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CAUSES OF SPREAD OF WATER LOGGING AND SALINITY IN PAKISTAN AND ITS REMEDIAL MEASURES

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SUMMARY

1.1. The main causes of spread of water-logging and salinity in Pakistan are, high sub-soil water table conditions, inadequate drainage, inadequate irrigation supplies for leaching of salts, not restricting irrigation supplies during periods of no demand, inadequate use of chemical amendments to reclaim sodic and saline sodic soils. In addition to the above, the country has a hot dry climate which aggravates all the factors leading to water-logging and salinity.

1.2. Since 1960, the problem has been tackled at national level with the help of International Donor Agencies and the World Bank. Though the spread of this twin menace has been arrested and gradually more area is now being continually reclaimed, there is a need to accelerate the pace of providing suitable drainage and reclaiming affected soils. Drainage options for different soil conditions continue to be the topic of research and efforts continue, to find a more satisfactory solution than the existing methods. Research in reclamation measures needs more attention, as reclamation of sodic and saline sodic soils has not progressed so well.

1.3. A case study of two different projects where tubewells have been used for providing sub-surface drainage have been evaluated in the paper. The first case is of tubewells in fresh ground water zone and the second case is of tubewells in saline ground water zone. The research has shown that marginal water quality (saline ground water mixed with canal water) has not had any marked deterioration of the soils or on the crop yields.

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2. INTRODUCTION

2.1 Geographically Pakistan is located in the arid/semi-arid zones of the World. To compensate for this short coming Nature has blessed her with fertile lands, flowing rivers and sunshine to grow and harvest crops throughout the year. Despite these bounties, the level of growth of agricultural production falls far short of the potential available.

2.2 The Indus basin,which is the main stay of agricultural production in the country, is a large, flat, alluvial plain sloping very gradually towards the Arabian sea. Being an arid zone, agriculture is practised through an irrigation system based on river and ground water development. The land is robust but has been exhausted due to constant cropping without adequate dozes of manures/fertilizers. The sub-surface water table has also risen causing water-logging and salinity in the irrigated areas which results in low yield of crops.

2.3 *Land Resources of Pakistan*. Two tables below give the land use and the land capability in the canal irrigated areas of Pakistan:

Table 2.1
Land Use in Pakistan[1]
Revised Action Programme for Irrigated Agriculture, Master Planning, WAPDA, May 1979.

Sr. No.	Land Use	Area (Million Acres)	Percentage
1.	Culturable canal commanded area	34.5	17.6
2.	Cultivated area from wells and streams	5.5	2.8
3.	Barani (Rain fed)	9.1	4.6
4.	Sailaba (Riverine and Torrential Residual)	5.6	2.8
5.	Range and forest land	28.3	14.4
6.	Total suitable for agriculture and forestry	77.9	39.6
7.	Total un-suitable for agriculture and forestry	118.8	60.4
8.	Total area of Pakistan	196.7	100.0

Source : 1. Soil Survey of Pakistan 1976 (Table 2.1)

Table 2.2
Land Capability in Canal Irrigated Areas[2]
Soil Survey of Pakistan 1976
(Million Acres)

Class	Capability	Punjab	NWFP	Sind and Baluchistan	Total	Percentage
I.	Very good	8.93	0.19	2.58	11.90	33
II.	Good	8.80	0.19	6.91	15.90	45
III.	Moderate	3.01	0.09	3.19	6.29	18
IV.	Poor	1.26	0.01	0.26	1.53	4
	Total :	22.00	1.10	12.22	35.62	100

Source : 2. Soil Survey of Pakistan 1976 (Table 2.2).

2.4 Inference drawn from the above tables is :

(a) About 40% of the area in Pakistan is suitable for forestry and agriculture, which is a high percentage considering world averages.

(b) The population of Pakistan has crossed the 100 million mark with an average increase of 2.5% annually. The present cultivated area has the potential to feed double the population if crop yields are brought upto the world average i.e. the land resources of Pakistan are in abundance; it requires appropriate preservation, reclamation of salinity affected areas and high yield technology.

