Economics of Water Use on Different Classes of Saline and Alkali Land in the Semi-arid Plains of West Pakistan

by

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INTRODUCTION

Soil salinity and alkali pose a major problem for agriculture in West Pakistan. According to one estimate [5, p. 39], out of the gross area of 46.5 million acres of the Indus Plains, 4.8 million acres were strongly saline and 11.1 million acres were partially affected by salinity. Although soil alkali was also recognized as a problem [1], it was generally considered to be of limited extent. Its full significance was realized only after studies in 1962 and 1963 by the Water and Soil Investigation Division of WAPDA and the US Salinity Laboratory in the Salinity Control and Reclamation Project No. 1 (WAPDA 1966). The soil surveys carried out by the Soil Survey Project of Pakistan have subsequently provided further information on saline and alkali soils.

The paper first deals very briefly with genesis and land capability of the various saline-alkali soils, which will be more fully reported on elsewhere. This is followed by a detailed discussion on estimated benefit-cost ratios for the private farmer investing money and water to obtain crops from different kinds of saline-alkali soils. Also, from the point of view of the national economy, we have estimated the addition to the gross national product per unit of water used on different kinds of land.

Soil Genesis and Land Capability

The stages involved in the development of saline and alkali soils are the formation of soluble salts, their accumulation (or salinization); the reaction of the sodium salts with the clay (or alkalization); and the formation of a dense subsoil if the process continues for a long enough period.

In West Pakistan, the Soil Survey Project has recognized three kinds of saline-alkali soils. Firstly, slightly saline soils with deep groundwater. These have formed by gradual salt accumulation out of irrigation water due to low

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intensity of irrigation. Although these are not as productive as the very good land in the province (class I in our Land Capability Classification), they are easy to reclaim by simple leaching. They are rated as class II (good land) under irrigation.

Secondly, saline-alkali soils with a recent high watertable. Here, the salts accumulate due to evaporation of shallow groundwater that has moved up in the soil by capillarity. In general, the high watertable has been caused by canal seepage. Reclamation of these soils involves drainage to lower the watertable and more extensive leaching. In the absence of drainage, even after leaching, salinity will recur. This continuing hazard and the higher cost of permanent reclamation place these soils in class III (moderate land) under irrigation.

Thirdly, soils with strong alkalinity to greater depth, unstable structure and dense and impervious subsoils. They have formed due to alkalization over very long periods of time. They are generally barren even in the midst of canal-irrigated land. Reclamation of these soils is very difficult, expensive and time-consuming because of the unstable and impervious subsoil. They are placed in class IV, poor (marginal) land.

The land capability classes referred to above, and their subclasses, are defined in a technical guide [9].

Examples of class I land are the soils around Okara in Sahiwal district and most of the soils of Lyallpur district. Examples of class II saline land are the scattered saline fields, both cultivated and uncultivated, along the highway from Okara to Sahiwal. Examples of class III saline-alkali land are widespread along the highway between Shahkot (Sheikhupura district) and Khurrianwala (Lyallpur district). Examples of class IV saline-alkali land are the Bara soils in Sahiwal district, and scattered uncultivated areas near Kala Shah Kaku (district Sheikhupura) and Khurrianwala in Lyallpur district.

ECONOMICS OF WATER USE

In order to estimate the economics of land and water use for crop production or reclamation on different kinds of land, we have made some simplifications and have restricted ourselves to the *kharif* season and to a small number of crops. Similar calculations could be made for other crops for the *rabi* season and for more land capability subclasses.

irl. Very Good Irrigated Land

About 85 per cent of the 3,420 square miles surveyed in the Lyallpur area consist of very good irrigated land [8]. Part of the remainder is either under *sailab* (flood-water) cropping or is barren. Moreover, the farmers tend to site their cotton on the best land. Therefore, seed-cotton yield figures from bulk data on Lyallpur district will not be far off from average farmer's yields on class irI land. The five-year average seed-cotton yield for Lyallpur district, 1960-65, is 9.4 maunds per acre [11]. At the recent average farm price of 37 rupees per maund of seed-cotton, this yield gives a gross return of 350 rupees per crop per acre. For the same years, the varietal trials at Lyallpur [4] resulted in yields of more than 19 maunds seed-cotton per acre, with reported gross returns exceeding 700 rupees both for American (two-year average) and *desi* cottons. This is more than twice the farmers' average, presumably due to better management, including seed and fertilizer and adequate irrigation water. Progressive farmers in Lyallpur district are also commonly getting 15 to 25 maunds seed-cotton per acre.

