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Scientific Land and Water Use for Increased Production in West Pakistan

By

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The availability of adequate resources and their proper use to meet the food and fibre requirements of a nation is essential for its existence and progressive development. This fact is particularly true for a country like Pakistan which is still in the process of its active and accelerated development. The experience, gained in the recent past after the conflict of September, 1965, warrants strong measures to be taken to expeditiously increase the agricultural production. Dependence merely on agricultural surpluses of the advanced countries is not safe for many reasons. This fact is now well realized and a serious consideration is given by scientists and administrators for a balanced planning for the development of the national economy. Efforts are being made for accurate determination of the basic resources and the maximum production potential; a prerequisite for building a stable and sound plan of action. West Pakistan has a major physical asset of having a flat and fertile Indus Plain and the great rivers that water it. The exploitation of water and land resources, preparation and implementation of the programmes with scientific understanding will help to achieve food self-sufficiency permanently.

Present use and future water needs

The Indus river and its principal tributaries, the Kabul, Jhelum, Chenab, Ravi and Sutlej have an average annual in flow of 164.5 maf. The flow of the western rivers, *i.e.*, the Indus, the Jhelum and the Chenab which according to the water treaty with India would be available for use in West Pakistan is 135 maf. Out of this total, 83 maf. are now in use and 24 maf. will be used to feed the canals and replace the water which is being withdrawn by India. After taking into account the losses, the water that will flow to sea will be 29 maf. compared to 60—70 maf. going to the sea previously.

Diversions of the river flow for irrigation use as stated above now average 83 maf; about 52 maf. in high flow season and—31 maf. in low flow season. The amount of diversion during high flow is generally limited by the operating capacity of the canal systems and in the low flow season by the

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available water supply. Present aggregate operating capacity of the 43 principal canal systems is 2,48,650 cusecs and the total length measures 38,000 miles. Construction of 390 miles of link canals is in progress.

The existing canals are almost unlined. As a consequence the conveyance losses amount to about 35 percent from headworks to the farms. The net farm deliveries at the outlet heads are therefore of the order of 54 maf. After taking into consideration further surface and percolation losses in the farm watercourses the net crop use is estimated to be 41 maf. Farm deliveries of surface water in the northern zone are estimated to average 2.2 acre feet per cropped acre during Kharif (May to September) and 1.6 acre feet per acre during October to April, compared to the optimum requirements of 2.7 and 2.4 acre feet in the respective seasons. So in the Indus Plain the lands are generally under-irrigated. To make up the present water deficiencies and to meet future requirements, a substantial development programme for exploitation of surface and ground water sources is already pursued vigorously. It is estimated that about 26 maf. of farm deliveries will be needed by 1975, over and above the present farm deliveries of 54 maf. To develop 26 maf. of waters it has been suggested to tap surface resources for 4 maf. and ground water resources for 22 maf. of water.

2. Land area and present land use

Out of the total area of 199 million acres the land unsuitable for agriculture and forestry is 126 million acres, the balance area of 73 million acres is regarded as suitable for agriculture and forestry. The area under command of canal irrigation is 33.5 million acres of which 20.3 million acres are designated for perennial irrigation and 13.2 million acres for non-perennial irrigation. Actually 25 million acres currently receive surface water supplies, the balance of 8.5 million acres is classified as culturable commanded waste.

The other cultivated area consists of 1.6 millions acres irrigated from streams, wells and tanks; 2.9 million acres is a riverain land while 8.0 million acres are rain-fed. The area under forest is 3.0 million acres. Thus the culturable waste that would be available for agricultural development is 24.0 million acres.

3. Land capability potentials of different physio-graphic division of soils of West Pakistan and scope for the exploitation

The soils of West Pakistan provide a satisfactory medium for plant growth, and do not impose any serious constraint. Majority of soils have favourable texture and have high potential productivity. The five main physiographic divisions into which the soils of West Pakistan as irrigation facilities are available can be divided are briefly described as below:—

The first one, and the westernmost, lies along the base of the Kirthar, Sulaiman and other ranges of the western mountains. This is one of the most desolate tracts, with strips of cultivation dependent on unreliable rainfall. This zone has strong potentialities for development as it has lot of cultivable land of high inherent fertility and no drainage problem.

The second major division occupies the basin between the Salt Range and the Himalayan foot-hills. It has been subjected to geological erosion on a grand scale. The land-use pattern shows an equally complex mixture of dry crop land, poor grazing lands and wild-gullied waste lands. There is not much potential for agricultural development. It is regarded as one of the least promising portions of the province, mainly due to rough and eroded terrain and shallow soils.

The third division comprises the small pediment plain deposited by torrents flowing from the Himalayan foot-hills. The greater part of this zone is fertile having well drained soils. It is most suited to dry farming, due to a high and reliable rainfall.

The fourth division is the Thal tract, which occupies most of the interfluve between the Indus River and the Jhelum-Chenab system. In this zone great changes have been brought with the introduction of canal irrigation. High water-table condition and spread of salinity at a rapid rate has created a serious problem for the developing agricultural economy.

The fifth physiographical division comprises the scalloped interfluve of Punjab, the level plains of recent river-laid alluvium in Punjab and Sind and small isolated out crops of similar alluvium near Peshawar and Bannu.

The soils of the Indus Plain are alluvial composed of material transported from its place of weathering and deposited elsewhere. The accumulation of soil materials results mainly from sedimentation by river. In the absence of adverse reactions due to salinity or alkalinity the soils have a good water-holding capacity, they have a reasonable permeability and infiltration rate. The soil texture tends to vary from loam to silty clay. Heavier textured soils are more common in Sind than in the Punjab. The soils on the whole, although low in organic matter, are productive if managed as required under the improved agricultural and complementary practices.

4. Present obstacles to increased intensification of cropping

The agriculture of West Pakistan mostly depends on the irrigation. The average annual rainfall is 3 to 15 inches except in the north-east near the foot-hills. According to the precipitation data 66.7% of the whole area of West Pakistan receives rainfall below 10″, 24.2% between 10 inches to 20 inches; 5.4% between 20 to 30 inches, and only 3.7% more than 30 inches annually. If rainfall had been the only source of water 96% of the total area of this province would be barren or sparsely vegetated.

Indus Plain is well suited to irrigated agriculture but a shortage of surface water supplies for the total culturable area commanded by the canal system (33.5 million acres) has been an important factor inhibiting the increase in cropped acreage.

Taking both acreage and gross production value (GPV) into account the dominant crops in West Pakistan are wheat, fodder, cotton, rice and sugarcane which together contribute more than 70% of 1964-65 GPV.

Gross production value from wheat, cotton, sugar, rice is in the order of 30.4%, 16.4%, 13.4% and 11.0% respectively as shown in table below:—

Present Area and GPV of Crops (1964-65).

Food Crops	Area (Mill. acres)	Percent of cropped area	GPV (Rs. Mill.)	Percent of GPV
Wheat ..	12.71	32.5	1,635	30.4
Coarse Grains ..	3.01	7.7	205	3.8
Pulses, Oilseed ..	3.02	7.7	390	7.3
Rice ..	3.52	9.0	589	11.0
Maize ..	2.16	5.6	251	4.7
Gram ..	2.93	7.5	277	5.1
Sugarcane ..	1.21	3.1	721	13.4
Fruit, Vegetables ..	0.41	1.0	391	7.3
Others (including Tobacco) ..	0.25	0.6	34	0.6
	29.22	74.7	4,493	83.6
Non-Food Crops				
Fodder ..	6.19	15.8	..	..
Cotton ..	3.71	9.5	880	16.4
Grand Total ..	39.12	100.0	5,373	100.0

Rice and cotton are the distinguishing kharif crops and are important source of cash income to farmers. Sugarcane is another important cash crop; although the area devoted to it is smaller than the areas covered by the other two. In 1964-65 area under rice was 3.52 million acres whereas the area under cotton and sugarcane was 3.71 million acres and 1.21 million acres respectively. The area under sugarcane is about one third of the area under rice, but the gross production value from sugarcane is 13.4% as compared to 11.0% from rice. The irrigation delta for both the crops is almost the same. Sugarcane has a high demand for the perennial water-supply and as such its cultivation is restricted on perennial channels. The food crops, however, occupy 74.4% of the cropped area and the wheat alone occupied 32.5% of the cropped acreage. Wheat is the largest single crop in terms of both acreage sown and gross value.

