Salinity and Ground Water Conditions in the Lower Indus Plains

Sukkur - Gudu Right Bank and Khairpur—Lower Indus Project

By

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The total designed commandable cultivable area of the Lower Indus Plains is 12,200,000 acres. Supplies are drawn from three barrages, of which Gudu provides a purely seasonal (kharif) supply, Kotri is mainly seasonal while Sukkur supplies are perennial. The seasonal canals are mainly used for growing rice and we have, therefore, been studying two broadly different irrigation systems in the Lower Indus Plains and these have different drainage requirements and ground water conditions. Our studies have not included the lands irrigated by the two largest left bank Sukkur canals, and Khairpur is the only perennial area in the strict sense which we have studied. Two of the Sukkur right bank canals, the Northwest and the Dadu are indeed perennial canals, but their cropping in Kharif is completely dominated by rice, and their ground water conditions are those of rice growing areas rather than of perennial areas.

In this paper we discuss a number of aspects of the Sukkur-Gudu right bank lands, with for comparison reference to the perennial Khairpur area.

The following percentage distribution has been found for soil salinity in the combined Sukkur and Gudu right bank lands :

Salinity Class	Acres CCA	Percentage	Effect on Crop Growth.
1.	738,000	16.3	No effects.
2.	1,042,000	23.0	Noticeable effect on some crops.
3.	951,000	21.0	Serious effects on all field crops.
4.	1,237,000	27.3	Unsuitable for any crops other than dates.
5.	562,000	12.4	Unsuitable for any crops and reclamation slow and expensive.

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For practical purposes Class 1 and Class 2 are satisfactory soils, Class 3 is usable with obvious restrictions on crop growth, Class 4 requires reclamation treatment and in our view Class 5 should not be developed until the formidable problems of Class 3 and Class 4 have been solved.

It is of great interest to compare these soil resources with the presently cropped areas. The area at present cropped in the Gudu command is 607,000 acres, made up of 490,000 acres of kharif, most of which is rice, and 115,000 acres of bosi rabi; there would in addition be a small area of land irrigated from shallow wells. The dubari area is not included because it follows the rice crop and requires no extra land. Thus the present need for land may be taken as say. 650,000 cropped acres. In the right bank Sukkur commands the total kharif cropping on the two seasonal canals is 383,000 acres, and the total irrigated rabi is 374,000 cropped acres. Most of this irrigated rabi does not follow kharif crops and so a conservative estimate of the area in actual use may be taken as 760,000 acres. On the seasonal Rice canal the area of land in use is about 350,000 acres. Thus considering only present cropping 1,760,000 acres of the area are in effective use.

It will be seen that this figure is very close to the total of 1,780,000 acres of land of Class 1 and Class 2 salinity. This means that it is theoretically possible to grow all the existing crops on substantially non-saline soil assuming that all these soils could be identified and exploited. This is clearly not possible but the figures do show that the land resources are ample for the present cropping without it being necessary to use a large proportion of saline soil.

It is now of obvious interest to consider the extent to which present cropping uses the various classes of saline soils. The information is not available for the whole area but two illustrations will be given. The first comes from our survey of the Larkana-Shikarpur drainage project. This area is irrigated by inundation canals, the Rice canal and the Northwest canal has an area of 546,000 acres. The land use is divided into four classes: cropped, current fallow, abandoned, and never cultivated lands. The table below shows the land use related to soil salinity :

It is clear from Table No. 1 that the used land, *i.e.* the cropped land and the current fallows are largely concentrated on the less saline soils. We believe this is not solely the result of selection, but is in part the *consequence* of irrigation. This belief is strengthened by the results obtained during a detailed survey of part of northern Khairpur, which included dry crop perennial areas as well as heavily irrigated rice areas. The results are given in Table No. 2.