The average water duty is about 300 acres per cusec, and the *kharif* cropping intensity in Lyallpur district is about 40 per cent [11, pp.12 and 186]. Thus, if six months' supply is given, about 35 acre-inches of irrigation water are used for an acre of *kharif* crops. This figure we assume for cotton.

TABLE I

ESTIMATED COSTS AND BENEFITS TO THE TENANT FARMER PER ACRE OF SEED-COTTON GROWN ON CLASS I LAND (ALL ESTIMATES ABOUT 1965)

	Average yield	High yield
(a) Per cropped acre, with normal canal-water supply (40 per cent cropping intensity), and cash rent of 4,000 rupees per square (25 acres) per year		
land rent[1]	200	200
seed[2]	6	6
labour[3]	56	78
water rates[4]	12	12
land revenue[5]	12	12
fertilizer	—	50
total-cost listed	286	358
yield, (mds./acres)	9.4	19
gross return	350	700
benefit-cost ratio	1.2	2.0
(b) Per additional cropped acre, otherwise under current fallow, with extra water supply		
seed[2]	6	6
labour[3]	56	78
water rates[4]	35	35
land revenue[5]	12	12
fertilizer	—	50
total cost listed	109	181
yield, (mds./acres)	9.4	19
gross return	350	700
benefit-cost ratio	3.2	3.9

(Contd.)

TABLE I (*Contd.*)

ESTIMATED COSTS AND BENEFITS TO THE TENANT FARMERS

(c) Per cropped acre, as under (a) but with share cropping, yields as well as all costs except labour being shared equally

land rent	175	350
seed	3	3
labour	56	78
water rates	6	6
land revenue	6	6
fertilizer	—	25
total cost listed	246	468
yields, (mds./acres)	9.4	19
gross return	350	700
benefit-cost ratio	1.4	1.5

(d) Per additional cropped acre, otherwise under current fallow, with extra water supply as under (b), but with share cropping, yields as well as all costs except labour being shared equally

land rent	175	350
seed	3	3
labour	56	78
water rates	17.50	17.50
land revenue	6	6
fertilizer	—	50
total cost listed	257.50	504.50
yield, (mds./acres)	9.4	19
gross return	350	700
benefit-cost ratio	1.4	1.4

[1] Cash land rent 4,000 rupees per 25 gross acres per year. Take half for *kharif:* Rs. 2,000. At 40 per cent cropping intensity, this would be 200 rupees per cropped acre per *kharif* season. Included in this figure, therefore, is the rent for 1½ acres of land under current fallow for which no water is available.

[2] Seed about 8 seers per acre at Re. 0.75 per seer.

[3] Labour for 3 ploughings, sowing and 1 interculture at 5 rupees each. *Sohaga* (levelling) Rs. 3.12, irrigations at Re. 0.50 per acre (1 man-day per 6 acres). Harvest labour at 1/16 of harvest, 22 rupees per 350 rupees. If the slack period of manual and bullock labour is also taken into account, total labour cost would be about 30 rupees higher (compare [7]).

[4] Canal-water rates 12 rupees per harvested acre for cotton *Gazette of West Pakistan*, November 15, 1965 at about 35 acre-inches per acre. Rates for extra water taken as 1 rupee per acre-inch, 35 rupees per acre per season.

[5] Land revenue assumed at 12 rupees per cropped acre.

For cotton cultivation with regular canal-water supply and under cash-rent conditions, Table I(a), total costs at average yield would be about 286 rupees, resulting in a benefit-cost ratio of 1.2. At the high yield obtained in the varietal trials or by progressive farmers, costs would be about 358 rupees per acre, resulting in a benefit-cost ratio of about 2. Under share-cropping conditions, Table I(c), the benefit-cost ratios to the tenant would be 1.4 and 1.5 respectively.

If extra irrigation water is made available to a tenant or owner-cultivator under cash-rent conditions, Table I(b), the extra production costs of cotton per acre, now fallow, would be 109 rupees for average yield and 181 rupees for high yield, resulting in benefit-cost ratios between 3 and 4 in both cases. The net value to the tenant of the extra irrigation water would be about 8 rupees per acre-inch for normal yield and about 16 rupees per acre-inch for high yields obtained with fertilizers and modern management. Under share-cropping conditions, Table I(d), the benefit-cost ratio to the tenant of extending cotton cultivation with extra water is 1.4 at average and high yields. The net value of the extra water to landlord and tenant jointly, being jointly paid for by them, would again be about 8 rupees per acre-inch for average yield and 16 rupees for high yield.