3. CAUSES OF WATER-LOGGING AND SALINITY IN PAKISTAN.

3.1 *Preamble.* Irrigation system for the Indus Basin was developed during the last 100 years. During the first 50 years,a complementary drainage system was not developed since the need to maintain the hydrological balance of the sub-soil water was not felt. With the rise in water-table, causing salinity the salt balance of the soil was also upset. Since 1960, Salinity control and Reclamation projects (popularly known as SCARP) are being implemented in the irrigated areas of the Indus Basin Table 3.1, 3.2 and 3.3 show the water-table positions and salinity affected areas from 1979 to 1987. These tables show that the spread of water-logging and salinity is gradually being arrested.

Table 3.1
Percent Area with 0-150 cm depth of water-table[3]
SCARP Monitoring Organization WAPDA

Sr.No.	Province	1979 June	1979 Oct	1984 June	1984 Oct	1985 June	1985 Oct	1986 June	1986 Oct	1987 June
1.	Punjab	12	18	8	17	5	12	8	13	9
2.	Sind	21	46	20	52	21	52	22	59	18
3.	Baluchistan	34	100	29	100	31	100	36	100	12
4.	NWFP	6	8	10	13	7	10	7	11	7
5.	Pakistan	15	30	12	32	11	29	13	30	12

Source : 3. SCARP Monitoring Organization WAPDA (Table 3.1)

Table 3.2

Percent Area - Surface Salinity[4]

Sr.	Province	Salt Free 53-65	Slightly 76-80	Saline 53-65	Moderately 76-80	Saline 53-65	Strongly 76-80	Saline 53-65	Misc. 76-80	53-65	76-80
1.	Punjab	72	84	15	7	5	4	6	3	2	2
2.	NWFP	75	78	10	8	4	2	2	2	9	10
3.	Sind	26	50	28	19	17	10	27	18	2	3
4.	Baluchistan	69	74	15	17	7	5	9	4	0	0
5.	Pakistan	56	72	20	11	9	6	13	8	2	3

Source : 4. SCARP Monitoring Organization WAPDA. (Table 3.2 and 3.3).

Table 3.3

Percent Area - Profile Salinity[4]

Sr.	Province	Non-Saline Non-Sodic		Saline		Saline Sodic		Non-Saline		Missing	
		53-65	76-80	53-65	76-80	53-65	76-80	53-65	76-80	53-765	76-80
1.	Punjab	55	73	6	7	27	14	11	5	1	1
2.	NWFP	27	79	50	11	23	7	-	2	-	1
3.	Sind	-	38	-	17	-	42	-	2	-	1
4.	Baluchistan	-	35	-	26	-	38	-	1	-	1
5.	Pakistan	55	61	6	11	27	24	11	3	1	1

4. SCARP Monitoring Organization WAPDA. (Table 3.2 and 3.3).

3.2 The main causes of soil salinazation in Pakistan are:-

3.2.1 *High Water Table.* Sub-soil water in the Indus Basin has risen gradually near enough the natural surface level to cause the moisture to move up by capilliary action. (The hot sun evaporates this moisture, leaving the salts in the soil profile as well as on the top crust). The magnitude of salinity depends upon the type of soil structure which facilitates movement of soil water by capilliary action.

3.2.2 *Hot dry climate.* Higher day temperatures cause greater evaporation and since annual precipitation is much less than annual evaporation, the leaching action by precipitation is nominal. To regain the salt balance, natural precipitation has to be augmented by artificial irrigation. If the quantity of irrigation supplies match evapotranspiration, then the surface and profile salinity gets washed down below the crop root zone, provided adequate drainange is available.

3.2.3 *Inadequate Drainage.* Unless the sub-soil water-table is not below the crop root zone, the leaching waters will not carry the salts below the root zone. In the Indus Basin, where the land is generally flat, efficient natural drainage is a problem. Artificial drainage can be as expensive as the degree of difficulty in extricating and collecting the saline effluent and disposing it through a gravitational or pumped drainage systems. In Pakistan this is a challenge to the scientists and drainage engineers to find an appropriate and economic solution to the problem.

3.2.4 *Inadequate Irrigation Supplies.* Because of shortage of irrigation water supplies,

farmers resort to thin watering of the fields, leading to insufficient leaching and consequently salinity. Ideally irrigation supplies should exceed the evapotranspiration, specially during the hot dry period.

3.2.5 *Failure to give closures in the Irrigation supplies during periods of no demand.* During the rainy and harvesting seasons, when the irrigation water demand reduces to almost zero, if canal closures are not provided, farmers divert the surplus supplies towards the low lying areas causing water-logging and consequently salinity. Relevant to this factor is the need for providing irrigation suplies according to scientific crop water requirements. However, it is not simple to change the existing fixed supply system to a regulatory system as siltation and scouring will occur if supplies are varied in the irrigation channels. The possibilities of providing frequent closures and conjunctive use of ground water during the peak demand periods is under study.