Comparison of the growth rates made by the Planning Department for the latest period 1957-58, 1962-63 and 1964-65 with those for the earlier period, indicates that a break of some kind has been made with the past. Increases in production seem less dependent on expansion of cultivated acreage than on yield improvement. This indicates a trend towards scientific use of existing land and water resources. Increased use of commercial fertilizers also supports the assertion. The availability may be also the reason for increased fertilizer use. It is interesting to note that the geographical distribution of the largest increase in fertilizer use coincides with the areas where rapid growth in private tubewells installation took place. The additional water contributed by private tubewells was nearly 6.0 maf. versus about 2.5 maf. delivery from public tubewells during the 2nd plan period. Approximately 3 maf. were also added from improvement in surface water supplies. The number of private tubewells installed in most recent years are shown in the table below:—

Estimate of Private Tubewells in Operation.

	1963		1964		1965	
	Number	MAF.	Number	MAF.	Number	MAF.
Private Tubewells ..	17,390	3.47	23,700	4.74	26,650	4.7
Private Tubewells supported by Deptt. of Agriculture. ..	1,109	0.22	1,475	0.29	7,350[1]/	1.3
Total ..	18,499	3.69	25,175	5.03	34,000[2]/	6.0
Rate of Growth ..			36%		35%	

1. Source: Agriculture in Pakistan, USAID, Karachi, 1966.
2. Exceeds IACA estimate by about 2,000 wells allowing for recent findings of a survey in the Northern zone.

There is ample scope of immediate exploitation of water resource in private sector. Implementation of scientific irrigation and agricultural practices within the command of canal irrigated area and paying more attention to important crops like wheat, rice, cotton and sugarcane will give larger exportable surplus. According to Harza Engg. Co. net return per acre to land and family labour is Rs. 494 from sugarcane, Rs. 348 from vegetable and orchards, Rs. 241 from cotton, Rs. 132 from rice, and Rs. 103 and Rs. 61 from maize and wheat respectively. With the introduction of high-yielding wheat and maize varieties the net return per acre is likely to go much higher. This will have appreciable impact on the NGP. As such more attention should be diverted to the cultivation of crops like maize, cotton and rice in summer followed by wheat in winter. Maize can also be grown as spring crop. The plant nutrient requirements, should be met with by the adequate application of commercial fertilizers. The following rotation of cropping can be suggested for different agricultural zones:—

(*i*) Rice Zone	Rice-Berseem-Rice. Rice-Wheat-Rice Rice-Gram-Rice.
(*ii*) Dry zones (Fertile land)	Cotton (to be harvested in December and sown with wheat). Cotton-Berseem/Senji-Cotton. Cotton-Senji-Maize-Wheat-Cotton Cotton-Senji (ploughed for g.m.) Spring maize-Wheat.
(*iii*) Dry zone (Land affected by salinity)	Rice-Berseem or gram-Cotton (for mild salinity area) Green manuring with Jantar-Rice-Berseem-Gram-Rice-Wheat-Cotton (for rare patch salinity area).

5. Existing cropping pattern with the present land and water use and scope for improvement

Land is available for cultivation but it cannot be used because of lack of water. Optimum growth of plants cannot be attained unless the irrigation requirements are met. In the canal-irrigated areas the actual intensity of cropping differs from the designed intensity due to a number of reasons. The water supplies in the canals depend upon the river supplies, which vary from year to year. In years of low river supplies the full designed supply is not available in the canals. After the treaty comes into operation, it is feared that the water supply position in the West Pakistan canals may be even less satisfactory than it is at present.

Water supply conditions also vary in different reaches of canals and distributaries. The distributaries and outlets in the head reaches are over drawn while those in the tail reaches suffer.

The tendency of the cultivator is generally to crop maximum possible area with the available water. If, however, there is scarcity of water at the sowing pariod than the area sown is reduced although the water supply con-itions may improve later during the growing period. Similarly, if the water supply is inadequate near the maturity period then the crop yield is poor and in the following year, although the water supply may be adequate during the sowing period the farmer hesitates to cultivate up to the maximum. So if inefficient and backward type of cultivators predominate then they cultivate comparatively less land than they should normally do. These cases, although not common, do occur in many districts.

To get a picture of existing cropping and irrigation practices, data were collected for various canals in the central region for one year 1961-62. Appendix I shows the actual intensity of cropping on perennial and non-perennial canals compared to the designed intensity. A study of these data shows that with few exceptions the actual cropping intensities are generally much higher than the designed. On perennial canals the only exceptions are the Gujranwala Division of the Upper Chenab Canal, the Bahawal Canals and the Fordwah Canal. In two of these cases, the difference between the authorized and actual intensities is negligible. On Fordwah Canal the actual intensity was six percent lower than the designed. On all other canals the actual intensity was higher than the designed by even up to 100 percent. As the cropping intensity rises the irrigation delta is reduced, resulting in water deficiency for plant growth as well as in soil salinization. As long as the existing water allowance is not raised or the good quality of ground water is built up sufficiently close to the root-zone, which could serve the purpose of sub-irrigation, the only practical relief is by keeping the cropping intensity as near the designed as possible. With this stap, the irrigation applications would be higher than the existing applications and the irrigated land would have a lower salinity hazard. At the same time the crop yields per acre would increase. The total crop output from the reduced area would be in no case be less than that from larger area given less adequate irrigation.

With respect to the area occupied by four major crops viz. sugarcane, rice, cotton and wheat on the perennial and non-perennial canals in different divisions the data is summarized in Appendix II. The perusal of this will indicate the distinct rice and dry cropping zones, depending upon the existing water-table conditions, availability and duration of water supply and other physico-chemical characteristics of soil. On some of non-perennial canals the major area occupied by Kharif crop is under rice, or cotton; and sugarcane is less than 5 percent. The farmers have taken to rice cultivation because these areas were getting waterlogged and other crops did not do well. A single crop economy is much more hazardous than mixed cropping. A calamity or crop pest can ruin the economic conditions in the area. Also the water requirements of rice crop are much higher than those of most other crops. If the farmers could grow other crops, the crop acreage as well as the farmers income would be much higher. Drainage is the prerequisite for a change-over from rice to other crops. During the interim period when the existing water supply conditions must continue an improvement in the cropping pattern and yields of the crops can be achieved if field drainage can be improved. Where sweet ground water is available the farmers are already getting interested in installing their own tubewells to raise irrigated crops in summer and in winter. Encouragement is being given by Government by extending credit facilities. The provincial Government has worked out a programme of installing 40,000 private tubewells during the 3rd plan period. Government has decided to import lining pipe for the private tubewell drillers on no-profit, no-loss basis. This will help to speed-up the installation of tubewells. In sweet ground water areas having non-perennial irrigation from canals, the Government is also seriously considering to instal tubewells to ensure the supply for the crops. About 3000 tubewells will be installed by Irrigation Department during the 3rd plan period. These wells will mainly be located in non-perennial and reverian areas of the Province.

In non-perennial area having brackish ground water the farmers can do little or nothing by way of drainage by pumping. The open drainage is the only solution which can only be provided by Government efforts.

The areas requiring water-table control in Indus Plain is about 10.7 million acres of the commanded area in which ground water is less than 10 feet from the ground surface. It is estimated that in this zone about 6.3 million acres are underlain by fresh ground water, which can be utilized to supplement the irrigation water (more than 3000 ppm), about 1.2 million acres can be developed for non-perennial rice cultivation for which the ground water control is not required. Similarly the balance of 3.2 million acres of salty ground water would need open or tile drainage system.

6. Soil factors influencing the growth and yield of crops

The clear understanding of such factors is a must for the success of farming. As a result of experimental work in the Directorate of Land Reclamation inquiring into the behaviour of the factor following results can be briefly mentioned.

Salinity and alkalinity status of soil is the determining factor for the growth and yield of farm crops. The bad effects of soil salinity on the crop yields is attributed to the toxic influence of the salts on vegetation and on the activity of soil micro-organisms. The decline in vegetations begins when salinity is equal to 0.4% on dry weight basis of solid residuals. The degree of toxicity of different salts varies considerably according to their chemical behavior or affirmity; for example, the sodium and magnesium chlorides are two to three times more toxic and sodium carbonate four to five times more toxic than magnesium and sodium sulphate. The investigations indicate that when leaching and drainage are provided then the safe contents of the salts in the soil solution may be up to 3,000 ppm of salts or 4.68 mmhos/cm. But if the salt content of soil exceeds 5,000 ppm or the conductivity 8 mmhos/cm then only salt tolerant crops will grow but the yields are likely to be reduced. If the salt content exceeds 15 mmhos/cm or the conductivity exceeds 10,000 ppm no crop are likely to give economic yields. The salt tolerance studies show that 0.2% total salt contents commonly taken as the critical value between good and deteriorated soil does not hold true for all salts and all crops. This is explained, more thoroughly, by discussing some of the data obtained from experiments conducted by Directorate of Land Reclamation.

Salt tolerance of rice, cotton, sugarcane, maize and sorghum was studied on field scale at 9 representative sites in West Pakistan.