For comparison, the rate of canal water is about Re. 0.35 per acre-inch[1]. The government tubewell water costs the farmer about 1 rupee per acre-inch; private electric tubewell water about 1 to 2 rupees per acre-inch, and private diesel tubewell water up to 3 rupees per acre-inch[2]. Even at the highest price quoted, extension of cotton cultivation on class I land would, thus still, be economic even for the average farmer, whether owner-cultivator or tenant.

So far we have only discussed the economics of land and water use from the point of view of the individual farmer. From the point of view of the national economy, the picture is simpler. Since there are large areas of good land under current fallow every year due to lack of irrigation water [11], the marginal social value[3] of water is the limiting factor for the contribution of the irrigated land to the gross national product. For the examples calculated above, the marginal social values are about 10 (average) to 18 rupees (modern management) per acre-inch of irrigation water, or 43,000 to 78,000 rupees per cusec for the *kharif* season (six months) under a relatively constant water supply[4].

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[1] *See* footnote 4 to Table I on page 26.

[2] Calculated from data supplied by farmers in Lyallpur, Sheikhupura, and Sahiwal districts.

[3] Marginal social value of irrigation water is the gross return per acre-inch of water minus the cost of all other inputs that could be profitably used otherwise. We have included only seed and fertilizers in these costs. We have excluded land rent since without water the land is lying under current fallow; and labour because during all of the cotton season there is still considerable un- and underemployment in most rural areas.

[4] One acre-inch is very nearly equal to one cusec-hour.

irIIa. Good Irrigated Land with a Minor Salinity Problem

Some good land, *e.g.*, in Lyallpur district, has minor salinity not associated with a high watertable, limiting the yields to some extent. In high-rainfall years the salinity decreases and yields are good, but in low-rainfall years there are spots of crop failure and in the rest of the field, yields are only moderate. An average yield depression of 20 per cent has been assumed for the following calculations.

Under the same assumptions as in the case of class I land, the benefit-cost ratio of cotton cultivation to an average farmer on irIIa land would be about 1 for a cash-rent tenant or owner-cultivator and the value of *kharif* water used on this land about 6 rupees per acre-inch.

About 5 inches of extra rainfall eliminate the minor soil salinity for a year. Calculating conservatively, 5 acre-inches of extra irrigation water per acre would add 70 rupees to the value of the cotton crop. Extra costs due to the increased harvest are about 4.5 rupees and extra irrigation labour costs less than one rupee, so the net return is about 64 rupees. Thus, the value to the farmer of extra water added for reclamation of irIIa land is about 13 rupees per acre-inch. Even at the highest water rate mentioned above, 3 rupees per acre-inch, the benefit-cost ratio to the farmer of eliminating salinity, would be more than 4.

From the viewpoint of the national economy, the marginal social value of water used in eliminating salinity from irIIa land would be about 14 rupees per acre-inch. In the case of regular cotton cultivation, with 5 inches extra water provided every year to maintain non-saline conditions and keep yields at the level of class I land, the marginal social value of *kharif* irrigation water would be more than 8 rupees per acre-inch under traditional and 16 rupees under modern management. About 3 to 5 years, with an extra 5 inches of water annually or alternatively an extra supply of 10 to 20 inches in one year, are expected to leach the salts to great depth, beyond the zone of capillary return, and make the land class I.

irIVa. Poor (Marginal) Irrigated Land with Severe Alkali and Structure Problems

Without reclamation most of the irIVa land (saline-alkali with a dense structure and low permeability) is barren. A small part produces cotton yields of 0.5 to 2 mds./acre or the crop fails altogether, as observed during the current soil surveys. Similar low returns are obtained with other crops (*see* [3] for detailed data). Such yields are manifestly uneconomic to the farmer. The marginal social value of *kharif* irrigation water under these conditions at present prices would be about nil to 2 rupees per acre-inch. This is clearly uneconomic for the nation in view of the large percentage of good land under current fallow every *kharif* season, where extra *kharif* water, would add 8 to 18 rupees per acre-inch to the gross national product.