3.2.6 *Use of chemical amendments for sodic and saline-sodic soils.* Monitoring results of surface and profile salinity in the Indus Basin, indicate that where-as there has been overall reduction in salinity affected soils, there has been minimal reduction in the percentage of sodic and saline-sodic soils. As is well known, in sodic soils during normal water leaching, the sodium ions are removed from the soil waters at a faster rate than the clay particles. This develops an equilibrium which causes the particles to deflocculate and the soil loses its permeability. Such soils, therefore require leaching with an alkaline/acidic solution or addition of a suitable chemical amendment like gypsum.In Pakistan reclamation of such type of soils has not been given higher priority yet. In Faisalabad Region, Studies are going on the use of gypsum as amendment in sodic and saline-sodic soils. The initial studies are encouraging.

4. REMEDIAL MEASURES.

4.1 The only practical means of reducing soil salinity is by leaching the saline soil water from the root zone with waters of lower salt concentaration. We have given the problem of ascertaining the quantity of water required to leach a given type of soil to the Irrigation, Water-logging and Salinity Research Institute of Pakistan. The variable factors being soil salinity, quality of leaching water, method of leaching, the depth of profile salinity and the soil properties. We realise that the salts cannot be completely removed from the soil surface and profile. The compromise solution would be a comparative reduction in soil salinity to an extent that the benefit of increased crop yields justifies the implementation cost of the reclamation project.

4.2 This brings us to the basic premise that salt accumulation is caused by the preponderance of evaporation over drainage. In this, if water balance can be controlled then the spread and growth of salinity can be prevented. The control of this water balance can only be achieved through effective drainage. In Pakistan we are concerned as to how to achieve effective drainage in the existing environments, which are:-

4.2.1 Vertical drainage has been tried since 1960. Now we feel confident that the technology of vertical drainage is well understood by the planners, designers and users to obtain optimum results in given soil lithology and water table conditions. However, the operation and maintenance of public tubewells has not been efficient and hence not cost effective. In sweet water zones, we have decided to transfer vertical drainage operations completely to the private sector.

4.2.2 Horizental sub-suface (tile) drainage started in 1978 as a pilot project, in the Lower Indus plain. We experienced certain operational difficulties which were overcome gradually. Now horizontal drainage is being installed in saline areas of upper and central Indus plains also. At present it is too early to predict its success or failure. However, it will basically depend upon the operation and maintenance capability of the users.

4.2.3 Sub-surface water-table in a fairly large area still remains between 0-1 meters during the major part of the year, which means that a very large saline drainable surplus has to be disposed off. Suitable disposal areas are a problem to find in the flat plains. Throwing the saline effluent in the rivers is not a satisfactory answer.

4.2.4 The Indus plain is flat as a pan cake; average slope being 1:5000. Gravity flow disposal of the saline effluent usually becomes a problem.

4.2.5 Sloughing and silting of surface drains is excessive due to high water-table conditions; also maintenance of the surface drainage system is generally poor. As a result, the storm water run off during the rainy season is not completely drained away within the permissible period. A study is underway to revise the design and concept of the surface drainage.

4.2.6 Soils which are affected by sodicity cannot be cured by simple leaching methods.

4.2.7 Completed SCARP projects are not being adequately maintained, basically due to shortage of maintenance fund. The water charges received from the farmers are not enough to operate and maintain the drainage infrastructure. However leving of a drainage cess or increasing water charges is a socio-political problem.

5. MINITORING RESULTS OF SOME COMPLETED SCARPS.

5.1 Thirty six SCARP projects have so far been completed in Pakistan to reclaim about 7.5 million hectares since 1960. Monitoring results of two SCARP projects i.e. SCARP-IV and one Unit of SCARP-V have been evaluated in this paper to assess the results of the reclamation efforts put in.

5.2 *SCARP-IV (Mangtanwala-Muridke Units) Monitoring Results.*

5.2.1 The scope of this project was to eradicate water-logging and salinity in about 200,000 hectares by installing 944 tubewells in sweet water zone of 2.5 cusecs capacity in the Upper Rechna Doab (Fig.1) in 1973.