TABLE 1

Land Use in Relation to Salinity

Land Use	No. of Sites	Percentage of Sites in Salinity Class				
		1	2	3	4	5
Cropped	263	38.8	34.4	15.9	9.5	1.9
Fallow	219	42.0	33.0	18.0	6.0	1.0
Abandoned	146	6.0	15.0	13.5	35.5	30.0
Never cropped	110	6.0	12.0	13.0	25.5	43.5

TABLE 2

Land Use in Relation to Salinity

Land Use	Percentage of Sites in Salinity Class				
	1	2	3	4	5
Perennial (cropped)	30.3	34.5	22.6	10.0	2.6
Perennial (fallow)	21.2	32.7	25.5	16.3	4.4
Abandoned and never cropped.	11.5	12.5	14.5	30.3	31.2
Rice	66.6	13.4	16.6	3.4	0.0

Here the well irrigated long established rice fields are predominantly on Class 1 Salinity lands, the dry kharif cropping with cotton and sorghum and rabi wheat and oil-seeds is mainly on Class 1 and Class 2 land, while the unused land is mainly either salinity Class 4 or Class 5.

Undoubtedly this situation is partly due to conscious development of the better land, to the abandonment of lands too saline to be profitable, and to the natural process of improvement under irrigation which one would expect from the use of high quality Indus water. At the same time the figures show that about 25 per cent of the used land in Larkana-Shikarpur is of Class 3 salinity or worse, while in the perennial part of the Khairpur area the percentage must be about thirty-five. It must be noted that we have been discussing only the existing situation, the designed area of cropping in the Gudu barrage command is much greater than the present cropping, and the two perennial canals in the Sukkur right bank command are very far from irrigating the designed rabi areas. The latter situation is discussed later in this paper.

Ground water levels.

The Drainage Circle of the Irrigation Department have made observations of the ground water level for many years over a large part of the Gudu and Sukkur right bank commands. They have made similar observations in the Khairpur and in the Rohri and Nara commands. We have examined the records for the right bank and Khairpur. Regular recordings started in 1933, the year following the start of Sukkur barrage irrigation.

In Khairpur the average depth below ground level in 1933 was 16.1 feet, in 1959 it was 7.0. feet, with minor irregularities the rise have been continuous but at a steadily declining rate. Even in 1933 there were considerable differences in depths to ground water over the area. In the south they were greater than they were in the north and this is true today. The list below illustrates the rise of the ground water and also its relation to the original depth, showing that the deeper ground waters have risen more than the shallower ones over the period 1933 to 1959.

Sites (7) with depth to ground water greater than 20 feet in 1933.

Depth 1933	25.9 feet	
Depth 1959	9.5 feet	Rise 16.4 feet.

Sites (10) with depth to ground water between 13 and 20 feet in 1933.

Depth 1933	16.9 feet	
Depth 1959	7.8 feet	Rise 9.1 feet.

Sites (12) with depth to ground water less than 13 feet in 1933.

Depth 1933	9.6 feet	
Depth 1959	4.85 feet	Rise 4.8 feet.

The relation of the rise to the mean depth of the watertable is of the form which would be expected, because the nearer the water rises to the surface, the smaller becomes the canal seepage contribution and the greater becomes the abstractions by evaporation from the surface and by transpiration. It will be noticed that in Khairpur the ground water before Barrage irrigation was not at great depth, as it was in parts of the Punjab. Khairpur, with perennial irrigation has no pronounced seasonal variation in the height of the ground water. This is what would be expected from a consideration of the principal elements of the regional water balance, which shows that the excess of water additions over losses due to evaporation and transpiration is relatively constant throughout the year.

During our survey of Khairpur it was found in the late rabi to early kharif period in 1959 that over half of the total area had ground water within 6.7 feet of the surface.

Depth to Ground water	Area
0—3.3 feet	76,000 acres
3.3—5.0 ,,	55,000 ,,
5.0—6.7 ,,	208,000 ,,
Deeper than 6.7 ,,	311,000 ,,

The worst affected areas are almost entirely in northern Khairpur, and it is these areas which are covered by the Khairpur drainage project which is to be undertaken by W.A.P.D.A. in the near future.

The Drainage Circle permanent observation pipes in the Sukkur Gudu right bank areas do not cover the northern part of the Gudu area. Although the Northwest and Dadu canals are perennial the cropping over most of the area is dominated by rice culture, with the consequence that the ground water regime has large seasonal fluctuations everywhere. The table below gives the mean April depths in the Sukkur-Gudu rice areas for 1934-1960.

