NATURE AND MAGNITUDE OF SALINITY AND DRAINAGE PROBLEMS IN RELATION TO AGRICULTURAL DEVELOPMENT IN PAKISTAN

by

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Summary. *The salinity and drainage problems have been getting undue importance at the expense of improvement of agriculture on good soils occupying about three fourth of irrigated area in our country. The available evidence suggests that these ills have neither taken a heavy toll of good agricultural land nor are they a growing threat.*

Reconnaissance soil surveys covering the Indus plains have revealed that, contrary to the general belief, salinity and waterlogging are not a 'twin menace'. Most of the salt-affected soils were formed in ancient times, much before the recent rise in water table due to seepage from the canal system. The recent high water table conditions have, however, produced a salt puff on these soils. The saline soils, that have been grouped in five main categories, occupy 14.3 *million acres in the Indus plains but only* 7.8 *million acres in the canal command areas.*

The saline cultivated soils of primary practical importance are of two types: (*i*) *soils with topsoil salinity sodicity occurring in patches in cultivated fields,* (*ii*) *partly reclaimed saline-sodic soils, together occupying about three million acres only. Waterlogging is a problem of some importance in about* 0.7 *million acres of non-saline cultivated land only.*

The SCARP programme has been examined and it has come out that these projects have not met the expected success because they were formulated without proper diagnosis of the problems of salinity and waterlogging. No doubt some positive results have been achieved but these are largely negated by the sodicity problem caused by low-quality tubewell water. This kind of sodicity is affecting about half of the area irrigated by tubewells.

Toward the end, priorities for agricultural development have been suggested, keeping in view the kinds and extent of the saline and waterlogged soils, the vast extent of high-potential but under-utilized agricultural land and the economics of water use in the country. The sore need to improve the general standard of farming has been reiterated. It has also been emphasised that the reclamation of saline or waterlogged lands can be done by site-specific measures only. The farmer is the key figure in all programmes of not only improvement in agriculture but also in reclamation of saline land. Therefore, he has to be guided properly and adequately. These objectives cannot be realized without paying due attention to agricultural research and extension services.

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Introduction. For the last one quarter of a century the problems of soil salinity and waterlogging have been haunting the minds of planners and decision makers in the country. Most often efforts for development of agriculture have been concentrated mainly on reclamation of areas affected by these land degradation processes.

The nature of salinity and waterlogging in the country was not well understood in the past and these problems were never seen in their true perspective because basic data about their characteristics and occurrence on a countrywide basis were not available. Incomplete information on a few bits of the affected land gave rise to some fallacious concepts such as: 'salinity and waterlogging is a twin menace' and 'one hundred thousand acres of irrigated land is going out of cultivation every year'. There is ample evidence to suggest that the approach followed to eradicate this 'menace', as developed from such concepts, has not produced the desired results.

We have investigated soil conditions throughout the Indus plains and have failed to find a basis for these concepts. Now that adequate data on the nature, genesis and magnitude of these problems are available, let us take stock of our past strategies and try to straighten the issue of salinity and waterlogging.

A Review of the Scarp Programme. *Premise.* Since early fifties, a simple hypothesis has been developed and propagated that there was no salinity in the Indus plains when the present irrigation system of canals was constructed around the turn of the last century and that all the salinity seen today has been caused by recent rise in water table. This hypothesis is based on the fact that at that time the water tables were generally very deep. Subsequently, however, seepage from the canal system raised the water table, bringing it close to the surface and, as it is asserted, the salts in the ground water got accumulated in the surface soil, thereby deteriorating the good cultivated land to the extent of rendering it unfit for cultivation. This explication of the genesis of salinity led to the corollary that if water table was lowered by installing tubewells and their water was used to leach salts from the affected lands, the problems would be solved.

Approach. Based on the above-cited thesis, reclamation of land affected by salinity and waterlogging has been undertaken under the name of SCARPS. The main feature of this programme is installation of tubewells that are employed as a means of subsoil drainage and additional water supply for the reclamation of salt-affected land. Provision of storm water open drains forms a secondary component of the SCARPS. In this programme however, nothing more than a lip service is given to improvement of the standard of farming.

Area coverage and costs. SCARP-I was launched in 1959 over an area of 1.2 million acres at a cost of Rs. 240 million. In 1970 it was declared completed and was handed over to the Punjab Irrigation and Power Department for maintenance. The present maintenance cost of this project amounts to Rs. 34 million (WAPDA, 1976a).

Work on other SCARPS was taken up in subsequent years and till December, 1974, a total area of about 6.4 million acres was covered by this programme at a capital cost of Rs. 1858 million.

Under the Accelerated Programme of Controlling Salinity and Waterlogging, starting from 1974-75, it has been planned to cover an area of 22 million acres during a period of 21 years. This programme is estimated to cost about 30.5 billion rupees (three billion US dollars). On the average it costs about Rs. 1400 per acre (WAPDA, 1976b). The main components of this programme are:

(1) Installation of tubewells	..	Rs. 16.3 billion
(2) Replacement of deteriorated tubewells		Rs. 2.7 billion
(3) Construction of open drains	..	Rs. 7.6 billion
(4) Tile drainage	..	Rs. 3.9 billion

Results. SCARP-I, that has been declared as successfully completed, may be taken as a case for assessment of the reclamation effected by the tubewell approach.

The pre-project and post-project conditions of the land in the area are reflected in aerial photographs taken in 1953-54 and 1976 respectively. The years 1953-54 represent the period of the worst conditions of salinity and waterlogging in this region because, at that time, the water table was the closest ever to the surface, and some small low-lying strips or patches of land were submerged under water.

A comparison of the aerial photographs, taken 23 years apart (plates 1 and 2), shows that:

(*i*) Most of the few wet areas have either become completely fit for cultivation or their limits have shrunk.