The following 4 types of fields were selected at each place:—

(*i*) Good land having no visible evidence of salinity and of uniform good growth of crop over the entire area of the field.

(*ii*) Good growth in some good portion of land in a rare patch salinity field.

(*iii*) Patchy and stunted growth in some deteriorated portion of land in a rare patch salinity field;

(*iv*) Plants failed to establish in saline patch of land in a rare patch salinity field.

The results obtained in the case of above types of field, in respect of growth of plant and salinity status of the soil are tabulated as follows:—

Table showing the influence of salinity and pH on the growth of crop.

S. No.	Crop	Non-saline good field. Growth of the plants good throughout the field	Good growth only in good portion of the field	Stunted or patchy growth in deteriorated part of the field	Crop failed to grow in portion of field with visible salinity
1.	Rice	..*pH 8.5 TS 0.30%	pH 8.6 TS 0.40%	pH 8.6-9.2 TS 0.40%-0.45%	pH 9.2 TS 0.45%
2.	Maize	.. pH 8.5 TS 0.35%	pH 9.0 TS 0.36%	pH 9.0-9.2 TS 0.36-0.37%	pH 9.2 TS 0.37%
3.	Sugarcane	.. pH 8.4 TS 0.30%	pH 8.5 TS 0.31%	pH 8.5-8.6 TS 0.31-0.38%	pH 8.6 TS 0.38%
4.	Sorghum	.. pH 8.25 TS 0.28%	pH 8.4 TS 0.30%	pH 8.4-9.0 Salts 0.30-0.55%	pH 9.0 TS 0.55%
5.	Cotton	... pH 8.0 TS 0.2%	pH 8.5 TS 0.22%	pH 8.5-8.6 TS 0.22-0.25%	pH 8.6 TS 0.25%
6.	Jute	pH 8.5 TS 0.16%	— —	pH 8.91 TS 0.19%	pH 9.31 TS·26%

*pH observed in soil suspension with 1: 5 in all cases.

From the results given above it is seen that cotton and sorghum do apparently well only at a comparatively low salinity and alkalinity status of the soil and thus could be regarded as salt sensitive crops under the West Pakistan conditions. However, the salt sensitivity of sorghum at a comparatively low salt content and low pH value is possibility due to lesser irrigation application which keeps the soil at moisture stress for a longer period during the crop growth. The salinity expressed in percent salt and alkalinity expressed as pH must remain less than 0.2 to 0.28% and pH 8.0 to 8.25 for good growth of cotton and sorghum under present irrigation practices. Sugarcane appears to be a little more salt tolerant than cotton and sorghum. Sugarcane has shown good growth with salt content less than 0.3% and pH less than 8.4. Rice and maize have shown still more tolerance to salt and pH with almost same level; pH less than 8.5 and salt content less than 0.35%, under the prevalent irrigation and agronomic practices. In case of maize the moisture is normally kept at a higher level during the period of its growth. This may be the cause of their, seemingly, withstanding comparatively high salts and alkalinity. The cotton and sorghum can be grown in rather salty soils by changing irrigation and agronomic practices. Under the prevailing irrigation practices, however the choice of the land for different crops should be in accordance with the criteria described above so as to attain the good growth and high yields.

7. Influence of salinity and alkalinity levels of irrigation water on crop growth and the soil profile

Present classification of water quality for irrigation use is considered to be a tentative one. Experience has shown that the limits put on the waters are not necessarily valid, because all kinds of factors will influence the final effects of waters on soils and crops. Some of the combinations of several factors have been and still are being investigated by the Land Reclamation Directorate.

Hereunder several of the results obtained thus far are discussed:—

(*a*) **Mineralized waters.** The agricultural yield falls in proportion to the salt content of the irrigation water. The experiments on non-saline non-alkali soils have shown that at lower concentration of salt in irrigation water up to E. C. 1500 micromhos/cm the yields were not affected to any great extent. At high EC's the yields were highly reduced.

The decrease in the yield of the crops with the increasing concentration of minerals in irrigation waters is illustrated in Fig. 1 and 2. The percentage decrease at the lowest and highest salinity levels of irrigation waters used in the experiment is given below:—

Name of crop	EC 10^6 of irrigation water	Total delta applied	Percentage decrease in yield
Wheat ..	2000	17.47″	5
,, ..	8000	,,	60
Cotton ..	1500	43.42″	6
,, ..	8000	,,	60
Sugarcane ..	1500	62.85″	8
,, ..	8000	,,	50
Berseem ..	1500	39.0″	4
,, ..	8000	,,	52
Gram Barley ..	1500	12.0″	5
,, ..	10000	,,	55

(*b*) **Alkaline waters.** Laboratory studies carried out with waters having varying content of bicarbonates: residual sodium carbonate and the SAR values on normal soil indicate that canal water of good quality; EC 230, ESP (Calc.) 2.31, SAR .76 and RSC nil do not have any ill-effects on soil. The results of the soil treated with the four qualities of water are given in the table below:—

Delta		ES	RSC	SAR	ESP(Calc.)
Original soil	..	1.90	.07	5.25	6.09
		Treated soil with water quality I			
12″	..	2.04	.94	1.67	1.18
24″	..	3.03	..	.27	.85
48″	..	2.71	.30	3.20	3.34
60″	..	2.42	.23	2.33	2.12
		Treated soil with water quality II			
12″	..	3.78	.02	5.94	6.97
24″	..	3.94	.62	5.40	7.56
48″	..	3.40	.42	7.14	8.49
60″	..	2.15	1.31	6.53	7.72
		Treated soil with water quality III			
12″	..	2.80	.48	8.53	7.72
24″	..	4.09	.83	6.35	7.49
48″	..	4.18	.62	7.15	8.51
60″	..	2.46	1.39	8.52	10.15
		Treated soil with water quality IV			
12″	..	3.68	2.03	8.58	10.22
24″	..	3.73	5.00	9.54	11.35
48″	..	6.46	2.93	10.40	12.35
60″	..	3.44	4.10	11.01	13.02

Water of quality II having RSC nil, ESP (Calc.) 24.9, SAR 4.75 and EC 2000 micromhos have not washed down any salines from the soil column. In fact some increase was observed in SAR and RSC. This indicates that even if RSC is absent, the HCO_3 contents of irrigation water increase the RSC of soil extract.