TABLE 3

Mean Depths to Ground Water (Sukkur-Gudu Right Bank)

Year	Depth	Year	Depth	Year	Depth
	ft.		ft.		ft.
1934	9.8	1943	7.4	1952	7.7
1935	9.4	1944	7.5	1953	7.75
1936	9.9	1945	7.6	1954	7.4
1937	9.1	1946	7.6	1955	7.1
1938	9.3	1947	7.7	1956	6.7
1939	9.4	1948	7.7	1957	6.4
1940	9.25	1949	8.1	1958	6.8
1941	8.9	1950	7.8	1959	7.3
1942	8.45	1951	7.5	1960	7.3

The figures show that over the period during which the Sukkur barrage has been effective the ground water has risen from 9.8 feet (below the surface) to 7.3 feet. There have been long periods of apparent stability and it is not possible to be sure that the rise is continuing at the present time. A second set of Drainage Circle figures is given in Table 4. These figures give an idea of the extent of the seasonal variation in ground water level.

TABLE 4

Mean Depths to Ground water. (Sukkur-Gudu)

	Depth to ground water—ft.			
Year	April	May	September	October
1934	10.4	11.0	5.4	6.5
1959	8.1	8.7	2.2	2.5

The pipes used for the results in Table 4 are not the same as those used for the first one. The high October and September figures for the water table show why the growing of cotton is now impossible in these areas. By contrast the 1934 water-tables were not high enough to stop the growing of this crop.

Apart from the differences in the seasonal fluctuations of the ground water in perennial and seasonal areas there are important differences in salinity. We do not as yet know whether Khairpur is representative of all perennial areas, but in Khairpur the ground water in its upper layers is much less saline than it is on the right bank. The average electrical conductivity of the ground water in the Sukkur-Gudu right bank areas is 15.2 mmhos/cm with only 28 per cent of the samples with E. C. less than two mmhos/cm. The Khairpur survey on the other hand give an average E. C. of 2.6 mmohs/cm for the upper ground water with 50 per cent of the samples having an E. C. of less than 2 mmhos/cm. Consequently there would in Khairpur be a possibility of re-using drainage water from shallow drains, while on the right bank this would only be possible in very restricted areas. The Khairpur soils are on the whole also considerably less saline than the right bank. The relationship of soil salinity to ground water salinity is illustrated for the Larkana-Dadu area in Table 5.

TABLE 5

The Salinty Class of the Upper Soil in Relation to the Ground water Salinity—Larkana-Dadu

E. C. ground water mmhos/cm	Upper Soil Salinity Class				
	1	2	3	4	5
	%	%	%	%	%
0—4	33.2	33.1	20.0	11.3	2.6
4—10	4.8	25.8	28.2	30.2	10.9
10—20	4.7	14.7	24.0	39.5	17.1
>20	0.6	4.2	14.7	40.7	40.0

These figures should be considered in the light of the immediate origin of the upper ground water. As we have shown above, land of low salinity is usually irrigated and the ground water is receiving regular additions of low salinity irrigation water. Lands of high salinity (salinity classes 4 and 5) are usually either un-irrigated or abandoned land, and their ground water is fed by lateral flow from irrigated land and channel seepage. Such ground water is concentrated by evaporation and transpiration and increased in salinity. Work done during the small detailed survey in northern Khairpur confirms that the distribution illustrated in Table 5 is found there as well as on the right bank.

The obvious deduction from the foregoing discussion is that much of the existing cultivation in Sukkur-Gudu right bank and Khairpur is on land which is not extremely salty and which has ground water of only moderate salinity. There is also a considerable area, mainly very saline which has very saline ground water and is not in use. Farming is in fact occupying a defensive position in an environment which is dangerously saline. If we consider only the presently used land, the present salinity situation is not very grave, and limited remedial measures would provide gradual improvement of the more saline lands now being used. Conversely, in the absence of any drainage the present situation is debarred from general improvement, and with the gradual accumulation of salt in the area the presently held position must come under increasing pressure.