(*ii*) Large tracts of salt-affected lands are still out of cultivation, as they were in 1953-54.

(*iii*) A small proportion of the salt-affected land has come under cultivation. This extension of cultivation has occurred generally on the margins of saline land and where the salinity occurred as small patches in a complex pattern within the areas of good land.

These observations are further confirmed by interpretation of LANDSAT imagery.

Field investigations in SCARP-I carried out by the Central Monitoring Organization of WAPDA and by the Soil Survey of Pakistan have shown that the water table has been generally lowered, and the cropping intensity has generally increased but only a few of the salt-affected fields brought under cultivation have been reclaimed completely. Most of the fields are still saline-sodic or sodic and produce only poor to moderate yields of a few crops like rice and wheat only (Hussain and Muhammad, 1976). The crop yields in the project area are hardly better than those in the adjoining non-SCARP areas.

A few specific studies (Jalal and Rafiq, 1973; Hussain and Muhammad, 1976) in SCARP-I have shown that large areas of very good salt-free soil have been damaged by sodicity to varying degrees by the tubewell water which is low in salts but carries a moderate to high sodium hazard. The extent of this damage has been displayed on a map (Jalal and Rafiq, 1973).

These observations provide enough evidence to say that the results of the SCARP are most disappointing from the point of view of reclamation of saline land.

Nature and Extent of Salinity and Waterlogging. *Soil salinity: Ancient salinity.*— Basic soil surveys conducted in the Indus plains over the last 15 years have revealed that:

(*i*) most of the salinity in the country is ancient, produced much before the recent rise in water table after introduction of the canals; and

(*ii*) accumulation of salts in the anciently salinized soils is the result of specific soil forming processes operating over hundreds or thousands of years. These processes are described at length by Rafiq (1975) and Brinkman (1971).

Segregation of saline areas from cultivated land.—At the time of canal colonisation, as given in the Punjab Colony Manual (Wace, 1934), sizeable patches of salt-affected land were excluded from the canal commanded area (CCA). Only the good, salt-free land was allotted to farmers. The saline patches which were small in size and occurred within good land in an intricate pattern were, however, included in the CCA. The proportion of saline and non-saline land varied from place to place. It was well realised at that time that there weredifferent kinds of salt-affected soils; some responded favourably to reclamation efforts whereas others defied such attempts. The farmers, who happened to get land with higher proportion of salt-affected soils or other kinds of inferior land (as found on cultivation), were given option to exchange it with the un-allotted area in the same locality. Generally, the Government reserved 10 to 20 per cent land known as '*baqaya*' (remaining land) in each village for this purpose as well as for future needs.

Within a few years of canal irrigation the good land came under cultivation while most of the salt-affected areas were sorted out and left aside. Small patches or individual fields of reclaimable saline soils were, however, brought under cultivation but the bad types of salt-affected soils remained uncultivated even where canal water had been allocated for them. As the pressure of population built up and additional water supplies (both surface and ground-water) were made available, some more areas of reclaimable saline soils came under cultivation. The worst affected soils, however, have all along been resisting reclamation bids, and most of them are still lying uncultivated.

Secondary salinity.—The Indus plains, although apparently level, are far from being flat. Small variations in relief, in the range of 3 to 6 feet within linear spans of one or two miles, are not uncommon (Alim and Ashraf, 1977). Soon after the introduction of canal irrigation, the water table started rising. It came closest to the surface in low-lying areas especially near highly permeable sections or head reaches of the canals. In some places, small areas were submerged by the rising ground-water and turned into marshes. The ponded areas were not salinized because large amount of water available for moving down the soil profile removed the soluble salts.

Plate 1. Scale 1 inch to 1 mile
Aerial Photograph of a local area : Beranwal unit in SCARP—1, taken in 1953—54. Small parts (W) are waterlogged ; some areas (*S*) are affected by slight/patchy salinity ; large tracts (S) are strongly saline.