FIG. I.—RELATIONSHIP BETWEEN DECREASE IN YIELD OF WHEAT, COTTON, SUGARCANE AND CONDUCTIVITY OF IRRIGATION WATER

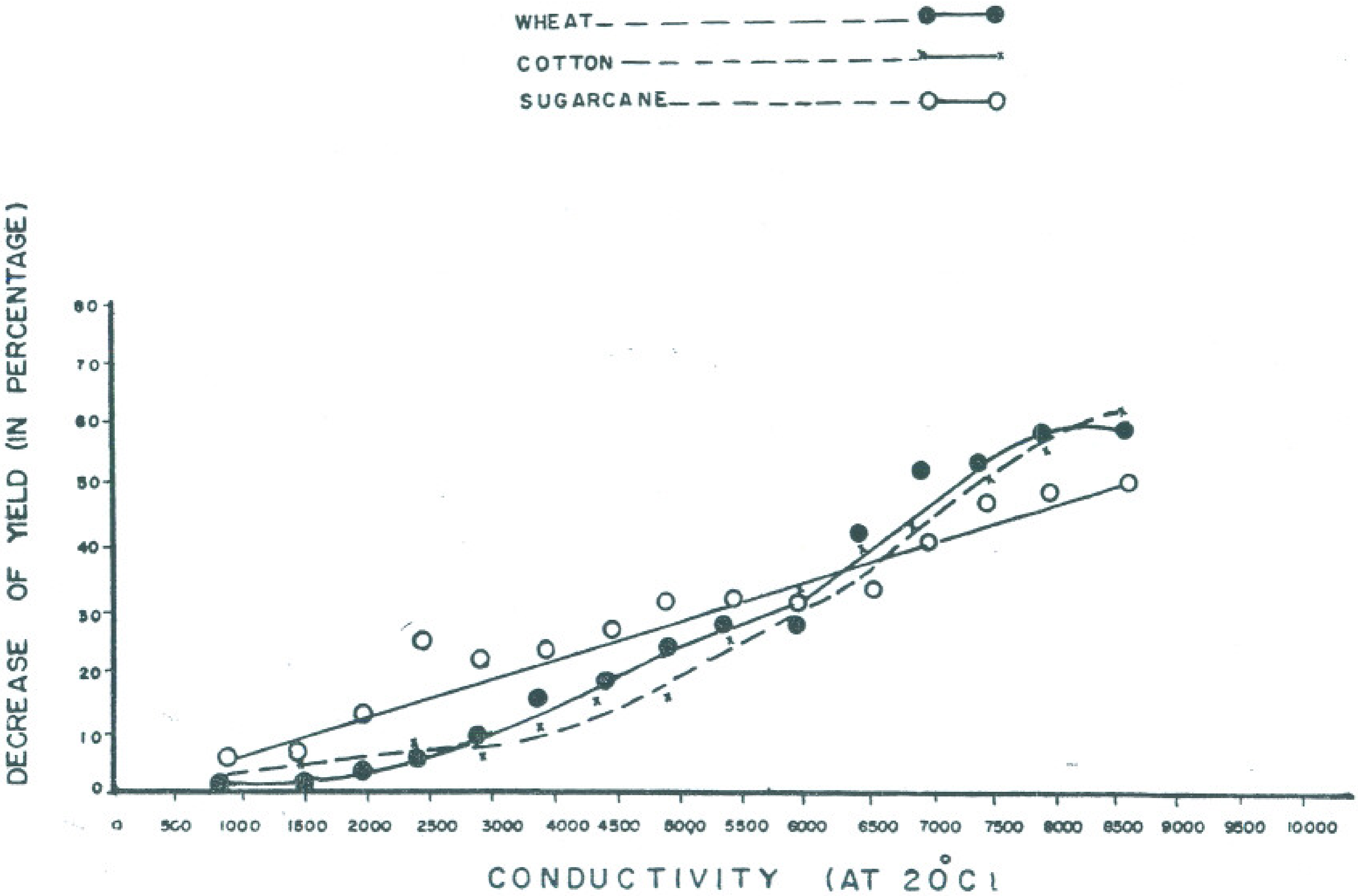
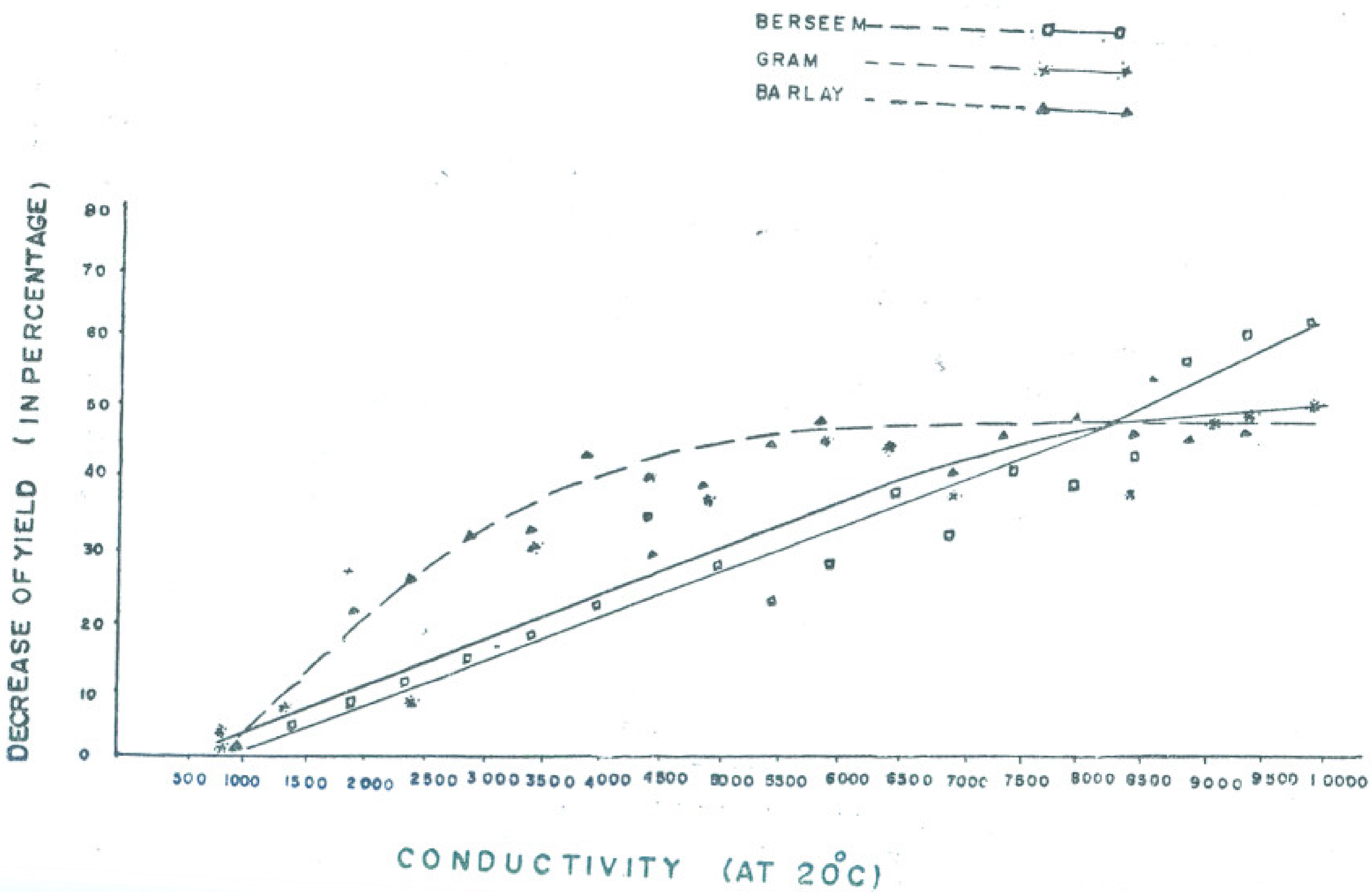


FIG. II.—RELATIONSHIP BETWEEN DECREASE IN YIELD OF BERSEEM, GRAM, BARLEY AND CONDUCTIVITY OF IRRIGATION WATER



With water of quality No. III having EC 2000, ESP 33.3 (Calc.) SAR 7.5 and RSC 0.3 significant increase occurred in ESP and RSC of the soil extract.

Water of quality No. IV having EC 2000 (Calc.) ESP 46.2, SAR 9.85 and RSC 7.4 had the most pronounced effects on soil. Not only the soluble sodium, but also the RSC and SAR have tremendously increased.

The experiments show that generally waters with ESP (Calc.) more than 20, RSC more than 2.5 will bring hazardous effects in soil with time especially under low irrigation. Considerable increase in exchangeable sodium occurs rather rapidly.

The use of 5 different qualities of water on the land in SCARP I for one year on good normal soils indicated that the quality of water with EC 750 µmhos, RSC 0 to 2.6 will increase the SAR values of normal soil in 7.3% of the observation plots.

The 2nd quality of water of EC 750-1500 and RSC 0.7-5.6 increased the SAR value in 14% plots. With 3rd and 4th quality of water having EC 1501 to 2250, RSC 0 to 7.3 and EC 2251-3000, RSC 0-11.9 meq/1, the SAR values increased in 53% and 37% plots respectively. The 5th quality waters EC more than 3000 micromhos RSC 0-17.2 meq/1 results in the increase of SAR values of the soils in 87.5% observation plots.

In respect of salinity there has been no change by the use of group 1 quality of water, whereas the use of 2nd, 3rd and 4th and 5th group quality water increased salinity in 9.7%, 6.7%, 43% and 12.3% profiles of good normal soil respectively. There is no consistency in the accumulation of salts on account of variation in the irrigation delta applied to the crops grown, but in case of alkalinity as expressed by SAR values there has been constant increase with the increase in RSC irrespective of the irrigation delta applied.

Another laboratory study with synthetic water of compositions similar to those of tubewell water indicate that waters of low salinity level 650 µmhos but with RSC 2.6 meq/1 is as much injurious as the water of high salt content 3000 micromhos/cm and low RSC 0.9 meq/l. However, the water having high salinity and high RSC deteriorate the soil at a much faster rate. It is also observed that by the use of waters of poor quality but with higher irrigation applications to effect some leaching, the soil deterioration period resulting from the use of such waters may be prolonged. The table presented below shows this trend conclusively.

Table showing percentage increase in the salt contents and SAR values of soils with the use of different quality of water under different sets of irrigation.

