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Land and Water Management in West Pakistan

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Introductory

For successful crop production the nation should have the ability to make proper use of the available resources. West Pakistan has a major physical asset of having a flat and fertile plain and good water quality of great rivers. The province of West Pakistan covers about 199 million acres with a population of about 59 million people. This part of the country was practically self-sufficient at the time of Independence. But since then the agricultural production, particularly the food grain did not keep pace with the increasing population. Thus a nominal import of food grain was started in normal years. The minimum net import of 15 thousand tons (1949-50) went up to the maximum of 2.3 million tons in the year 1966-67. This was indeed a grave situation and therefore the Government laid great stress on the implementation of food self-sufficiency programme.

Inadequate soil moisture is the major drawback in crop production in West Pakistan. Failure of rains at time of sowing of crop and during the growing period affect the growth and size of area under crops. Rains also affect the supplies of water in the rivers. The climatic conditions do not permit successful crop production in the major part of West Pakistan without irrigation. The average annual rainfall is 3"—15" 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 inches, 24.2% between 10 to 20 inches, 5.4% between 20 to 30 inches and only 3.7% more than 30 inches annually. The climatic variations, however, do not impose any serious constraints except for the necessity of irrigation due to scarcity of rainfall.

Of the annual mean discharge of 168 M.A.F. from the rivers entering the Indus plains—the flow that would be available after the implementation of Indus Basin Treaty with India is 135 M.A.F. Out of the total 102.8 M.A.F. is now (1967-68) in use and 24 M.A.F. will be used to feed the canals and replace the water which is being withdrawn by India. In due course of time the balance supply will also be used after the capacity of existing canals is enlarged.

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The water is available year round but not in an adequate quantity. About 66% of the annual flow in the rivers is concentrated in three months, June through August; at present a good deal of which goes waste to the sea. The other source of water supply is the ground water reservoir. Useable ground water underlies a gross area of 18.8 million acres. It is estimated that 44 M.A.F. per year can be pumped from usable ground water sources without exceeding the annual recharge of the aquifer. The present utilization of the ground water source is roughly 11.5 M.A.F.

Out of 132 millions of acreage (reported 1966-67) 48.6 million acres is cultivated. The uncultivated acreage (83.4 million) includes 5.3 million acres of forest. The uncultivated but culturable waste available for cultivation is 32.2 million acres and not available for cultivation is 45.8 million acres. Out of total available cultivable area of 80.8 million acres the area at present under cultivation is 48.6 million acres including 33.3 million under the command of canal irrigation. The area irrigated in 1967-68 is reported as 29.73 million acres out of the total cropped area of 39.2 million acres. The crops raised barani or sown with the help of open persian wells are about 10 million acres. For self-sufficiency in food on a firm footing, the implementation of a well-planned programme under the existing conditions is necessary. This will be briefly discussed in this paper.

Scope for the Extension in Area under Cultivation

The cropped area can be increased by improving the irrigation facilities and by increasing the cultivation in the rainfed areas or in the active flood plains. About 5.2 million acres lie adjacent to the rivers, and are inundated during the summer floods. A large part of the area is fit for crop production during winter months when the excess of the water is drained off after the floods recede. At present most of the area remains uncultivated as sufficient means are not available for the preparation of the seed bed in time for the winter crops. In certain parts there is a fair deposition of sand which is not fertile enough and it will require application of the artificial manures to raise crop. If arrangements are made to crop this area in suitable blocks of 500 to 1000 acres (irrespective of the ownership) by mechanized cultivation, a winter crop can be raised quite successfully. In the active flood plains there is enough reserve of soil moisture and full benefit of it can be derived by properly handling the area under some organized scheme. Arrangements of power for this area will further accelerate the land development work along with the development of ground water. Portions of rolling and levelling sand plains (3.8 million acres) have the most actual or potential promise for productive agriculture if proper measures are taken for conservation of soil moisture derived

from scanty rains. The rainfall variation in different parts play an important role in the agricultural development. Ahmad and Khan (1960) in their study on variation of moisture type divided West Pakistan in 3 sections as shown in map, Appendix I. The problems and solutions of each section are discussed herein as under.