5.2.2 Soil monitoring studies were started on biannual basis from 1976 to study the effect of tubewell waters on the irrigated soils, watch progress of reclamation and changes in cropping intensities, cropping patterns and crop yields.

5.2.3 For this purpose small plots were selected on 5 percent tubewells in the project area. Data collected from 1973 to 1980 for 46 non-saline, non-sodic plots and 141 farm holdings were evaluated and reported in CMO (WAPDA) publications 110 and 175.

5.2.4 From 1984-85, observations were reduced from biannual to once in 4 years on 50% selected tubewells as no change of any consequence was being observed. Thus SCARP Monitoring report SM-31 (1984-85) pertains to 24 non-saline, non-sodic and 26 saline/sodic plots along with agro-irrigational data for 75 farm holdings of different sizes.

5.2.5 *Inference for Non-Saline, Non-Sodic plots.* The usable quality waters i.e. EC ranging from 360-940 micro mhos/cm, SAR from 0.6 to 3.3, RSC from 0-1.9 meq/litre, after mixing with canal water did not deteriorate the soil and the yield of crops remained satisfactory.

5.2.6 *Inference for Saline/Sodic plots.* Out of 26 plots, 13 were irrigated by tubewell waters of usable quality as mentioned at para 5.2.5 out of these 11 (84.62%) were reclaimed due to usable water quality and goodmanagement practices, whilst 2 plots (15.38%) remained saline-sodic as before.

5.2.7 Next 13 plots received marginal quality water i.e. EC ranging from 530 to 1020 micro mhos/cm, SAR from 3.6 to 7.1 and RSC from 2.95 to 4.1 meq/litre. This was mixed with canal waters in the ratio of 1:1. Out of 13 plots, 9 (69.23%) were fully reclaimed, whilst 4(30.77%) remained saline-sodic.

5.2.8 *Inference - Cropping Intensity.* Pre-project cropping intensity for the Scarp area was 65%. During 1984-85, the results were as follows:-

Serial	Kharif	Rabi	Annual Total	Remarks
1.	85.90 %	96.74 %	172.62 %	Irrigation by wells with usable water quality.
2.	83.70 %	76.10 %	159.80 %	Irrigated by wells with marginal water quality.

Thus we see that optimum cropping intensity results are being obtained with conjunctive use of ground water

5.2.9. **Inference - Cropping Patterns.** During 1984-85, the cropping pattern was as given below : -

Serial	Cropp	Area covered in Kharif sowing season	Area covered season	Remarks in Rabi sowing
1.	Rice	68.75 %	-----	The water-table which has been
2.	Sugarcane	2.72 %		been lowered in 1976, has gradu-
3.	Fooders	9.57 %		ally come up and rice production
4.	Wheat	-----	48.3 %	still remains prominent.
5.	Rabbi	-----	29.3 %	

5.2.10 *Inference - Crop yields.* The yield of all the crops has shown increase as compared in the report. However, it continues to be below the average international yields.

52.11 *Use of Fertilizers and Pesticides.* The use continues to be far below the recommended dozes. However, increase in quantum of fertilizer use, beyond the optimum rate, yielded only marginal increase in crop yield.

5.3 *SCARP-V (Shorkot Kamalia) Monitoring Results.*

5.3.1 The problem of water-logging and salinity was due to seepage from Haveli and Trimmu-Sidhnai Link Canals (see Fig.1), yearly inundation of river Ravi, lack of any drainage system, non-judicious use of irrigation supplies and climatic conditions. As a result a large part of Shorkot-Kamalia Unit became unproductive, WAPDA installed 101

tubewells in 1976-77. The pumping of these tubewells not only lowered the ground water table but also added to irrigation supplies to enhance agricultural production.

5.3.2 Base line survey in 1976-77 indicated 15% area as slightly saline, 5% as moderately saline and 42% as strongly saline. The monitoring in 84-85 SCARP Monitoring (WAPDA) vide SM publication No.25 indicated 28% area slightly saline, 2.8% moderately saline and 30.4% strongly saline.

5.3.3 *Observation:*

(a) Nominal decrease in surface salinity.

(b) The affected soil profiles decreased by 1.3%.

(c) Aggregate discharge of tested tubewells in 84-85 decreased by 26.74% since 1976-77. Out of a total of 92 working tubewells, 28 fell in the reduction range of more than 50%.