As an example of reclamation of poor (marginal) saline-alkali land we have recalculated the data given by Asghar and Hafeez Khan [2]. The authors calculated the actual cost and income during the reclamation period from the point of view of the individual farmer. These data are summarized below, adjusted to 1953 at different rates of interest, and considered both from the point of view of the individual farmer and from the aspect of marginal social value of water used.

The land was reclaimed under "half resumable reclamation conditions", *i.e.*, at the time when the land is "declared reclaimed" the operator may buy half the land very cheaply and the government resumes the other half. From the economic viewpoint of the private farmer, reclaiming land from 1947 to 1952 and buying half in 1953 should be compared with the alternative of buying other land in 1953. Therefore, in Table II, all expenditure and income have been adjusted to 1953, interest-free, and at 6 and 9 per cent interest[5].

TABLE II

DEVELOPMENT COSTS OF BARA LAND*

Year	Total expenditure	Adjusted to 1953		Income	Adjusted to 1953	
		at 6%	at 9%		at 6%	at 9%
1947	7,146	10,150	12,000	166	235	280
1948	5,024	6,740	7,740	490	520	600
1949	3,585	4,500	5,050	815	1,030	1,140
1950	3,534	4,200	4,580	1,324	1,580	1,720
1951	4,719	5,300	5,620	1,824	2,050	2,170
1952	5,768	6,100	6,280	5,756	6,100	6,270
1953	5,268	5,270	5,270			
Total	35,044	42,260	46,540	10,275	11,515	12,180
Net cost 35 acres	24,769	30,745	34,360			
Net cost per acre	708	880	980			

* 1947-1952 figures apply to 70 acres. 1953 figures are the price for 35 acres bought from government. The other 35 acres revert to government. All figures are in rupees.

[5]Agricultural Development Bank long-term loans are given at 6 per cent, and the interest rate of a local cooperative credit society in the area [3] was about 9 per cent in 1959.

Asghar and Hafeez Khan [2] quote a price of 1000 to 1200 rupees for an acre of good land in the neighbourhood at the same time. Therefore, the price to the farmer of an acre of Bara land "declared reclaimed" is 70 to 90 per cent of the price of good land, depending on the interest rate assumed.

In 1952, the year in which the land was "declared reclaimed", with normal plus reclamation supplies, the reclaimed Bara land produced 82 rupees per acre. Without reclamation supplies in the following years, the *rabi* production might be equal and the *kharif* production about half of the 1952 figure. As a rough estimate, the total production per acre might be three-quarters of the 1952 figure, or about 62 rupees.

For comparison, we calculated from [11] that the 1954-55 seed-cotton yield in Lyallpur district was 6.7 maunds/acre, and the wheat yield 13.2 maunds/acre. At 1954 prices of about 28 rupees per maund seed-cotton and 12.50 rupees per maund wheat, these crops would give a gross return per cropped acre of 190 and 165 rupees respectively. In order to have a sound basis of comparison with the data of Asghar and Hafeez Khan [2], we assume an average 10-acre farm on class I land, having 40 per cent irrigation intensity in *kharif* and 60 per cent in *rabi*, including one acre under fodder in each season[6]. The annual production on such a farm, excluding fodders, could be 3 acres of cotton and 5 acres of wheat, giving a gross return of about 1,400 rupees per year, or 140 rupees per gross acre per year at 1954-55 prices. This fits well with data given at the 1964 Seminar [*see* 5, p. 27] that the average productivity in all canal-irrigated districts of the former Punjab was about 140 rupees per acre per year for 1949-59.

Thus, even after 6 years of reclamation, Bara land would produce less than 50 per cent of good or average land (*i.e.*, 62 rupees vs. 140 rupees per acre per year), although its cost would be about 80 per cent of that of good land. The reclamation operation has been considerably less economic than outright purchase of good land at prevailing prices. Converting to 1965 prices and costs, this would mean benefit-cost ratios for crop production in the *kharif* season of the order of 0.7 to 0.8 (in other words, a very low productivity of labour) for the average farmer, and about 1.2 for a farmer practising modern management (cash-rent tenants or owner-cultivators). These figures should be compared with benefit-cost ratios between 3 and 4 for extension of cotton cultivation on class irI land now under current fallow.