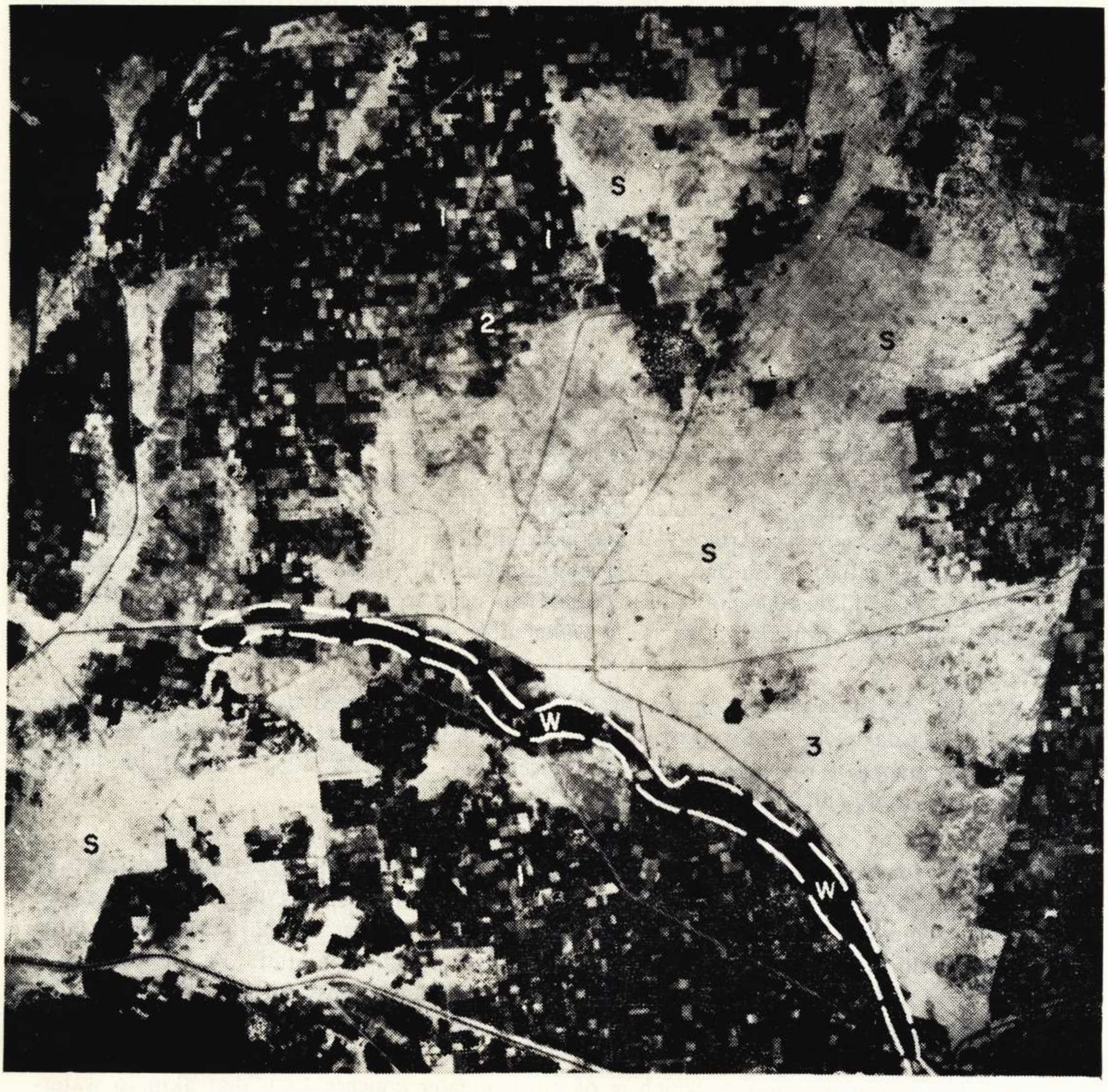

Plate 2. Scale 1½ inch to 1 mile

Aerial Photograph of a local area : Beranwala unit in SCARP—I, taken in 1976. A comparision of condi-in 1953-54 (plate 1) with those 1976 shows that ; very small extent (1) of previously saline land; some areas (2) of previously waterlogged land have come under cultivation; some waterlogged areas (3) have been drained but have turned saline; small belts (W) of earlier waterlogged land are still excessively wet; some areas (4) of Initally slight salinity have become more saline; large tracts of strongly saline land (5) have not undergone any change.

In margins of the marshy spots the water table came close to the surface, but it affected different areas quite differently. In non-saline soils that were under cultivation a change in cropping pattern occurred in such a way that crops with high water requirements, such as sugarcane and rice, replaced those having low water requirements. The additional water needs of the crops were met partly through sub-irrigation and partly by extra irrigation. The high rate of water application also kept the salts under check. In the same topographic positions other high water table areas, that were less frequently irrigated, were salinized in the topsoil, but their subsoil largely remained free of salts. In the high water table areas upward movement of moisture as compared to percolation of water through the soil was more intense on slightly raised parts than in the dips. Therefore, the slightly higher patches within the low-lying stretches of land were affected most severely (Choudhri, 1977).

The anciently salt-affected soils which were mostly lying uncultivated, showed a marked effect of the rise of water table. These soils occupy margins of depressional areas and in most of them the water table came within capillary reach from the surface. A lot of salt appeared on their surface because it was already present in the subsoil and substrata, and it simply moved up to the surface with the evaporating water. This process imparted a fluffy appearance to the surface. It may be pointed out that during the original condition of deep water table, the surface of these soils generally appeared salt-free to the casual observer. The efflorescence of salts on these soils led to the common belief that all salt-affected soils were formed by the rise in water table during recent years.

The marshy and very high water table conditions occurred in a very small proportion of the total area, as governed by topographic positions. In by far most of the areas away from depressions the water table was never high enough to induce salinization and/or affect crop production adversely. (see plate 3).

The topographic sequence described above is repeated within short distances all over the Indus plains, with the result that never more than one per cent of the canal commanded area was waterlogged (see Annexe), and the secondary salinization due to high water table conditions affected only a very small proportion of the cultivated land. According to our studies, the spread of the salt-affected land in any canal command did not increase by more than 5 per cent of the anciently salinized areas.

The secondary salinity, which is of much greater concern than that akin to water-logging, is the build-up of high sodicity in first-rate, non-saline agricultural land caused by irrigation with low-quality tubewell waters (plates 4 and 5). This type of salinity was introduced with accelerated use of ground-water. The symptoms of the sodicity of soils are widespread, as observed from hardening of topsoil, decrease in rate of infiltration and inadequate seed germination, especially of alkali-sensitive crops. This mode of salinization is treacherous, as it operates insidiously and the farmers, due to slow rate of soil deterioration, become aware of the problem after considerable damage has been done.

Kinds of salt-affected soils.—All the saline land is not alike. It has a variety of soils that can be grouped into five main categories (Rafiq, 1975), as given below in table 1.