(d) Area under 0-2 metre depth to water table decreased 6.2% where as from 2-3 meters depth of water table, the area decreased by 4.4% since 1976-77.

5.3.4 *Inferences:*

(a) Reclamation process has been slow due to early reduction of discharge of tubewells and inadequate maintenance of the surface drainage system.

(b) Tubewells whose specific capacity has reduced between 100-50%, should be rehabilitated immediately.

(c) New reclamation projects should cater for improved design of tubewell and surface drainage maintenance measures should be improved.

6. IMPROVEMENTS SUGGESTED IN EXISTING SYSTEM.

6.1. *Surface Drainage*: This is the weakest link in the drainage systems operating in Pakistan. The major short-comings are:-

6.1.1. Outfalls of the main drains in the rivers have generally negligible heads, specially during the rainy season.

6.1.2. Branch drains in the drainage basins exist, but sub-drains connecting the farm drains to the branch drains are missing. A pilot project to provide effective linkage between farm and branch drains is starting in 1989-90.

6.1.3. Depressions in the low-lying areas not connected with surface drainage cause water-logging and salinity problems. In Faisalabad SCARP project, depressions in irrigated areas are being connected with the surface drainage system by providing mobile pumping arrangements during the rainy/flood season.

6.1.4. Drain embankments slough and silt during rainy season and sometimes even during construction/remodelling. This is mainly due to poor soil structure and high water table. Studies are also being undertaken to find satisfactory solution to this problem.

6.1.5. Maintenance of drains is generally poor which causes silting and weed growth preventing evacuation of designed discharge. Desilting of drains requires continual operation of mechanical plant, which is a weak link.

6.2. *Vertical Sub-Surface Drainage:* Where sub-surface drainage is by tubewells, operation and maintenance of tubewells is at a very low efficiency. Following measures can improve the efficiency of the vertical sub-surface drainage in Pakistan:-

6.2.1. Tubewell effluent of useable and marginal water quality should not be disposed off in the drainage system, but used in conjunction with canal waters to augment the existing meagre water supply. Monitoring of such conjunctive use of waters have shown no deteriorating affects as feared.

6.2.2. Saline effluent of tubewells should invariably be carried through lined channels so that the soil is not affected by salinity and the recurring maintenance of channels is reduced.

6.2.3. Operation and maintenance standards of tubewells be upgraded to ensure that there are minimum stoppages of pumping, so that extrication of designed discharge is maintained.

6.3. *Horizental Sub-Surface Drainage.* Horizental sub-surface drainage in Pakistan because of water and soil conditions has to be atleast one meter deep; spacing depending upon the hydraulic conductivity of the affected soils. The major problem occurs in sandy soils with high water-table, where trenching operations beyond 2.8 meters depth have not been successful without other allied measures. Operation and maintenance of horizental drainage requires more technical skill as compared to vertical drainage and the operation and maintenance staff will take sometime to acquire this skill.

6.4. *Lining of Channels and Water Courses.* To conserve the already limited supply of

irrigation water, the programme of lining of water courses has been very successful in Pakistan. Now lining of smaller irrigation channels has also been undertaken, to further reduce the seepage of channels, specially in saline ground water areas. Thus lining of channels and water courses act as preventive measures to eliminate water-logging and salinity, apart from conserving the meagre irrigation waters.

7. CONCLUSION:

7.1. Water-logging and salinity is the twin menace in Pakistan which has adversely affected the irrigated lands and consequently the crop yields. Continuous efforts continue to combat this menace. After forty years of struggle, the scientists, irrigation engineers and the farmers are on the thresh hold of success in controlling water-logging and salinity. This, however, should not make them complacent, for the fight against salinity is a continuous affair and not a one time effort.

7.2. Operation and maintenance of the drainage and reclamation infra-structure demands disciplined and rigorous measures to maintain the efficiency of the system. The maintenance staff and the farmers must absorb the technology essential for maintenance of the sophisticated sub-surface drainage system.

7.3. Thus successful eradication of water-logging and salinity implies efficient management in the construction stage, efficient operation and maintenance subsequently and meaningful minitoring and evaluation continually to suggest corrective measures.

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(c) SM-110 Publication of Scarp Monitoring Organization WAPDA - 1987.
(d) SM-175 Publication of Scarp Monitoring Organization WAPDA - 1987.

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