(*i*) The Arid Zone

The moisture index of a particular tract points out the prevalent types of climatic condition. The moisture index as shown in Appendix II is derived by weighing the water surplus and water deficiency against the water need. From the stand-point of climate the water need is mainly the function of temperature which is a quasi-constant element of climate. The moisture index in arid zone is —40 to —100%. This covers the middle and southern Indus plain and quadrangle of Baluchistan Plateau comprising an area of 1,34,00 sq. miles. This area has larger water deficiencies where success of the crops without irrigation is impossible. In this zone though the water deficiency is persistently high and rainfall most variable, the moisture is adequate to support certain grass species on which pastoral farming could be developed. In certain parts of the areas lying on the foot-hills, the run-off water of hill torrents can be conserved for raising both summer and winter crops. In normal years this is successfully practised in some parts of Dera Ghazi Khan & Dera Ismail Khan with similar rainfall pattern. Full use of rain shower should be made by immediate cultivation for proper moisture conservation. The advantage of dry climate should be taken in areas with high elevation 3000—6000 feet as is done in Kabul, Kandhar and Ghazni. Wahab (1968) in his recent report has indicated prospects for production of almonds, grapes, pomegranates, sugarmelons, apples etc. in areas like Gilgit, Skardu, Chitral, North Waziristan and Quetta, which have in general similar climatic conditions as are prevailing in the fruit-growing tracts of Afghanistan.

(*ii*) The Semi Arid and Dry sub-humid Zone

The moisture index of semi arid zone is —40 and dry sub-humid —20. This is the zone where the associated moisture type undergoes the greatest fluctuation. It extends over the submontane strip of Indus Plain, the Potwar Plateau and the western hills. In this zone there is a serious problem of soil erosion. If unchecked by grass or other vegetation cover, myriads of water channels arise converting the country into scrab land or bad land. Many areas in the Potwar Plateau serve as its remarkable example. The average rainfall in the different parts of the region varies from 20 to 30 inches annually. Such lands should be treated in a different manner. In the submontane plain including the districts of Sialkot, Lahore, Sheikhupura, Gujranwala and Gujrat

where irrigation facilities are available, all available land should be brought under regular crop use. In areas where the irrigation facilities are not forthcoming, the cultivation should be regulated and confined to crops which are able to stand soil moisture stress due to the fluctuation of rainfall. Crops like wheat, barley, gram, bajra, linseed, sesamum and groundnuts can be successfully grown.

In the Potwar Plateau where the mean rainfall is generally good but variable, dry farming and pastoral farming can be successfully carried out. The run-off water from the foot-hills should be conserved by construction of bunds. The part of the plateau which suffers from gully erosion needs levelling. This task can be achieved at Government level by employing the heavy machinery, *viz.*, bulldozers. The use of tractors for the cultivation of land after every shower of rain will help to conserve soil moisture in a better manner on larger part of areas. In order to provide extensive and efficient erosion control, a strong extension service will be necessary for soil conservation.

In the case of Western hills arboriculture in conjunction with pastoral farming will be more appropriate.

(*iii*) The Moist Zone

The moist zone includes sub-humid with moisture index zero, humid and per humid with moisture indices as +20 and +100 respectively but with hazard of hail-storm. It constitutes only about 4% of the total area of West Pakistan. This area lies between the plain and the central Himalayas. In this zone attention should be given for water-shed management, maintenance and extension of forest control. This is all the more necessary to prolong the life of the dams on the river Jhelum at Mangla and the river Indus at Terbela. Under the present agricultural practices neither the soil potential nor the available moisture in spite of suitable climate are utilized economically. Such areas are eminently suitable for raising of orchards.

Irrigated areas

The problems of the area where the facilities to supplement the soil moisture with artificial irrigation from river diversions or of the ground water use are numerous and quite complicated. Water shortage is the great handicap which accounts for low crop yields. Because of the seasonal nature of the rivers and shortage of surface storage nearly half the river water flows to the sea unused during the months of June, July & August. Nearly 66% of combined annual flow occurs in these three months. A large fraction of diversion is lost from irrigation canals before it reaches the farmers' fields.

As already stated, the total area irrigated during the year 1967-68 was 29.73 million acres with the total river diversions of 102.8 M.A.F. Since the canals are unlined there are about 50% conveyance losses including those in water courses. The net field delivery is of the order of about 50 M.A.F. The farm deliveries thus work out to 1.7 acre-feet per cropped acre.

It is rather difficult and expensive to eliminate losses from the unlined channels, but the conditions can, however, be improved in case of field water courses (more than 60,000 in number) by straightening the water courses, keeping them free of vegetation and sealing the pervious beds of water-courses with some impervious material. Even if the present losses which may amount to about 20% of the discharges at outlet head are reduced it will give at least a saving of about 5 M.A.F. of water for crop use. A regular campaign is needed for education of the cultivator in this direction; services of the basic democrats and farm guides can be used for this purpose.