TABLE 1

Kinds and characteristics of salt-affected soils

Kind of soils	*Main soil characteristics*	*Land cap. subclasses*
(*i*) Dense saline-sodic soils	Strongly to slightly saline, strongly sodic almost impervious soils. ECe: 4 to 20 mmho/cm. ESP: 50 per cent or more. pH: 6.9 to 10.5	VIIIa/VIIa/ irIVa
(*ii*) Porous, saline-sodic soils	Strongly to slightly saline, moderately sodic, moderately to slowly permeable soils. ECe: 4 to 20 mmho/cm. ESP: 20 to 30 per cent. pH: 8.6 to 9.6	VIIIa/VIIa/ irIIIa
(*iii*) Strongly saline soils containing gypsum	Strongly saline usually non-sodic soils with crystals of gypsum scattered throughout the soil profile but concentrated in the surface layers. ECe: <20 mmhos/cm. ESP: $<15\%$. pH 8.0 to 8.2	irIIIa/VIIIa
(*iv*) Prorous, moderately saline soils or normal soils with saline-sodic surface	Moderately to strongly saline and sodic topsoil over a permeable, porous, saline or non-saline subsoil. ECe: 6 to 18 18 mmhos/cm. pH 8.1 to 9.2	irIIa/irIIIa/ irIVa
(*v*) Normal soils with saline-sodic surface resulting from the use of low-quality ground-water	Moderately to strongly saline-sodic topsoil over a normal porous subsoil affecting choice of crops and their germination and yields. ECe: 4 to 9 mmhos/cm. pH: 8.5 to 9.2	irIIa

Extent of salt-affected soils.—Several agencies have reported on the extent of salt-affected soils. The statistics given by various agencies differ from one another due to differences in recognition of salinity and in methods and scales of mapping. In some cases, data of some surveys have been misrepresented as well. According to estimates by the Soil Survey of Pakistan, the total extent of salt-affected soils in the Indus plains is 14.3 million acres, as given in table 2.

The figures of other agencies with our comments are presented in the annexe.

Plate 3. Scale 1 inch to 2.5 miles approx.

A synoptic view of central part of the Rachna doab as photographed from the air in 1953-54. Intense dark colour (W) indicates infilled channel beds that are severely waterlogged and, in places, submerged under water; white patches (S) over about one quarter of the area represent salt-affected soils which occur mainly on margins of depressions. The remainder (A) more than two-third of the landscape is cultivated, salt-free, well-drained land, indicating that, even at the time of nearly the worst conditions of high water table in this region by far a large proportion of the land was unaffected.

Plate 4. Topsoil subsoil of a (non-saline) loamy soil under canal irrigation. The topsoil is porous and granular like the subsoil.

Plate 5. Topsoil and subsoil of a (previously non-saline) loamy soil under irrigation by low-quality tubewell water. Structure of the topsoil has been damaged, resulting in formation of a crust, due to accumulation of sodium salts present in the tubewell water. This type of soil damage causes problems of poor seed germination, patchy and weak crop stands, low infiltration and poor soil aeration.

TABLE 2

Extent of Salt-Affected Land by Province

000 acres

Province	CCA	Extent of salt-affected land			
		Within CCA		Outside CCA	Total
		Acreage*	Percentage		
N.W.F.P.	791.0	33.8	4.3	1,239.2	1,273.0
Punjab	16,489.8	3,987.7	20.4	2,788.3	6,776.0
Sind	13,217.0	3,783.8	28.6	2,517.2	6,301.0
Total Indus plains	33,497.8	7,805.3	23.3	6,544.7	14,350.0

*Excluding the areas damaged by tubewell water.

Propagation of salinity.—Although soil salinity is widespread in the Indus plains, there is little evidence to suggest that it is a growing threat. The available data, for the Indus plains as a whole, indicate that a sort of equilibrium, between the *small extent* of land going out of cultivation due to secondary salinization and that being restored to productive use by reclamation, had established by late forties. Thereafter, till 1960 hardly any change occurrred in the total extent of salinity, as shown by yearwise figures published by the Directorate of Land Reclamation (Hussain, 1970-annexe). Subsequently, as indicated by these data, a negative trend set in owing to the reclamation undertaken with tubewells installed mostly in private sector.

The salinity figures, however, do not include the soils affected by high sodicity caused by the use of low-quality pumped ground-water. Precise data on the extent of this type of secondary salinity are not available. According to a rough estimate, however, about one half of the area irrigated by tubewells is affected to varying degrees (Rafiq, 1977).

Waterlogging: High water table.—As discussed earlier (*Secondary salinity*), when water table rose due to seepage from the canal system, it did not come to a uniform depth below the land surface. Small specific, low-lying belts or isolated patches, especially those near the head reaches of big canals, were submerged under water. Margins of these areas experienced high water table, but in far more extensive areas in the same landscape, the water table did not ascend high enough to cause adverse effects on crop production.

As a rule, with gradual rise in water table, evaporation losses of ground-water increase and eventually an equilibrium is established when the recharge and losses of ground-water are almost equal. When such an equilibrium is reached, as was the case in Shikhupura District in mid-fifties and, may be, in some parts of D.G. Khan and Bahawalnagar Districts today, further rise in the water table is halted. In the Indus plains where the irrigation intensity is low, the equilibrium is established when only a small proportion of the total area is waterlogged to such an extent as to affect aeration of root zone and thereby the crop yields. According to the relevant data (Hussain, 1970; Rafiq, 1975), never more than 0.6 per cent of the CCA was severely waterlogged in Pakistan.

Collection of run-off.—There are large tracts of land in the Indus plains which collect considerable run-off from the adjoining high-lying areas during the monsoon season. Some of the rain water as well as irrigation water, after entering the root zone in the higher lands finds its way in the form of sub-surface flow to the adjacent lower areas. The depressional sites, therefore, get excessively wet mainly during the monsoon season even though the water table is generally deep. These lands are erroneously referred to as water-logged. The water regime in these areas is ideally suited to rice cultivation which is their main land use established since times immemorial, as in Gujranwala, Gujrat, Sialkot and Sheikhupura Districts.