From the viewpoint of the national economy, we now calculate the marginal social value of the *kharif* water used for reclamation of the Bara land discussed above. We assume that half of the annual production is obtained in *kharif*, half in *rabi*. During reclamation, an extra supply of 1 cusec per 45

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6 For three draught animals and one milch buffalo.

acres is available for 5 months in *kharif*, equivalent to about 80 acre-inches per acre. This is in addition to the regular supply of 1 cusec per 300 acres for the whole year which, if divided equally over *kharif* and *rabi* seasons, is equivalent to 14 inches in each season. The total *kharif* supply during reclamation is, therefore, about 94 acre-inches per acre. The expenditure in *kharif* water and annual *kharif* production per acre are listed in Table III, recalculated from [2]. We assume that of the other inputs, only the seed would be economically used otherwise.

TABLE III

PRODUCTION AND WATER USE DURING RECLAMATION OF BARA LAND

Year	Acre-inches of *kharif* water	Cost of seed (approx.) (Rs. per acre)	Gross *kharif* production of reclamation crops (Rs. per acre)
1947	94	3	1.20
1948	94	3	2.80
1949	94	4	5.80
1950	94	3	8.80
1951	94	3	13
1952	94	5	41
Total :	564	21	72.60

The marginal social value of the *Kharif* water used is, therefore, about Re. 0.10 per acre-inch for the reclamation operation at 1952 prices. Even if prices have doubled since then, at present prices, the marginal social value of *kharif* water would be about Re. 0.20 per acre-inch, or about 900 rupees per cusec for the *kharif* season. This figure should be compared with 43,000 to 78,000 rupees for the alternative use of this water to extend cotton cultivation on very good, and good land.

We have examined further the development of the land "declared reclaimed" in 1952, and in 1967 found it non-alkali (*chemically* reclaimed) down to about 36 inches, below which depth the soil was still strongly alkali. The porosity is still poor however, so the soil is not *physically* reclaimed even after these 20 years. The farmer, who is now using the land with modern management, is obtaining about 70 per cent of the yields which an equally good farmer of the same village is getting on very good land.

irIIIa. Moderate Irrigated Land with Salinity-Alkali Problems

We have not had an opportunity to calculate the economics of water use for an example of this land. After lowering of the watertable, an estimated two to three years of intensive reclamation efforts using gypsum, if available, with fertilizer applications and rice cultivation, at the cost of a total 150 inches of *kharif* water (50 inches per season), should change this land into class irII land, with paddy yields during reclamation of about 10 mds./acre. At a price of 15 rupees per maund this would give a gross return of about 150 rupees per season. We assume that of the other inputs, seed (6 rupees), gypsum (1 ton at 70 rupees) and fertilizers (50 rupees), could be economically used otherwise. Then the marginal social value of the irrigation water would be about Re. 0.50 per acre-inch.

Comparison of Production Efficiencies of Kharif Water

In Table IV, we have listed the marginal social values of *kharif* water used for different purposes and the estimated amount of water required for reclamation of different kinds of land, *i.e.*, for the improvement of each kind of land by one class. These improvements are not additive since, for example, improvement of irIVa land over a period of 20 years brings it into class irIIs, not irIIa. Different measures are needed to improve irIIa or irIIs land to irI land.

TABLE IV

EFFECTIVENESS OF KHARIF WATER USED FOR DIFFERENT PURPOSES

Land capability subclass	Marginal social value of *kharif* water used, Rs./acre-inch		*kharif* water needed for improvement to next higher class, acre-inch/acre
	for cultivation	for improvement to next higher class	
irI	10 (average) to 18 (modern management)	—	—
irIIa ..	8	about 14	10 to 20
irIIIa ..	not calculated	0.50 (estimate)	150 (estimate)
irIVa ..	0 to 2	0.20	560

SUMMARY

To summarize: although soil salinity has long been recognized as a major agricultural problem in West Pakistan, the importance of soil alkalinity as a major problem in addition to, and distinct from, salinity in West Pakistan has only been fully appreciated within the last few years. The paper compared the economics of water use for production and reclamation on different saline-alkali soils and on very good soils that are under current fallow. It was found that reclamation of poor saline-alkali land for agriculture is uneconomic or marginal for a private person, even at concessional irrigation water rates. On the other hand, it is very economic to use additional irrigation water, even at high rates, to raise irrigation intensity on very good and good lands now lying tion as current fallow for want of water.

It is further estimated that one cusec of irrigation water during the *kharif* (summer) season adds 43,000 to 78,000 rupees to the gross national product if used to raise irrigation intensity on very good and good lands under current fallow because of insufficient water; and that the same amount of irrigation water adds about 900 rupees to the gross national product, if used for reclama- of poor saline-alkali land.

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