Exploitation of the potential of indigenous varieties

Different varieties of crops have a definite yielding capacity under optimum conditions. Previously desired production in wheat could not be obtained as the high yielding varieties were not available in this country. Similar was the case with rice and maize. The introduction of new high yielding Maxi-Pak wheat varieties, Irri-Pak rice varieties and improved varieties of maize have solved the problem to a great extent. Now efforts are being made to introduce such high yielding varieties of cotton as well.

In this Directorate studies have been made to determine the potential yield capacity of the existing indigenous varieties of cotton because the same varieties were yielding different outturn at different places with very marked yield variations. From the detailed study of the analysis results of various soil sites it was found that the requisite requirements of all nutrients are not met with even with the application of the chemical fertilizers. The main deficiency was of calcium, the level of which should be maintained at about 15 me/1 to obtain the maximum outturn which the existing varieties are capable of giving. With the application of calcium the tracts which were capable of giving only 6 maunds/acre have given yield of 20 maunds/acre. The only extra expense was the nominal cost of gypsum applied to meet with calcium deficiencies. The yield results for some of the observation plots are given in Appendix III. In respect of the mode of application the details have been given in a separate publication (September 1967).

Improvement in Irrigation Efficiency

With the type of water modules in use with an average discharge of

1.5 cusecs the experiments on irrigation efficiency showed the maximum efficiency of 70% as obtained in 1/8th acre plot of cotton which was 15% higher than one acre plot. In case of wheat the efficiency in 1/8th 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 plot as compared with one acre, by 56.6% and 26.7% at two experimental stations.

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. This system of layout has also proved very effective in the prevention of upward movement of salt and elimination of appearance of salinity patches on the soil surface.

System of Landholding

Fragmentation and small size of holding is a major bottle-neck in the efficient use of irrigation and farm animals. As shown in Appendix IV the size of the holding varying from 1 acre to under 5 acres forms 49% of the total holdings. The percentage of holding varying in size from 5 to under 12.5 acres, 12.5 to under 25 acres, 25 to under 50 acres, and 50 acres to under 150 acres, is 28%, 15%, 6% and 2% respectively. The size of 150 acres and over is less than 0.5%. The average size of farm holding works out to 9.8 acres, but the size of holding per cultivated area is 6.8 acres only. The small size of holdings has posed serious problem of the distribution of canal supply, as the individual share of water has been reduced to minutes, framing of warabandi by the Canal Officers is becoming a cumbersome job. Some solution to this important issue is the immediate need. The cultivators have to adjust their cropping to meet the need of food, fibre and fodder. He has to maintain at least a pair of bullocks all year round for a small unit of holding, even though the maintenance of bullocks is not economical. This results in poor nourishment and poor output of work. Because of that, the capital cost of a tractor is actually less per horsepower than that of animals. Thus there is a tendency amongst the farmers to purchase tractor, which is fully utilized by not only ploughing their own fields but also their neighbours for a fee of Rs. 5-6 per acre. The input horsepower in Pakistan is lowest in the world which is also one of the major factors for low yields and low production. There is a

fairly good relationship of crop yields and horsepower per hectare for a number of nations and areas. It is calculated that at least 0.5 horsepower per hectare is needed to achieve high yields. In the table given below the data is shown on the available horsepower per hectare of available land in different regions.

TABLE.—*Available horsepower per hectare of arable land and land under permanent crops.*

	Asia except Mainland China and Japan	Africa	Latin America	United States	Europe
Tractor (riding) ..	0.02	0.03	0.18	1.00	0.78
Garden tractor ..	0.03	..	..	0.014	0.02
Animal ..	0.09	0.01	.05	..	0.08
Human ..	0.05	0.01	0.04	0.003	0.05
Total ..	0.19	.05	0.27	1.02	0.93

From the data given above it is apparent that the developing free world is far short of the power required for agricultural efficiency. Timely and better seed bed preparation counts towards increased production. There is a general loss in yields for many crops of about 1 percent per day if seeding is delayed beyond 10-15 days. Inadequate and delayed seed bed preparation in most fields after rice harvest results loss in yield. Rapid seed bed preparation by mechanical methods can make wheat cultivation feasible after even the harvest of cotton to the extent of another 2.5 million acres. This can easily be practised in areas where irrigation facilities are quite adequate especially in SCARPS and in the sweet water table zones where the cultivators have installed their private tubewells. The total number of private tubewells is estimated to be 60,000 which cover gross area of about 10 million acres providing facilities for irrigation in conjunction with canal supply and in many cases independently with about 11 million acres feet of water supply annually pumped.