The Indus right bank basin in Sind with peculiar soil and drainage conditions is another example of pseudo-waterlogging. It is a vast depression enclosed by relatively high silty and sandy levees along the Indus on one side and by a gently sloping piedmont plain on the other. It is built up by alternating layers of piedmont clays and silty clays of the Indus alluvium. Having only a very gentle slope to the south, it is dotted with marshes which were originally the collection sites for flood waters of Indus river and hill torrents. Now the floods have largely been checked by the flood protection embankments along the Indus but excess irrigation water and sub-surface flow from rice fields collect in the marshes. A considerable part of the basin has ancient salinity and is lying barren. The cultivated fields are mostly non-saline and ideally suited for growing rice. In this vast area present land use benefits the soil and drainage conditions, and to call the whole area waterlogged would be a misnomer.

Salinity and waterlogging as two distinct problems. All the salt-affected soils in the Indus plains are not waterlogged. There are large areas of saline land which never experienced high water table conditions during the last hundred years, e.g. Multan and Vehari Districts. Conversely, all the waterlogged soils are not saline. For example, in Mona Experimental and Reclamation Project, in an area with water table at two to three feet depth, neither the soil has been salinized nor the yields of dryland crops affected adversely. There are many similar instances of a discrete problem of salinity or that of high water table, scattered all over the Indus plains.

This is so because the salt in the Indus river system is mainly calcium bicarbonate which precipitates on evaporation of water and becomes a harmless part of the soil. The real salt burdon is caused by the sodium salts but these are, luckily, in very small amounts (about 50 to 70 ppm) in our river waters. The leaching requirements to remove these (sodium) salts from the root zone of the soil would be about one or two per cent in excess of the crop water requirements (Rafiq, 1977). The leaching of this magnitude is easily affected by heavy rains once in three to five years. It is further insured by inclusion of a high-delta crop in the crop rotations once in three years or so.

Salinity and waterlogging are two separate problems and should be seen as such. By linking the two as a 'twin menace' the issue has been confused.

Significance of the problems in Relation to Agricultural Development. *Limited extent of the affected cultivated land: Soil salinity.*—A critical assessment of the salinity problem reveals that, of the various kinds of salt-affected soils, besides those deteriorated by low-quality tubewell water, only two kinds occur in the cultivated land and are, therefore, of primary practical concern. These are:

(*a*) areas with topsoil salinity/sodicity occurring in patches, and
(*b*) partially reclaimed saline-sodic soils.

These soils occupy about 2.9 million acres, making up about nine per cent of the CCA and about 38 per cent of total saline land in CCA, as shown by data in table 3.

The uncultivated salt-affected areas of some practical significance include porous saline-sodic soils and saline gypsiferous soils, both occurring over 3.5 million acres.

The agencies dealing with the so-called control and reclamation of salinity have been presenting a very dismal state of agricultural land afflicted with salinity and water-logging. They have formulated and implemented projects on the plea of reclaiming all kinds of salt-affected land within the geographic limits of the canal commands. But, in effect, the projects could bring about some improvement in the above-cited soils only, the other saline areas were mostly excluded from CCA at the time of colonisation (Wace, 1934) and up-till now, even in SCARPS, they have no water allocations. It would be an intriguing exercise to include these 'uncommanded' areas in project feasibility studies.

Secondary salinity of really great concern is the sodicity induced in good soils on an extensive scale by low-quality pumped ground-water. This type of salinity is a disaster that may quickly beset a large proporion of good, productive land, thereby degrading an irreplacable natural resource. It is a strange antithesis that the steps taken in the name of eradication of salinity are creating a kind of salinity that is both extensive and highly detrimental to crop production. In view of the necessity of continuing the use of such waters due to the shortage of canal supplies, some corrective measures have to be adopted without further loss of time.

Waterlogging.—In only about 0.72 million acres of non-saline cultivated land is the water table within six feet from the surface (Rafiq, 1975). In about one half of this area, rice is the main crop and, therefore, the high water table does not really affect crop production. However, the other half, which is used for dryland cropping, has to be reckoned with for provision of drainage. Another independent survey (Hussain, 1970) supports our finding that the areas affected by high water table are very small in extent.

Vast extent of high-potential, non-saline agricultural land: Basic soil surveys conducted throughout the country have revealed that about 75 per cent of the canal commanded area is free from salinity or waterlogging (table 4), and virtually whole of it is under cultivation. By far most of this land has very high potential for crop production. It has no inherent soil limitation that could limit the crop yields. But, unfortunately, this vast resource is being used far below its potential. In every village, the crop yields obtained

TABLE 3

Extent of saline land in canal commanded areas

000 acres

Province	CCA	Cultivated saline land				Uncultivated saline land				Total saline land	
		Class II	Class III	Class IV	Total	Class III*	Class VII	Class VIII	Total	Acreage	Percent
N.W.F.P.	791.0	5.9	4.1	—	10.0	23.0	0.8	—	23.8	33.8	4.3
Punjab	19,489.8	1,148.0	311.3	105.0	1,564.3	1,764.1	488.8	170.5	2,423.4	3,987.7	20.4
Sind**	13,217.0	826.0	306.9	252.3	1,385.2	1,739.6	381.8	277.2	2,398.6	3,783.8	28.6
Total	33,497.8	1,979.9	622.3	357.3	2,959.5	3,526.7	871.4	447.7	4,845.8	7,805.3	23.3
Percent of CCA		5.9	1.9	1.1	8.9	10.5	2.6	1.3	14.4		

*Potential Class III land, occurring either in fresh ground water zones or in areas where canal water is available for this land. At present, this land is not under cultivation and is Class VII or VIII land.

**Including Pat Feeder Canal in Baluchistan from the non-saline land by different farmers vary by two or even three times due to variations in the farming standards. This shows clearly that the development gap lies in the utilization of good soils; a breakthrough in agriculture cannot be made without filling this gap. The foremost need, therefore, is to improve the general standard of farming.