The behaviour of the ground water in rice areas differs sharply from that in perennial areas. The high level in rice areas during kharif is to be expected and is not of itself undesirable for paddy. However, although rice is adapted to growth in water logged conditions, the reducing conditions associated with this are not favourable. This is true even when toxic reduction products such as hydrogen sulphide are not formed. The presence of hydrogen sulphide in the soil of this area has been demonstrated, and this substance is known to be very damaging to rice. Surface drainage of rice fields provide temporary relief from reducing conditions, and the Sind practice of Pancho with continuous flow over the fields must have a favourable effect in this respect. Although it does not require detailed water table control rice does need some degree of drainage for its best growth. The drainage is required to combat stagnant reducing conditions, and not to lower the water table. Indeed with standing water on the rice fields it would be easy to abstract too much water in a drainage system. The exact degree of drainage required for good growtn of rice is not known. There is a distinct possibility that sub-surface drainage may be made unnecessary by water control combined with short drying out periods. In Sind it is not the practice to puddle the surface of the rice fields. The reason for this may be the custom of growing a dubari rabi crop on the rice field's residual water, which might suffer from the damage puddling might do to the soil structure. It is also obviously desirable where dubari cropping is practised that soil moisture storage should be as large as possible and a measure such as puddling may reduce the end-of-season water contents. However, puddling would tend to check the rate of entry of water and to this extent, under ponded water would be equivalent to an increase in the effectiveness of natural drainage. As indicated above, the high ground water levels associated with rice growing prevent the growing of crops such as cotton which are sensitive to high ground water conditions. It is not practical to control the ground water levels at the widely different depths required by say cotton and rice within one canal command.

There are further considerations which affect the drainage of the rice lands of the Sukkur-Gudu right bank commands. The first is that the storage of drainage water and its ultimate dispesal depend on the use and regulation of storage in Manchar lake, and preliminary design and costing indicate that drainage during the rice season must be restricted to relatively small flows. If the small flows are derived from the rice fields either by surface flow or sub-surface flow, remembering the relatively non-saline ground water under rice, it is unlikely that the salinity of the drain water will be high enough to maintain a satisfactory regional salt balance. The second is that attempts to obtain limited drainage flows from rice fields with ponded water give salt removal only in the immediate vicinity of the drain.

It is of interest to consider the situation in Sukkur right bank, in relation to the possibilities of further developments with particular reference to the two perennial canals. We are particularly interested in these two canals because it is here that the original intention of the designers has most conspicuously been set aside. The designed cropping with kharif cotton as the main cash crop cannot be followed, and the winter cropping is wasteful of water. The table below shows how the cropping of the area has developed in comparison with the designed expectations.

TABLE 6

Northwest and Dadu Canals : Designed and Actual Cultivated Areas

	Rice	Dry Kharif (Acres)	Rabi (Acres)	Total
North-West Canal.				
Designed Cultivation	110,500	172,500	478,000	761,000
Average Cultivation 1954-55 to 1957-58	222,900	44,000	232,700	499,600
Actual Cultivation as present of design	202	26	48	
Dadu Canal.				
Designed Cultivation	68,200	95,500	261,400	425,000
Average Cultivation 1954-55 to 1957-58	85,300	35,200	145,400	266,000
Actual Cultivation as percent of Design	126	37	. 55	

The important points in this table are :

1. the large areas of rice which were allowed in the design.
2. the much larger areas of rice actually cultivated, particularly on the Northwest canal.
3. the failure of dry kharif cropping. This is particularly true of cotton, which never reached any considerable extent on the Northwest, but which did so in the Dadu command. This is in remarkable contrast to the left bank perennial areas, where cotton constitutes 60 per cent of the total kharif area on the Rohri.
4. Failure of irrigated rabi to reach design expectation.

We believe that the original acceptance of some 40 per cent or rice in the Kharif season was an error, which by causing high ground water conditions made large scale cotton growing impossible.

Consideration of the salinity of the commands reveals that attainment of the designed areas could only be possible with a considerable reclamation programme. Inspection of Table 6 shows that for the present areas cropped on the two canals, a minimum of 685,000 acres of land is needed, assuming that no irrigated rabi crop follows a rice crop. With the same assumption the designed cropping areas require an area of 917,000 acres. Study of the soil salinity data shows that within the two commands there is 819,000 acres of salinity classes one to three. It is, therefore, theoretically possible to grow the present areas of crops on land of only moderate salinity, but *designed* cropping acres would require the use of considerable areas of highly saline lands. This understates the seriousness of the position, for the required areas have been calculated assuming that *all* dry kharif areas are followed by irrigated rabi. Now with cotton this is not possible, and if half the dry kharif crop were cotton, the land requirement for designed cropping would go up from 917,000 acres to 1,037,000 acres. It is clear, therefore, that the development of these areas according to design would have encountered formidable problems of reclamation. These in fact were not faced and the cropped area was limited to a more practical figure.