Timely Agricultural operations

Improved implements for sowing, hoeing and the application of fertilizers play an important role in land management. The increased power can also improve yields by facilitating more efficient and timely harvesting and thrashing,

The experiments conducted in Rangcon, (Burma) have shown that a yield of long grain paddy decreases 2 percent for every day the harvest is postponed after the grain is ripe. To increase the present horsepower per hectare from 0.19 to 0.33 it will take several years. It is necessary to pay immediate attention to install in the country, manufacturing plants for the tractors, power tillers, power sprayers, power harvesting and thrashing equipment and also light animal equipment to meet the minimum requirements of 0.5 horsepower per hectare as early as possible. All the surplus Engineers will be usefully employed to develop, produce and provide for the distribution of machinery. Engineering Universities should provide to produce more Mechanical Engineers, rather than the Civil Engineers. The most appropriate way to make best use of available resources is to increase the yields per acre and to increase the gross harvested area through double or triple cropping. The limiting factors in agricultural development are not natural resources, but economic, institutional and social problems.

Human migration is almost certainly required in the crowded agricultural districts. According to population census of Pakistan 1961 out of total 42.9 million the rural population is 33.2 million, urban population being 9.7 million. The rural population forms 77.5% while the urban population is only 22.5%.

Problems of Water Management

Problems of water management and the interaction of water with other factors of production needs a special attention. Whenever irrigation removes the moisture ceiling on crop yield other management practices such as fertilization, use of amendments and improved varieties and insect and disease control are to be attended to. The advantages of irrigation can only be achieved if other acquired practices are properly followed. In West Pakistan apart from the surface flow, the other major source of water supply is the ground water reservoir which is estimated to contain 2 billion acre feet of water supply to a depth of 450 feet. The quality of ground water is not as good as that of river waters. The salt balance studies of the Indus Plains show that under the prevailing conditions the addition of salt from the canal water with salt concentration of 250 ppm in the northern region is in the order of 0.6 tons per acre and 1.1 tons per acre in the southern region respectively. In respect of water quality of ground water strata of Indus Plains it is estimated that about 48% of the 29.36 million acres in West Pakistan has ground water of salt concentration of less than 1000 ppm. In roughly 12% of the area the salt concentrations vary from 1000—2000 ppm. About 4% area has a salt concentration of 2000—3000 ppm, and 36% area is with salt concentration of

above 3000 ppm. With the use of water of high salt concentrations the input of salts is likely to increase. In the case of the ground water, therefore, the quality of water has been paid a serious attention and efforts have been made to concentrate studies to watch the effects both on crops and soils. With the increasing concentration of salts the additional water requirements over and above the consumptive use also increase tremendously to maintain favourable salt balance in the root zone. If the irrigation water has 1000 ppm of salt the required amount for leaching is at least 10. The use of ground water is also imposing a serious problem of alkali. Some of the ground waters characterized by presence of sodium, carbonate and bicarbonate ions in appreciable amount have increased the alkali hazards in certain parts of irrigated lands in northern zone of West Pakistan.

Type of Salinity

In the use of ground water, it will become more appropriate to have full knowledge of type of ions, and their permissible limit for normal growth of different kinds of crops. Studies on the role of these ions on soil deterioration and the reclamative and preventive methods that could be adopted for restoring the productivity of soil will be of great utility and interest.

Hussain *et al* (1968) has shown that absolute amount of (Ca+Mg) concentration in the saturated extract greatly influence the relationship between ESP & pH of the saturated paste. The soils in which calcium plus magnesium content is fairly higher than the soluble sodium can safely be rendered productive after removal of excessive salts by simple leaching. For the correct evaluation of the effects of salinity on the soil profile and agricultural crops it is necessary to differentiate salinity according to cation and anions of the predominating salts. The four main types of salinity indicated in respect of anions are:—

(*a*) Salinization of sulphate type.
(*b*) Salinization of chloride sulphate type.
(*c*) Salinization of sulphate chloride type.
(*d*) Salinization of chloride type.

In conjunction with carbonate and bicarbonate the effects of salinity types listed (a to d) become more pronounced with the variation in the soil texture; for example, clayey soil may exhibit a more pronounced salinity because they are capable of storing more water than sandy areas. In practice it is, however, easier to get rid of salts in sandy soil. The most harmful are all sodium salts and all the chlorous compounds.

The sulphate and chloride sulphate type of salinity is noticed in the former Punjab, Peshawar region, Sakrand on Rohri canal and Ghotki area on

Guddu Barrage of former Sind. In case of sulphate type of salinity the ratio of Cl to SO_4 is 0.5 and in chloride-sulphate type of salinity this ratio ranges between 0.5 to 1.0.