TABLE 4

Extent of different kinds of land in CCA

000 acres

Province	CCA	Non-saline					Saline
		Class I	Class II	Class III	Class V	Total	
N.W.F.P.	791	196	470	36	—	702	34
Punjab	19,489	7,411	5,992	503	749	14,655	3,987
Sind	13,217	2,662	5,939	755	77	9,433	3,784
Total:	33,497	10,269	12,401	1,294	826	24,790	7,805

Note: The difference in the sum of the areas of non-saline plus saline land and CCA is largely due to inclusions of non-saline, very sandy soils, as, for example, in Thal canal command.

Economics of water use: Some studies about the economics of water use in the Indus plains (e.g. Ashraf, Brinkman and Rafiq, 1972 and Rafiq, Alim and Brinkman, 1968) have repeatedly shown that net financial returns per unit of water used on different kinds of land range from a negative figure to several hundred rupees simply owing to diffeıences in the quality of the soil. The returns are alarmingly low from reclamation and use of strongly saline and saline-sodic soils. For instance, net rerurns per acre-foot of water used in main semiarid part of the country, according to 1970 prices, are in the order of minus Rs. 12 on dense saline-sodic soils, Rs. 110 on porous saline-sodic soils, Rs. 185 on soils with topsoil salinity only and Rs. 235 on salt-free, flawless agricultural land, all in kharif under an assumed uniform cropping intensity and standard of farming. Similar comparative figures for the rabi season and for other climatic regions are given in Ashraf et al (1972).

From the returns per unit of water it is clear that with modern management irrigation water costing upto about Rs. 50 per acre-foot in kharif and Rs. 120 per acre-foot in rabi (under the comparable, 1970 costs) can be economically used on class I and II land, and would give generally marginal returns on class III land. On class IV land, i.e., dense saline-sodic soils, its use would be definitely uneconomic. Only the use of current canal supplies, costing next to nothing,* would be economic or marginal on class IV land, but it must be noted that all these supplies are already committed to better land.

*Only the maintenance costs of the canal system; the capital costs have been recovered since long.

In our country, of the two basic resources, water and not the land is the limiting factor for agricultural development. Therefore, we should measure agricultural production per unit of water rather than per unit of land, and all efforts should be made to make the best use of this scarce resource. This can be done by intensifying cropping on the already cultivated land rather than by extending irrigation to salt-affected, uncultivated land. The farmers, but unfortunately not the planners, have all along been following this line of approach as shown by past records. For instance, soon after the introduction of canal irrigation, experiments with temporary leases of salt affected land showed that 'the lessee tended to concentrate on the better portion of his leased land and to pay little attention to the improvement of weaker acres' (Wace, 1934).

Suggested Approach for Improvement of Salt-affected and Waterlogged Areas. *Development Priorities:* From the above discussion emanate the following development priorities that should be pursued in future:

First, improvement of standard of farming; corrective measures to offset and prevent soil deterioration resulting from the use of low-quality tubewell water; and reclamation of salinity occurring in patches within the cultivated fields.

Second, increase in water supply to achieve a cropping intensity of at least 150 per cent on already cultivated, good agricultural land.

Third, wherever water is available in excess of the needs of better land, e.g., in fresh ground-water regions and in Indus delta, extension of cultivation to Class III land comprising porous saline-sodic soils and porous saline soils containing gypsum.

Reclamation of Class IV land comprising dense saline-sodic soils should have a very low priority and may be deffered for a few decades.

About 2.9 million acres of the salt-affected area is presently under irrigated agriculture. In this area salinity/sodicity occurs mostly in patches which cover about 20 per cent of the area of fields. These patches need to be reclaimed on a high priority basis, as the salinity/sodicity is an important limiting factor affecting production from this land. In a high proportion of this area sodicity, rather than salinity, is the grave problem. The available experience shows that provision of additional amounts of water alone is not sufficient for complete reclamation of these soils. So the practice of providing only additional water for reclamation is wasteful of precious irrigation water. Proper amelioration of these soils can be effected quickly and economically by using gypsum. In most cases, the salinity is so low that only a little leaching is needed and the soil would improve dramatically by application of gypsum.

In order to overcome the sodicity resulting from low-quality tubewell water, it is extremely necessary to mobilize all resources to make gypsum available to the farmer at a reasonable price. This would, however, not be possible if left to itself. Therefore, the Government would have to step in and subsidise gypsum for use in agriculture. The problem however, is so big and the gypsum requirement so high that the needed capital cannot be made available unless the SCARP programmes are cut by limiting the development of ground-water entirely to the private sector. As a matter of fact, at present about three fourth of the pumped ground-water for irrigation is obtained from private tubewells, indicating that the private sector is fully capable of taking care of the rest.

Drainage measures: The present concept of considering the soils waterlogged if the water table is within ten feet from the surface is baseless. The production of most crops is not at all affected by water table below about six feet depth If ten feet depth is taken as the limit for waterlogging, the entire Nile delta in Egypt would be severely waterlogged, and one would wonder how a flourishing agriculture is sustained by it.

There are very small areas, not more than one million acres, in the Indus plains where crop yields are affected by high water table. Of this, only a small proportion is affected severely. Such areas need to be identified carefully and improved by site-specific remedies. While fixing the safe depth of water table, the envisaged cropping patterns must be kept in view. For instance, the drainage needs of rice areas are quite different from those of dry-land crop regions. Similarly, the drainage problems of rhe Peshawar vale, D.G. Khan plains or Indus delta are not alike. Even within each of these tracts, there are local variations calling for different treatments.