Crop rotation	Depth of irrigation (inches)	Quality of water used for irrigation: EC. 650 μmhos — Salt increase %	EC. 650 μmhos — SAR increase	EC 2000 μmhos — Salts increase %	EC 2000 μmhos — SAR increase	EC 2500 μmhos — Salts increase %	EC 2500 μmhos — SAR increase	EC 3000 μmhos — Salts increase %	EC 3000 μmhos — SAR increase	Total surface application
Maize-Berseem ..	6	..	**28**	1	15	7	21	9	**24**	276
Cotton-Sorghum- ..	4	3	32	9	18	21	26	25	36	204
Gram ..	3	..	..	19	23	54	33	82	68	165
Maize-Mililot ..	6	..	22	5	16	7	18	7	22	274
Sugarcane- ..	4	2	26	7	20	17	22	22	41	198
Vetch-Wheat ..	3	..	33	30	23	63	27	84	71	161
Maize-Alfalfa ..	6	..	22	5	13	18	17	21	31	226
Wheat-Sorghum ..	4	7	30	19	39	37	58	47	119	165
Gram ..	3	13	33	50	101	67	112	103	142	136

For the maintenance of salt balance in the soil the amount of each irrigation application is as important as the total quantity applied in a particular crop rotation. This seems to hold especially true for water with high salinity and RSC. It is conceivable and quite probably true that in salt-affected soils, the cumulative effects of salt from poor quality irrigation water will be such as to prevent germination and plant growth even of the more salt resistant plants if no leaching or drainage is provided. This has been noticed in a large area of 57200 acres in SCARP I where after 3-4 years of irrigation with poor quality of water the soil is not fit to grow even 25 paisa crops.

8. Influence of water-table on the desalinization of the soil profile

Laboratory studies were undertaken to determine the movement of salts in three kinds of synthetic salty soils and their effects on the chemical characteristics of soils which were subjected to three different water-tables *viz.* (*i*) High water-table with free drainage (*ii*) High water-table without drainage (*iii*) Deep water-table, and then irrigation periodically with a total amount of 18″ of canal water. Fine sandy loam soil representing a major area of agricultural land in Punjab was used in this experiment.

The percentage decrease of different cations and anions in three salt soils is given in the table below:—

Table showing Reduction in different ions (percentages)

	Ca	Mg	Na	HCO3	Cl	SO_4
Saline soil						
1. High water-table no drainage ..	67	75	74	..	87	69
2. High water-table free drainage ..	68	71	80	..	87	69
3. Deep water-table ..	78	78	90	20	95	89
Saline alkali soil						
1. High water-table free drainage ..	22	25	83	21	89	85
2. High water-table no drainage ..	10	11	74	15	83	72
3. Deep water-table ..	17	23	83	23	86	89
Alkali soil						
1. High water-table free drainage ..	16	33	70	18	80	82
2. High water-table no drainage ..	18	18	71	12	83	85
3. Deep water-table ..	38	42	75	23	89	83

From the above results it is clear that there is a significant removal of total soluble salts from all the soil columns under the three different ground water-table conditions but the salt ramoval is more at deep water-table than the high water-table with free and no drainage in all types of soils.

There has been a sizeable reduction in the anions like chloride and sulphate in all soils at different water-tables. Carbonate and bicarbonate ions have, however, shown persistent resistance to leaching. This shows that carbonate and bicarbonate once they entered the soil are not so easily removed even when a good quality of water is used for irrigation. The constant additions of carbonate and bicarbonate anions from the high ground water source by capillary or from surface application of water (which is high in both salt concentration and HCO_3) will therefore be a regular deteriorating process of irrigated soils if preventive measures are not applied.

Another important conclusion that can be drawn from this experiment is that the desalinization of the soil profile under deep water conditions is easier than in case of high water-table conditions. Under the situations where the area is underlain with sufficient fresh ground water throughout or in any specific horizon of water-bearing strata it is advantageous to adopt vertical drainage to suppress the water-table and salts from the soil profile, if the water so pumped can be safely utilized for irrigation purposes.

In brackish water zone, fresh water can be built up at a reasonable depth close to the root zone 5—6′ from the ground surface. This can be achieved by prolonged irrigation and artificial drainage by open or covered drains. The desalinization of the sub-soil layer and ground water is well demonstrated by the results of Chakanwali Reclamation Experimental Farm where an area has been laid out in blocks with horizontal drainage system having 64.75 miles of field drains and 11.5 miles of collector drains. This farm comprising an area of 3645 acres was started in the year 1925. Out of this an area of 685 acres were fit for rice cultivation and the balance 2960 acres were marshy, saline and alkaline. At present practically the entire area is under cultivation and all kind of crops including those sensitive to waterlogged conditions like cotton and maize and many fruit trees are grown successfully. As a result of the reclamation measures a fresh ground water has been built up and the salinity has been removed both from the soil profile and the sub-soil water as is indicated by results of H plot of Chakanwali Reclamation Farm. The quality of water drained 1933-1967 are given in appendix III.

In the year 1930 salt concentration of the drainage water ranged within a limit of 925-2500 micromhos/cm. A year later in 1931, it decreased considerably and at present in 1967 the quality of the drainage water is almost similar to that of the canal water. Under such conditions the danger of secondary salinity is eliminated. This is evident from the condition of the bumper cotton crop grown in Kharif 1967, as shown in plate I.

The depth to water-table in the block having cotton as measured on 8-9-1967 was on the average 1′—10″. The detailed chemical analysis of samples of ground water collected on 8-9-1967 are given on next page.

Plate I

Cotton under high water table conditions with adequate drainage system at Chakanwali Experimental Farm

Table showing the analysis results of the ground water in cotton Block at Chakanwali Reclamation Expt. Farm.

	Milliequivalents per litre									
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total cations anions	D.S. by Evap	$EC10^6$ at 25°C
Site No. 1	4.93	3.19	..	..	7.75	0.37	..	8.12	547	856
Site No. 2	4.00	4.19	..	..	7.25	0.68	..	7.93	554	867
Site No. 3	3.29	1.51	..	..	4.25	0.37	..	4.62	384	600
Site No. 4	4.04	4.06	..	..	7.60	0.67	0.80	9.09	554	867

This block is drained with field drains spaced at 55′ to 110′. No irrigation was given to cotton except one to prepare seed bed. Total moisture requirements of the crop are met from the ground water reservoir or the monsoon precipitation which was 8.34″ up to the 8th September, 1967. The total irrigation requirements based on the consumptive use data is about 30″ in deep water-table zone under similar conditions. In Kharif 1966 this block of land gave a yield of seed cotton of 6 maunds or less in 45% plots, 6-10 maunds per acre in 44% plots and above 10 maunds per acre in 11% plots. In the experiment under progress physiological effects on the plants are also observed to attain higher yield.

Similarly it is possible to mature rice crop with 30″ irrigation application as compared with 60″ needed under deep water-table condition. The data obtained from different experimental farms is given in the table below:—

Average Results of Rice (Mds./acre) at different Farms with varying water-applications.

Treatment	Yield 1963		Yield 1964			Yield 1965		Yield 1966	
	C.R.F.	M.R.F.	C.R.F.	B.R.F.	M.R.F.	C.R.F.	B.R.F.	C.R.F.	B.R.F.
Irrigation 30″	13.75	8.80	24.90	12.10	16.10	20.50	3.68	13.50	4.05
40″	17.25	9.25	30.40	12.50	23.10	27.20	4.76	18.75	3.45
50″	12.00	10.45	27.75	15.50	26.70	25.48	5.25	16.50	5.30
60″	12.50	11.65	24.75	18.66	33.50	22.45	6.25	14.50	8.40

C.R.F.=Chakanwali Reclamation Farm (Shallow water-table) with fluctuation 1′ to 3 feet.

M.R.F. Moharanwala Reclamation Farm (Water-table about 12 feet from ground surface).

B.R.F. Bhallewala Reclamation Farm, Water-table about 22 feet from ground surface.

From the above it can be inferred that for rice crop there is reduction in irrigation needs and number of waterings by about 50% whereas in case of cotton practically full requirements are met from ground water source.

The maintenance of the open drainage system is a laborious task, but because of the permanent advantages of build-up of fresh ground water by desalinization of the salinized ground water, it is a paying proposition, especially because it represents a tremendous saving in the irrigation water applications. The data collected at the Chakanwali Experimental Reclamation Station support the version for horizontal drains in the brackish water zone, instead of vertical drainage system particularly where the water so costly pumped is difficult to dispose of.

9. Influence of the rising water-table on the existing cropping pattern

The five major variables to determine the cropping pattern which influence the irrigation practices are soil texture, water allowance, soil salinity, alkalinity, water-table and weather conditions. In an irrigated region, the depth of the water-table determines the cropping pattern in more than one way. If it is so high that the land becomes waterlogged, the growth of common crops is impossible. On the other hand, if the root-zone depth of soil is free from waterlogging but the water table is within the capillary fringe and in quality is good, the ground water supplies at least a part of the water needs thus reducing the irrigation requirements.

The fluctuations in the depth of water-table during the year will also affect the cropping pattern. If for a part of the year water-table remains within the root zone depath then during such period crops can be grown which have a shallower root system or those which can stand an excess of water.