The restriction of area was accompanied by rising pressure from the farmers for permission to grow more rice, pressure which was quite understandable from those facing salinity problems, and which was made general by the fact that rice was the traditional crop and the usual food of the people. The presence of considerable areas of permitted rice and the large purely rice growing areas of the Rice canal set an example which nearly everybody wished to follow. As the rice area increased the raising of the sub-soil water level made cotton, the only possible alternative kharif cash crop, more and more difficult to grow.

In discussing the salinity of cropped lands in comparison with unused lands, it was shown that heavily irrigated rice fields were less saline than lands under normal, non-rice perennial regimes. This is not likely to be solely the result of selection, and must be the manifestation of the fact that these soils, irrigated even with a minimum of drainage evolve in the direction of decreasing salinity. The region as a whole has negligible natural drainage, this can be shown by consideration of regional ground water slope and the transmissibility of the aquifers. Within the area, however, there is a degree of natural drainage from irrigated to unirrigated land. In the rice growing areas conditions in kharif favour the passage of ground water from the areas of ponded water to fallow and unused land, the land which accepts ground water from the rice fields is subject to salinization. This is for two reasons, the first is that with the incoming ground water it receives salt and secondly, and more importantly because later in the kharif season the ground water rises close to the surface elsewhere, and permits upward movement of the saline ground water to the surface. Now although this mechanism provides drainage which tends to keep the field actually irrigated non-saline, it also involves a period during which land that is fallow in kharif, receives salt. If such land is irrigated in winter, this summer accumulation of salt is reversed, but it will be appreciated that this is not an ideal method of using the land. This points to one of the difficulties of combining rabi irrigation with a dominant irrigated rice crop. Agriculturally and from a fertility point of view, it is undesirable to follow a rice crop by an irrigated crop, the dubari system with a leguminous rabi crop is a good rotation. As shown above land fallowed in kharif has been subject to the salinization process and it is precisely this land which is available for the rabi crop. In addition one may assume that the best land will be used in summer for the preferred rice crop so that irrigated rabi crops are forced on to the worst land. If the present kharif cropping were combined with the designed rabi cropping, assuming that all the non-rice kharif crops were followed by irrigated rabi, some 1,047,000 acres of land would be needed. This is larger than the estimated 819,000 acres of land which is free from serious salinity, so that it is evident that an attempt to expand the rabi cropping to the designed area would require extensive reclamation of heavily salinized lands.

The water supplies in rabi on the two right bank perennial canals are in excess of the design requirements for the present cropped areas. Table 6 above compares the present rabi cropped areas with the original design figures. The present rabi withdrawal by the Dadu and Northwest canals are respectively 75 per cent and 86 per cent of the authorized withdrawals and these figures are higher than the rabi cropped areas should require.

It is evident, therefore, that excess water is being applied to land which has a continuing salinity problem. This is exactly what would be expected and indeed recommended in these circumstances for salinity control. The excess supplies may well be part of the cost of maintaining the lands in production. A similar position is found in Khairpur where in the absence of installed drainage excess water is used in rabi. We consider that both there and on the right bank it would be dangerous to enforce a reduction in water duty without drainage. With drainage, however, there is every reason to advocate the use of only a sufficient excess of water over consumptive use, and a benefit of drainage in addition to the control of salinity and the ground water-level is that it becomes possible to eliminate the use of excessive supplies and to redeploy these supplies productively on new lands. Over and above the efficient use of existing supplies, it becomes possible to introduce new supplies: in Khairpur this is considered to produce the largest benefit attributable to drainage. The description of the ground water situation in Khairpur at present makes it clear that additional supplies without drainage would lend at once to a ruinous extension of water logging. Thus although we indicated earlier in this discussion that there was a present need for drainage in Khairpur, this recommendation was not very emphatic, now, considering Khairpur in the light of an expanding agriculture it becomes clear that future expansion as well as present salvation requires drainage.

It does not seem likely that the right bank lands can, in the immediate future, be supplied with adequate drainage on the rabi irrigated fields. This suggests immediately that the rabi water used there might be better used elsewhere, where less saline lands are available in a drained area or in an area where there is no drainage problem. This however, is not a decision to be taken without considerable thought since there are at present 378,000 acres of irrigated rabi lands in the two commands, and removal of these lands from cropping would in equity require a compensatory increase in kharif water supplies, which would require enlargement of the canals.