Although tubewells have lowered the water table in fresh ground-water zones, yet there are excessively wet areas which can be improved only by open drains. The present storm water drains are far from adequate even in SCARPS. In order to be really effective, the drainage network has to be a mirror image of the irrigation system. The existing drains are at best comparable to distributaries in the irrigation system; the drainage counterparts of watercourses and field ditches are simply not there. The public sector should cater to provide and maintain drains upto the level comparable to Government watercourses. The provision and maintenance of field drains should be a responsibility of the farmer. Unless the missing feeder drains are constructed, the farmer in most of the waterlogged areas cannot link his fields to the drain. The existing drains are in a miserable state, not being maintained in a proper way. They should be maintained as meticulously as the irrigation system.

For improving the waterlogged areas in saline ground-water zones research is needed to find out the most suitable drainage system. Various systems should first be tried in pilot projects before extending any to large areas. Tile drainage, if at all desired, should yet be tested in a small experimental area only. It works efficiently only in very high water table areas having high irrigation intensity. At the same time, being an expensive device, it can be justified only if very high crop yields of high value crops are obtained. Under the prevailing standard of farming the economics of installing tile drainage in any area are doubtful.

Installation of drainage without proper site investigations is examplified by the Gaja Pilot Tile Drainage Project in which tile drains were installed in two sections. Later on the Dutch experts found out that this kind of drainage was not useful in this area because of the generally deep water table conditions and the low envisaged irrigation intensity (IDFC, 1976). It is feared that the same mistake may be repeated in other areas, e.g., in East Khairpur Tile Drainage Project.

Guidance to the farmer: The chances of success in programmes entailing reclamation of salt-affected land would be feeble as long as it is taken up in public projects planned and implemented by Government agencies. It is the farmer himself who could undertake reclamation provided: (i) he has spare water and labour after fulfilling the needs of non-saline land, and (ii) he is not a tenant but cultivates his own land.

Combination of these conditions is not common in our country where irrigation water is generally in short supply and 34 per cent of the farms are tenant farms besides 24 per cent reported as owner-cum-tenant farms (GOP, 1972).

The farmers who are in a position to venture reclamation of hitherto uncultivated, salt-affected land need to be guided as to:

(*i*) which area of their farms should be taken up first so as to start with the relatively better soils on priority basis, and

(*ii*) what are the most economic reclamation techniques.

Education of the farmer in both these fields is a big job. Various kinds of soils occur close to one another in a complex pattern and the farmer must be apprised of the differences in soils and their predicted behaviour under different reclamation methods. This objective can be realized by detailed soil surveys but, since these are time-consuming, quick guidance to the farmer should be provided by agriculture extension personnel some of whom should be made specialists in identification and categorisation of salinity and in recommendations on various types of salt-affected soils.

The agriculture extension service, however, cannot be made really effective unless:

(*i*) organisational structure of the service is improved,

(*ii*) agricultural research effort is increased considerably, so as to commensurate with the number and mangnitude of problems to be tackled with, and

(*iii*) there is a close co-ordination (feed-back and feed-forward relationship) between agricultural research and agriculture extension services.

The co-ordination between the reclamation experiments and agriculture extension service is hard to achieve as long as the Land Reclamation Directorates are parts of the Irrigation Departments and not those of agricultural research institutes.

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Annexe

ESTIMATES OF EXTENT OF SALT-AFFECTED AND WATERLOGGED SOILS BY VARIOUS AGENCIES

(I) *Land Reclamation Directorate Lahore*

Year	Total area surveyed (million acres)	Salt-affected area Million acres	Salt-affected area Per cent	Waterlogged area Thousand acres	Waterlogged area Per cent
		PUNJAB			
1944-45	11.99	2.03	17.1	23	0.19
1946-47	11.95	2.26	18.9	16	0.13
1948-49	12.00	2.19	18.2	15	0.12
1950-51	12.69	2.34	18.5	12	0.09
1952-53	13.05	2.46	18.9	7	0.05
1954-55	13.47	2.92	21.7[1]	7	0.05
1956-57	15.27	3.06	20.1	29	0.19
1958-59	15.62	3.05	19.5	41	0.26
1959-60	16.78	2.98	17.8[2]	43	0.26
		PAKISTAN			
1961-62	34.69[3]	5.27	15.2	84	0.24
1962-63	37.69[4]	5.61	14.9	196	0.52
1964-65	36.97	5.44	14.7	249	0.67
1966-67	37.47	5.47	14.9	197	0.57
1967-68	38.06	5.47	14.3	209	0.55

*Source: Hussain (1970).

(1) Due to addition of 0.41 and 0.23 million acres of Muzaffargarh and Punjnad Canal Division with 67% and 35% area affected by salinity respectively.

(2) Due to addition of Leiah, Kala Bagh and Khushab Canal Divisions with total areas as 0.68, 0.2 and 0.55 million acres with thur percentage of about 0.1, 0.6 and nil respectively.

(3) Inclusion of 39 Canal Divisions of N.W.F.P., Bahawalpur and Sind.

(4) Inclusion of 5 additional Canal Divisions.