With reference to the depth of water-table, cropping patterns will depend on the provision of absence of an efficient drainage system which can drain the required depth of soil for good growth. With a rising water-table, in the absence of drainage, the ordinary crops gradually go out of the cropping pattern and ultimately, when the water table comes to the surface and the area gets submerged under water, then even crops such as rice, which can stand excess moisture, cannot be raised. The rise of water-table in the Indus Plain, after the inception of the various canal systems in the absence of effective drainage, has had a marked effect on cropping patterns. In the perennial canal colonies of ex-Punjab, the Kharif (summer) acreage under cotton has gone down from fifty six to thirty-three percent. In areas where the water-table has risen within five feet depth, cotton has practically gone out and occupies only three percent of the Kharif (summer) acreage. It forms only twenty-eight percent of Kharif acreage in areas with water-table in the range of five to ten feet. In areas with water-table ten to fifteen feet deep, the percentage is about five percent compared with the area of water-table more than fifteen feet deep. In the Sind Plain, the instance of Dadu Division is typical. Cotton formed forty-four percent of the Kharif acreage in 1937-38, after which because of high water-table there was a rapid decline. It now comprises only two percent of the Kharif acreage. Similarly, other water sensitive crops, such as maize, gram, oil seeds, etc. have gone out of production.

There has been a corresponding increase in the acreage under rice in the rising water-table zones. In the area having water-table within five feet, sixty percent of Kharif acreage is under rice. It goes down to twenty-four percent for areas in the five to ten foot range, fourteen percent of those of ten to fifteen feet water-table depth, and only eleven percent in areas with water-table deeper than fifteen feet.

The cropping patterns and irrigation practices will also change as the good land becomes salinized and as saline land is reclaimed from salinity. Secondary salinization and formation of sodium soil can be checked by appropriate irrigation and drainage practices. Even if the farmer is willing to follow these practices, the provision of water resources for correct irrigation is not in his control. The drainage installation cannot be provided by him as the disposal works cannot be provided for a holding individually and independently. The drainage system is designed for a hydrologic unit and this work must be undertaken by public investment or collective efforts.

10. Influence of the quality of water used for irrigation on cropping pattern

Long experience exists among experts and farmers in the use of good quality river water for the past 60-70 years. The scientists are quite in line with the advanced countries in their understanding of soil-water-plant relationships. The existing cropping pattern discussed earlier have been established in response to the good quality of water utilized under the various environmental conditions, soil characteristics and water-table situations. The most recent use of ground water of poor quality during the past 3-4 years in SCARP I, have brought about radical changes in the cropping pattern even under the favourable conditions created by lowering of water-table to a reasonable depth of 18-19′.

Out of 2150 tubewells installed in SCARP I, the quality of water of fairly large number of tubewells is not good. It should be mixed with canal water in proper proportion so as to improve the quality of irrigation water for irrigation purposes. Unfortunately this has not been done, and it has resulted in reduction in the cotton area by 3.5% and increase in the rice acreage by 2.5%. The ill-effects in the soil profile are also quite pronounced where the indiscriminate use of poor quality water has been made. This was predicted well ahead that the problem of waterlogging can be solved for the time being, but the salinity and alkalinity problem can be aggravated. The view of the provision of more supplies through tubewells as a measure of increased crop production thus no longer holds good for many tubewell waters. This calls for the scientific use of such waters and detailed scientific and precise studies of the effects of ground water put to use for irrigation.

11. Suitable crop rotation for Salinity Control

One of the major problems of irrigated agriculture in the arid zones is the maintenance of productive status of soil. When a land is brought under irrigation salts inherently present in the soil move down and accumulate at a certain dopth in the soil profile. To keep this zone of salt accumulation well below the root zone it is necessary to follow the appropriate crop rotation under the prevailing irrigation and agricultural practices. Under a crop rotation where the trend of movement of moisture is upward, the process of secondary salinization is developed.

In order to determine the most suitable rotation a set of 10 patterns of varying cropping intensities were tried on a non-saline, non-alkali soil at Moharanwala Experimental Reclamation Farm (Lyallpur District) where water-table was about 9 feet.

The rotations studied to determine salt movement and economic returns were:—

(*i*) Guara (G. M.)-Wheat-Toria-Cotton;
(*ii*) Wheat-Gram-Cotton;
(*iii*) Wheat-Wheat;
(*iv*) Cotton-Berseem (G.M.);
(*v*) Cotton-Senji (G.M.);
(*vi*) Chari Guara-Gram-Cotton;
(*vii*) Wheat-Cotton/Senji (G.M.)-Sugarcane; and
(*viii*) Guara (G.M.)/Wheat-Cotton-Sugarcane.

Following results have been obtained:—

1. Rotation (*i*) to (*vi*) may be safely adopted for more than 3 cycles, while those at (*vii*) and (*viii*) need an alteration with any of the others at (*i*)-(*vi*) after two cycles.

2. Rotations sugarcane-sugarcane and cotton-cotton gave poor performance in respect of their effect on salt movement. These are long duration crops gradually losing moisture and through prolonged transpiration are causing an upward movement of salines. The crops, in view of their importance in our agricultural economy, should therefore be grown in rotation with other crops.

3. Summer fallowing does not appear to be so harmful in respect of salt movement as crops grown continually on irrigation delta which is less than consumptive use requirements of the crops.

4. Winter fallowing is harmful and a crop cover is essential to avoid rise of salines but the crops must receive their consumptive use requirements.

12. Scientific use of water for increased irrigation efficiency and crop production

Salinity control can be exercised to a great extent even under present irrigation delta, provided the cultivators take care of proper levelling of land, layout of fields in proportion to the amount of water available and uniform application of water over the entire strip of land. Investigations have brought to light that one of the major causes of upward movement of salts, waterlogging, and uneven distribution of soil moisture in the root-zone is uneven application of water over the surface of the land. To prove the extent of the above effects, irrigation experiments were conducted at different experimental research stations of the Directorate of Land Reclamation. The size of the experimental plots varied from one-eight of an acre to one acre, having locations of water inlets and watercourses at different positions. The yield of crops and efficiency of irrigation practice were studied in the experiment.

From data collected on cotton it is revealed that the maximum application efficiency of 70% was obtained in one-eighth acre plot which is 15% higher than one-acre plot. In case of wheat the efficiency in case of one-eighth acre plot was 69% as compared to 54% with one acre plot.

From the yield results it is concluded that if the size of the plot is arranged in proportion to the size of stream the yield can be much increased. In cotton this increase has been 55.6%, 68.5% and 43.0% at three different research stations with one-eighth acre plot as compared to one acre plot.

The yield of wheat that followed cotton gave the higher return in case of one-eighth acre plots as compared with one acre, by 56.6% and 26.7% at two experimental farms.

The experiments have shown that more uniform distribution of irrigation water and higher crop yields are attained with the size and shape of the plot of one-eighth acre.

13. Administrative Problems

As indicated earlier most of the irrigated agriculture in West Pakistan is dependent upon canal water. The cultivators are assessed for different crops grown according to a specified schedule of occupiers' rates. This does not give any incentive to a progressive cultivator who has a large area under improved agriculture-irrigation practices. It would, therefore, be quite advisable to levy the flat rate on C.C.A. instead of the cropped area rate. The absentee land-lords and the idle cultivators do not like this idea because now they pay for only the matured crops even if they let the water go to waste. Instances are known where they sell the water instead of utilizing it for irrigation purposes. With the imposition of flat rate the extra expenditure on the organization for collection and assessment can be reduced to a great extent. And there would be incentive for cultivators to make better and effective use of water.

14. Mechanical cultivation

For bringing more area of waste land under cultivation initial breaking of the land is an important factor for increased crop production. This task cannot be taken up with under-fed bullocks and old primitive implements. This may be done by a Government Agency and vigorously perused by strengthening the organizations like Agricultural Development Corporation or Agriculture Department who have been assigned this job.

The use of improved seed, fertilizers, implements, pesticides for insect control, sowing and harvesting of crops in time and other credit and marketing facilities play a significant role for increased crop production. These should be given due attention by the Government in order to achieve the set goal of self-sufficiency in food by the President, Field-Marshal Mohammad Ayub Khan. The indiscriminate use of fertilizers will not give as much benefit as that can be derived by the use of balanced fertilizers.

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APPENDIX

Cropping Patterns on Various Canals, 1961-62.

