733306	168230	9.70
9.	Depalpur.	1008123	133219	13.21
10.	Pakpattan.	1411063	109600	7.76
11.	Mailsi.	750977	82714	11.01
12.	Haveli.	1133461	282903	24.95
13.	Muzaffargarh.	851224	195709	23.26
14.	Thal.	2374799	16375	0.68
15.	Rangpur.	356739	99515	27.89
16.	D.G.Khan.	953881	123223	12.91
17.	Punjnad.	1507025	258842	17.17
18.	Abasia.	296027	22768	7.69
19.	Bahawal.	906204	35132	3.87
20.	Qaim.	45128	7086	1.57
21.	Sadiqia.	1228727	171906	13.99
22.	Fordwah.	464554	148851	32.04
23.	Small Dam.	32217	-	-
24.	Civil Canal.	13599	-	-
Total		23235051	2868929	12.35

1 *Thur* is a wide term used in Irrigation and Power Department for all categories of salt affected soils.
BD= Bari Doab

Table 2: Reclamation supply and area reclaimed during different year (1981 to 1995)

Years.	Reclamation supply actually utilised (cusecs)	Area operated (acres)	Area reclaimed during the year (acres)	Area reclaimed upto date (acres)
		Area reclaimed upto 1980:		1069159
1981	1465.89	69806	22575	1091734
1982	1216.36	62383	15465	1107199
1983	1037.82	55682	25284	1132483
1984	823.40	39505	18451	1150934
1985	805.80	37944	10092	1161026
1986	860.12	42738	8514	1169540
1987	1015.16	48866	16362	1185902
1988	1118.62	51992	14007	1199409
1989	984.96	47170	17219	1217128
1990	1074.63	46270	16424	1233552
1991	973.96	45774	12998	1246550
1992	1011.82	48090	15613	1262163
1993	900.68	42332	13655	1275818
1994	567.49	26105	9096	1284914
1995	330.14	14856	4952	1294010

(Source: Ali, 1995)

TABLE: 3
CHEMICAL PROPERTIES OF VARIOUS AMENDMENTS FOR RECLAIMING SODIC SOILS.

Amendment	Chemical Composition.	Physical description.	Solubility in Cold water kg m^{-3}	Amount Equivalent to 1 Kg of pure gypsum (kg).
Gypsum	$CaSO_4.2H_2O$	White mineral	2.4	1.0
Sulphur.	S_8	Yellow element	0	0.2
Sulphuric acid.	H_2SO_4	Corrosiro liquid	very high	0.6
Lime Sulphur	9% Ca+24% S	Yellow brown solution	very high	0.8
Calcium Carbonate	$CaCO_3$	White mineral.	0.014	0.6
Calcium Chloride	$CaCl_2.2H_2O$	White salt.	977	0.9
Ferrous Sulphate	$FeSO_4.7H_2O$	Blue green salt	156	1.6
Pyrite	FeS_2	Yellow black mineral	0.005	0.5
Ferric Sulphate	$Fe_2(SO_4)_8.9H_2O$	Yellow brown salt	4400	0.6
Aluminium.	$Al(SO_4)_3.18H_2O$	Corrosive granular material.	869	1.3

(Source: Hoffman, 1986)