Annexe

(II) *Colombo Plan Report*

REGION	Mapped as predominantly poorly drained or waterlogged		Mapped as predominantly severely saline		Area in which saline patches are common*	
	Sq. miles	Per cent of region affected	Sq. miles	Per cent of region affected	Sq. miles	Per cent of region affected
	1	2	3	4	5	6
Peshawar Vale	251	11.5	—	—	113	5.0
Bannu Basin	—	—	—	—	—	—
Sulaiman Piedmont	571	7.5	—	—	111	1.5
Kachhi Plain	163	2.5	127	2.0	—	—
Kirthar Piedmont	140	11.5	12	1.0	—	—
Karachi Plain	—	—	12	1.5	—	—
Potwar Uplands	—	—	—	—	—	—
Salt Range and Salt Range Piedmont	—	—	109	2.5	—	—
Himalayan Piedmont	—	—	—	—	—	—
Sind Sagar Doab	803	8.0	290	3.0	701	7.0
Chaj Doab	1,010	23.0	272	6.0	889	20.0
Rechna Doab	4,232	35.5	1,770	15.0	3,598	30.5
Bari Doab	55	0.5	164	1.5	920	7.0
Bahawalpur Plain	779	13.0		—	244	4.0
Indus Flood Plain	—	—	62	1.0	40	0.5
Indus Corridor	81	1.5	154	3.0	2,942	62.0
Upper Sind Plain	5,137	98.0	1,691	32.5	3,385	64.5
Central Sind Plain	1,609	14.0	343	3.0	2,991	25.5
Lower Sind Plain	2,890	93.5	1,548	50.0	1,342	43.5
Indus Delta	1,062	27.0	1,298	33.0	416	10.5
Indus Plains	18,783 (12.02 M. acres)	17.0	7,852 (5.02 M. acres)	7.0	17,692 (11.3 M. acres)	16.0

*Does not include areas tabulated in column "Mapped as Predominantly Severely Saline".

Source: Colombo Plan, 1958

Notes: (*i*) **Soil salinity.** The land with salt efflorescence covering more than half of the area has been mapped as predominantly severely saline (column 3). If about 60 per cent of this land is assumed to be salt-affected, the extent of saline land in this unit comes to about 3 million acres (A). The figures in column 5 denote areas of salinity patches covering less than half of the tracts. If it is assumed that the patches make up about 40 per cent of these tracts, the area of saline land in this unit would be 4.5 million acres (B). The sum of A and B, i.e., total saline area, is 7.5 *million areas.*

(*ii*) **Waterlogging.** Marshes with standing water and lands having wet surface have been mapped as waterlogged. Since it is hard to differentiate between the 'wet' soils and the clayey soils used for rice the latter have been wrongly mapped as waterlogged. This explains as to why 98% of the Indus right bank or 35% of Rachna Doab has been reported as waterlogged.

Annexe

(III) *Lower Indus Project**

Command	Percentage of gross area: Nonavailable	Moderately salt affected	Severely salt affected	Unclassified (seasonal swamp)
Gudu				
Desert Pat Feeder	5	29	66	
Begari-Sind Feeder	6	54	40	—
Ghotki Feeder	15	53	32	—
Sukkur				
North-west Canal	4	40	45	1
Rice Canal	4	70	21	5
Dadu Canal	1	51	47	1
Khairpur Feeder West	5	79	16	—
Khairpur Feeder East	30	62	8	—
Rohri Canal	7	91	2	—
Eastern Nara Canal	5	71	23	1
Ghulam Mohammad				
Kalri-Baghar Feeder	2	24	67	7
Pinyari Feeder	5	33	50	12
Fuleli Canal	3	41	49	7
Akram Wah	5	38	50	7

Notes: According to these estimate, 70 to 98 per cent of the command areas of individual canals in Sind is moderately or severely affected by salts. The supporting text, however, gives the following description of the two categories.

*Source: Hunting Technical Services Ltd. and Sir Macdonald and Partners, 1966. Lower Indus Report (Summary), WAPDA.

"The first category covers all soils where the average electrical conductivity (saturation extract) both of the upper soil (0-150 cm) and of the substratum (150-450 cm) is less than 16 millimhos per cm. Clearly this is a very broad category, covering entirely non-saline soils and those on which crop growth is seriously affected. It embraces the majority of soils now in use, and which with drainage and proper watering will improve, and it indicates the unused land where irrigation will be immediately practicable without leaching programmes.

The Severely Salt Affected land includes all greater degrees of salinity, and again is a very broad category. It includes soils classified as ultra saline, in which the electrical conductivity ranges from 40 millimhos per cm up to much greater values".

Obviously, in the above table all the non-saline, good land is included in the category 'moderately salt-affected' land and therefore, the estimates are grossly exaggerated. At the same time, the classification which groups the non-saline with the saline soils cannot be rightly termed as a classification of sa'inity and data about the first category is of no use.

Annexe

(IV) *Summary of WASID Land Classification Surveys**

Description	Thal Doab (1000 acres)	Chaj Doab (1000 acres)	Rechna Doab (1000 acres)	Bari Doab (1000 acres)	Bahawalpur Plain (1000 acres)	Total Northern Indus Plains (a) (1000 acres)	(Percent)
Soil Salinity Classification:(b)							
S_1 Non-saline	2,821.2	1,606.7	4,226.6	4,786.3	2,915.9	16,356.7	69.7
S_2 Slightly saline	397.4	511.2	905.6	1,179.2	492.8	3,486.2	14.8
S_3 Moderately saline	119.2	121.7	362.3	277.5	123.2	1,003.9	4.3
S_4 Highly saline	119.2	121.7	422.7	416.2	451.7	1,531.5	6.5
Unclassified (c)	516.6	73.0	120.8	277.5	123.2	1,111.1	4.7
Gross Area Classified	3,973.6	2,434.3	6,038.0	6,936.7	4,106.8	23,489.4	100.0

(a) Not including Right Bank Indus.

(b) Visually estimated by WASID

(c) Does not include areas surveyed that are outside existing canal systems.

Note: According to the above table, the total extent of salt-affected land in the northern Indus plains, (the Punjab excluding D.G. Khan District) is 7.1 million acres. This estimate, although based on visual observations of the salinity, is fairly close to our estimate for the Punjab which is 6.8 million acres.

*Source: Tipton and Kalmbach, 1967. Regional Plan: Northern Indus Plains, WAPDA, Lahore.