Name of Division						Kharif
	Sugar-cane	Rice	Cotton	Maize	Chari	Bajra
1	2	3	4	5	6	7
						Lower Bari Doab
Balloki Division ..	11.0	6.1	11.5	7.0	5.1	2.1
Khanewal Division ..	4.9	1.6	23.9	6.2	5.9	3.1
Montgomery Division ..	8.3	5.2	16.7	9.0	5.5	2.5
						Lower Chenab Canal
Burala Division ..	7.9	2.4	13.5	8.1	10.5	1.3
Lower Gugera Division ..	12.0	1.4	7.4	7.2	8.3	0.2
Upper Gugera Division ..	8.6	9.7	11.3	7.0	7.9	1.6
						Lower Chenab Canal
Khanki Division ..	2.6	13.7	7.2	1.3	11.1	..
Hafizabad Division ..	13.5	3.0	6.4	7.7	9.0	3.2
Lyallpur Division ..	12.3	2.6	11.1	9.0	9.4	2.4
Jhang Division ..	9.4	1.2	13.2	6.1	9.6	3.6
						Upper Chenab
Gujranwala Division ..	2.6	17.8	1.4	1.3	5.1	0.6
Sheikhupura Division ..	3.1	20.5	2.6	2.7	6.3	0.9
						Lower Jhelum
Kirana Division ..	5.4	1.5	19.1	6.9	4.8	8.0
Rasul Division ..	4.0	1.4	21.5	4.3	3.5	11.5
Sargodha Division ..	1.6	1.7	14.5	1.1	8.1	4.0
						Upper Jhelum
Gujrat Division ..	4.8	10.9	11.2	3.7	2.6	9.9
						Central Bari
Lahore Division ...	7.0	4.4	12.8	4.3	15.4	4.4

I

Actual Cropping 1961-62—*Percent of C.C. Area*

Perennial Canals.

			Rabi								
Other Crops	Rauni	Total	Wheat	Barley	Gram	Mixed Crop	Oil Seed	Other Crops	Rauni	Total	Grand Total
8	9	10	11	12	13	14	15	16	17	18	19
Canal Circle											
11.5	0.6	54.9	30.9	0.7	3.7	..	5.2	2.7	0.3	43.5	98.4
9.8	1.1	56.5	28.7	2.3	2.8	..	12.2	14.5	0.3	60.8	117.3
11.1	0.5	58.8	31.7	0.8	4.3	..	8.2	16.9	0.2	62.1	120.9
East Circle											
8.6	0.4	52.7	26.4	0.1	2.0	0.8	12.1	19.3	0.2	60.9	113.6
9.0	0.3	45.8	21.5	0.2	1.8	..	19.6	18.2	0.1	61.4	107.2
2.4	0.4	48.9	18.6	0.4	0.3	2.8	12.7	14.7	0.3	19.8	98.7
West Circle											
1.4	1.7	39.0	32.6	0.4	1.8	..	2.4	19.5	0.7	57.4	96.4
5.9	0.8	49.5	29.5	0.1	1.2	..	3.0	30.0	0.2	64.0	113.5
3.2	0.5	50.5	26.0	0.7	3.0	1.9	15.6	14.6	0.2	62.0	112.5
3.0	0.9	47.0	3.3	0.4	2.4	38.9	3.7	13.5	0.2	62.4	109.4
Canal Circle											
1.1	1.7	31.6	11.0	0.8	..	1.4	6.7	9.5	0.7	30.1	61.7
1.9	1.1	39.1	20.8	0.1	0.5	1.6	1.4	14.0	0.7	39.1	78.2
Canal											
5.7	1.6	53.0	31.7	0.5	0.7	..	1.9	19.0	0.4	54.2	107.2
10.8	1.4	58.4	29.4	0.2	0.4	..	1.1	26.1	0.4	57.6	116.0
2.7	2.1	35.8	26.6	0.6	0.6	..	1.1	13.5	0.7	43.1	78.9
Canal											
10.3	0.6	54.0	27.2	0.3	0.8	..	2.6	17.4	0.4	48.7	102.7
Doab Canal											
5.7	0.2	54.2	17.4	2.2	2.7	8.4	6.9	10.0	0.3	47.9	102.1

APPENDIX

Cropping Patterns on Various Canals, 1961-62.

Name of Division						Kharif
Name of Division	Sugar-cane	Rice	Cotton	Maize	Chari	Bajra
1	2	3	4	5	6	7
						Pakistan
Western Bari Division ..	3.6	0.5	23.7	1.0	7.1	2.5
Eastern Bari Division ..	5.5	2.4	23.3	2.6	7.0	2.3
						Eastern Sadiqia
Sadiqia Division ..	6.2	0.1	15.8	0.7	..	..
Hakra Division ..	6.1	0.5	14.3	0.8	4.8	1.8
						Bahawal
Baghdad-ul-Jadid ..	6.8	1.8	2.8	2.7	...	1.1
						Abbasia
Ahmadpur Division ..	13.2	0.1	6.7	1.4	0.4	3.2
						Panjnad
Rahimyarkhan Division	10.2	0.1	17.0	1.9	0.2	1.1
Khanpur Division ..	9.3	0.2	16.4	1.2	7.8	1.6
						Fordwah
Fordwah Division ..	13.5	1.3	12.2	0.8	..	1.8
						Haveli Canal
Multan Division ..	3.5	3.0	25.1	2.2	14.0	0.3
Shujabad Division ..	1.4	0.5	26.9	2.2	15.8	0.3
Trimmu Division ..	5.7	4.6	17.6	1.7	6.3	1.4
						Lower Bari Doab
Balloki Division ..	1.8	7.6	15.6	1.8	4.5	0.6
Khanewal Division ..	..	..	1.9	0.4	0.5	0.2

I—*Contd.*

Actual Cropping 1961-62—*Percent of C. C. Area*
Perennial Canals.

			Rabi								
Other Crops	Rauni	Total	Wheat	Barley	Gram	Mixed Crop	Oil Seed	Other Crops	Rauni	Total	Grand Total
8	9	10	11	12	13	14	15	16	17	18	19
Canal											
3.0	1.5	42.9	29.8	0.1	1.4	..	6.8	7.7	0.7	46.5	89.4
3.6	1.1	47.8	36.1	0.6	0.6	0.3	5.9	9.5	0.3	53.3	101.1
Canal											
22.7	0.9	46.4	7.9	0.1	1.6	8.0	3.8	19.2	0.2	40.8	87.2
18.1	1.0	47.4	3.8	0.1	2.4	14.6	4.0	18.7	0.3	43.9	91.3
Canal											
22.9	1.6	39.7	9.7	..	1.1	14.2	6.8	6.7	0.7	39.2	78.9
Canal											
18.6	1.2	44.8	14.3	..	5.8	6.5	4.1	9.4	0.9	41.0	85.8
Circle											
16.1	1.2	47.7	28.3	0.1	1.4	0.2	3.9	13.2	1.1	48.2	95.9
5.9	1.0	43.4	25.7	..	0.5	2.2	5.7	10.6	1.0	45.7	89.1
Canal											
9.8	0.4	39.8	15.0	0.2	1.1	15.9	1.7	5.0	0.1	39.0	78.8
Circle											
7.3	3.0	58.4	42.0	0.9	0.9	..	4.6	18.4	0.8	67.6	126.0
5.0	3.2	55.3	42.1	0.3	0.2	..	5.0	15.0	1.0	63.6	118.9
4.6	2.4	44.3	26.1	0.4	2.4	0.1	3.9	4.2	0.5	37.6	81.9
Canal Circle								Non-Perennial Canals			
2.8	..	34.7	7.4	..	8.9	..	0.1	12.4	0.2	29.0	63.7
85.7	..	88.7	1.6	0.2	..	..	0.4	67.7	..	69.9	158.6

APPENDIX

Cropping Patterns on Various Canals, 1961-62.

Name of Division						Kharif
	Sugar-cane	Rice	Cotton	Maize	Chari	Bajra
1	2	3	4	5	6	7
						Lower Chenab Canal
Khanki Division ..	0.9	31.4	0.6	0.1	4.3	—
						Upper Chenab
Marala Division ..	1.3	22.0	1.2	0.2	3.9	..
Gujranwala Division ..	0.7	32.5	0.5	0.3	3.7	0.4
Sheikhupura Division ..	0.7	24.3	0.6	0.9	4.5	..
						Lower Jhelum
Shahpur Division ..	2.2	3.9	18.3	2.3	10.3	1.1
						Dipalpur Canal
Kasur, Khanwah and Suleimanki Division ..	3.0	12.5	4.2	0.8	7.0	2.4
						Pakpattan
Suleimanki Division ..	0.7	19.5	6.7	0.6	7.4	..
Khanwah Division ..	1.5	5.0	18.0	0.6	14.1	2.0
						Eastern Sadiqia
Sadiqia Division ..	1.3	4.2	4.9	0.3	...	...
						Mailsi
Islam Division ..	0.7	0.6	21.2	0.3	17.3	2.7
Lodhran Division ..	0.5	0.1	17.7	0.3	16.2	5.4
						Bahawal
Baghdad-ul-Jadid Division	2.1	2.3	10.3	0.2	..	1.2
Ahmadpur Division ..	1.2	0.2	7.4	0.3	5.3	8.2
						Panjnad
Rahimyarkhan and Dallas Division ..	4.9	3.8	22.7	1.6	0.5	2.5
						Qaim
Baghdad-ul-Jadid ..	2.1	7.6	13.0	0.2	..	2.8
						Fordwah
Fordwah Division ..	1.2	6.1	7.5	0.5	0.5	1.3
						Haveli
Shujabad Division ..	1.5	1.2	18.6	2.1	16.1	2.7
Trimmu Division ..	4.0	5.3	10.3	1.5	7.7	2.3

I—*Contd.*

Actual Cropping 1961-62—*Percent of C. C. Area*
non-Perennial Canals.

			Rabi								
Other Crops	Rauni	Total	Wheat	Barley	Gram	Mixed Crop	Oil Seed	Other Crops	Rauni	Total	Grand Total
8	9	10	11	12	13	14	15	16	17	18	19
West Circle											
4.3	0.1	41.7	12.4	0.1	0.2	..	0.2	18.8	0.6	32.3	74.0
Canal Circle											
1.5	..	30.1	11.1	0.3	0.6	9.6	0.7	3.1	0.3	27.7	57.8
0.9	..	39.0	11.8	0.2	0.6	1.5	3.5	15.4	0.8	33.8	72.8
..	..	31.0	37.5	...	1.5	1.1	..	5.2	0.4	45.7	76.7
Canal											
6.6	0.9	45.6	26.3	0.1	2.2	..	0.1	17.3	1.1	47.1	92.7
Circle											
							Wad Watter			7.0	
1.0	0.3	31.2	11.0	0.5	0.9	3.3	0.2	3.5	0.5	26.9	58.1
Canal											
0.8	0.3	36.0	13.3	0.6	3.2	2.6	0.3	26.8	1.1	47.9	83.9
1.0	0.6	42.8	19.6	0.5	6.1	2.4	2.3	9.0	1.7	41.6	84.4
Canal											
13.6	..	24.3	0.4	0.6	1.7	0.3	..	14.9	0.2	18.1	42.4
Canal											
4.2	0.5	47.5	31.7	0.4	3.4	..	5.4	6.9	1.2	49.0	96.5
1.8	0.4	42.4	24.1	0.3	3.4	..	5.6	4.3	1.7	39.4	81.8
Canal											
24.2	..	40.3	30.1	..	6.3	1.2	4.3	4.5	1.1	47.5	87.8
18.9	..	41.5	29.1	..	8.5	..	7.0	6.0	2.0	52.6	94.1
Circle											
14.4	0.1	50.5	23.6	..	2.8	..	2.8	7.5	3.2	41.9	92.4
Canal											
14.2	..	39.9	27.9	0.1	12.7	2.3	3.5	6.4	0.9	53.8	93.7
Canal											
17.1	0.2	34.4	12.9	0.3	2.8	10.6	0.6	9.4	0.3	36.9	71.3
Canal											
9.3	1.9	53.4	30.1	0.6	1.0	..	1.7	17.5	1.4	52.3	105.7
11.4	0.9	43.4	..	..	..	..	..	..	..	...	43.4

APPENDIX II

Area under Major Crops on Various Lands in 1961-62
(Percent of C.C.A.)

PERENNIAL

Name of Division	Sugarcane	Rice	Cotton	Wheat
Ahmadpur	16.6	Less than 4	8—12	12—16
Fordwah	13.5	Less than 4	12—16	12—16
Hafizabad	12—14	Less than 4	4—8	28—32
Lyallpur	12—14	Less than 4	8—12	24—28
Balloki	10—12	4—6	8—12	28—32
Lower Gugera	10—12	Less than 4	4—8	24—28
Montgomery	8—10	4—6	16—20	28—32
Upper Gugera	8—10		8—12	16—20
Jhang	8—10	Less than 4	12—16	Less than 4
Rahimyarkhan	8—10	Less than 4	16—20	28—32
Khanpur	8—10	Less than 4	16—20	24—28
Burala	6—8	Less than 4	12—16	24—28
Lahore	6—8	4—6	12—16	24—28
Sadiqia	6—8	Less than 4	12—16	8—12
Hakra	6—8	Less than 4	12—16	Less than 4
Baghdad-ul-Jadid	6—8	Less than 4	2—4	8—12
Khanewal	4—6	Less than 4	20—24	28—32
Rasul	4—6	Less than 4	20—24	28—32
Kirana	4—6	Less than 4	16—20	28—32
Gujrat	4—6	10—12	12—16	32—36
Eastern Bar	4—6	Less than 4	20—24	..
Gujranwala	0.4—4	16—18	Less than 2	8—12
Sheikhupura	0.4—4	20 maximum	2—4	20—24
Sargodha	0.4—4	Less than 4	16—20	28—32
Khanki	0.4—4	12—14	4—8	32—36

NON-PERENNIAL

Name of Division		Sugarcane	Rice	Cotton	Wheat
Ahmadpur	..	0.4—4	Less than 4	4—8	28—32
Shujabad	..	0.4—4	Less than 4	24—28	More than 40
Multan	..	0.4—4	Less than 4	24—28	More than 40
Western Bar	..	0.4—4	Less than 4	20—24	..
Suleimanki	..	..	..	4—8	12—16
Gujranwala	..	Less than 4	32—36	0.4—1.2	..
Khanki	..	Less than 4	28—32	0.4—1.2	..
Sheikhupura	..	Less than 4	24—28	0.4—1.2	..
Marala	..	Less than 4	20—24	0.4—1.2	..
Kasur	..	Less than 4	12—16	4—8	..
Balloki	..	Less than 4	8—12	24—28	..
Suleimanki	..	Less than 4	8—12	8—12	..
Baghdad-ul-Jadid	..	Less than 4	8—12	8—12	..
Khanewal	..	Less than 4	4—8	12—16	..
Shahpur	..	Less than 4	Less than 4	16—20	..
Islam	..	Less than 4	Less than 4	20—24	..
Lodhran	..	Less than 4	Less than 4	16—20	..
Baghdad-ul-Jadid	..	Less than 4	Less than 4	16—20	—
Rahimyarkhan	..	4.8	Less than 4	20—24	..
Khanpur	..	4.8	Less than 4	..	..
Dallas	..	4.8	Less than 4	24—28	..
Shujabad	..	4.8	..	20—24	..
Fordwah	..	4.8	..	8.12	..

APPENDIX III

Quality of Drain Water in H/I Plot in Different Periods under open Drainage System at C. R. F.

Drain No.	1930		1931		1964		1965		1966		1967	
	Conductivity in Micromhos/cm	Dissolved salts ppM	Conductivity in Micromhos/cm	Dissolved salt ppM	Conductivity in Micromhos/cm	Dissolved salts ppM	Conductivity in Micromhos/cm	Dissolved salts ppM	Conductivity in Micromhos/cm	Dissolved Salts ppM	Conductivity in Micromhos/cm	Dissolved salts ppM
1.	925	661.8	750	536.7	Dry	...	Dry	Dry	...	..	335	214.7
2.	1100	787.5	750	536.7	330	236.1	...	..	..	..	391	250.4
3.	1100	787.5	875	626.1	460	329.0	...	...	671	429	391	250.4
4.	1250	894.4	950	679.7	390	270.0	..	...	447	286	414	264.6
5.	1250	894.4	900	643.9	470	336.2	..	...	894	572	581	372.2
6.	1150	823.1	825	590.3	400	282.2	..	...	492	315	436	279.0
7.	1650	1180.6	800	572.4	450	322.0	..	...	527	336	391	250.4
8.	950	679.7	800	572.4	390	279.0	..	..	477	286	503	322.0

9.	1800	1287.9	950	679.7	Dry	..	..	...	391	251	391	250.4
10.	990	708.3	1050	751.3	350	250.5	...	..	503	322	526	336.2
11.	880	629.5	800	572.4	Dry	..	..	..	559	358	257	164.6
12.	2150	1538.4	1100	787.5	400	286.2	..	..	716	458	525	271.8
13.	1350	966.0	800	572.4	Dry	..	..	..	458	293	268	171.7
14.	2250	1609.9	1200	858.6	..	..	..	..	559	358	280	178.9
15.	2500	1788.7	900	643.9	..	..	..	..	671	429	391	250.4
16.	730	522.3	825	590.3	..	...	..	..	527	336	380	243.2
17.	850	608.2	1350	966.0	..	..	..	..	503	332	..	..
18.	1050	751.3	850	608.2	490	350.6	..	..	615	394	369	236.1
19.	950	679.7	775	554.6	Dry	..	..	..	1208	774	324	207.4
20.	950	701.1	825	590.3	380	271.8	..	..	..	..	380	243.2