Chloride and sulphate chloride type of salinity is noticed in former Bahawalpur, Ghulam Mohammad Barrage, Rawalpindi and Quetta tracts. The range of ratio of Cl to sulphate in case of sulphate-chloride of salinity is 1.0 to 5.0 and in case of chloride type of salinity it is over 5.0.

The chloride type of salinity in fact is comparatively more injurious than the sulphate type of salinity. The salinity of Nacl is 264 gm/1. Even 0.1% of this salt is sufficient to retard the normal growth of plants. The degrees of the toxity of different salts varies considerably according to their chemical behaviour or affinity, for example, the sodium and magnesium chlorides are two to three times more toxic than magnesium and sodium sulphate. The presence of carbonate and bicarbonate creates a serious problem of severe alkali and may warrant the use of gypsum for the amelioration of saline alkali soil if divalent ions (Ca+Mg) are not adequately available.

Scope for use of waters of high salt concentration

. The analysis of the saturated extract of the normal good soil indicates EC of less than 4 mmhos, salt concentration on dry weight basis less than 0.2%, exchangeable sodium less than 2-3 meq/1 100 gm of soil and pH of saturated paste is about 8.0. What should be the reasonable concentration of salts in the root zone for the normal growth of various farm crops under prevailing irrigation practices has been given in the previous paper No. 384, Proceedings of Engineering Congress March, 1967. In order to maintain a favourable salt balance there are limitations on the use of ground waters. Herein attempts have been made to indicate up to what salt content the irrigation waters can be used safely for various crops. On the basis of the U.S. Salinity Laboratory salt tolerance data, the E.C. value to be used in calculating the leaching requirements for some lands as adopted by Maasland and Chaudhry (1966) is reproduced in table on page 11.

Based upon the permissible salt concentrations of leachate the content of irrigation water at 10% and 20% leaching would be as shown in column No. 4 and 5 of the table mantained above.

When leaching requirement is limited to 10%, the salt content of the applied irrigation water may be about 1000 ppm for barley, cotton, wheat, sugarbeet, rye-grass and sorghum and not to exceed 500—600 ppm for rice, sugarcane, corn, cabbage, soybean tomatoes and alfalfa.

TABLE.—*Permissible salt concentrations of leachate expressed as electrical conductivity (ECd), for calculating the leaching requirement for various crops.*

Crop	Permissible ECd		Possible salt concentration (ppm) of irrigation water with leachng requirements of	
	mmhos/cm	ppm	10%	20%
1	2	3	4	5
Barley (grain) ..	18	11520	1152	2304
Barley (hay) ..	13.5	8640	864	1728
Sugarbeet ..	16	10240	1024	2048
Cotton ..	16	10240	1024	2048
Wheat ..	14	8960	896	1792
Sorghum ..	12	7680	768	1536
Safflower ..	12	7680	768	1536
Ryegrass ..	13	8320	832	1664
Soybean ..	9	5760	576	1152
Sesbania ..	9	5760	576	1152
Alfalfa ..	8	5120	512	1024
Tomato ..	8	5120	512	1024
Sugarcane ..	8.5	5440	544	1088
Rice ..	8	5120	512	1024
Corn ..	7	4480	448	896
Cabbage ..	7	4480	448	896
Potato ..	6	3840	384	768
Sweet potato ..	6	3840	384	768

ppm is equal to 640 × mmhos/cm.

If the leaching requirement is limited to 20%, the salt content of the irrigation, water must be approximately 2300 ppm for barley, 2000 ppm for sugarbeet, cotton and wheat, 1500 ppm for ryegrass, sorghum and 1000 ppm for soybean, rice, sugarcane, corn, cabbage and alfalfa.

At present, as already expressed, we are applying less irrigation application. But with the increased water supply from the ground water source and with 150% intensity of cropping as aimed at in our SCARPS it will be

possible to meet with the full consumptive use requirements and the leaching requirements to the extent of about 10%. As such, theoretically, under no circumstances we should exceed the limit of 1000 ppm of the salt concentration of our irrigation waters. But in actual practice the irrigation field efficiency in case of one acre plot is about 55% and in 1/8th acre plot is 70%. This would mean that about 45% of water is wasted or passed through the root zone in case of one acre plots whereas about 30% in case of 1/8th acre plots. The penetration in one acre plot is, however, not uniform throughout the field and farther ends receive shallow irrigation application even to wet the soil to a proper depth of root zone. This results in salinization (in slick spots) and unnecessary wastage of water in other portions. From this it can be inferred that at 70% irrigation efficiency under ideal field conditions approximately 20% leaching requirements are automatically met with from the irrigation water applied irrespective of the consumptive use requirement of crops. From this it appears that permissible limit of the salt concentration of irrigation water can thus be raised without any danger of salinity, to the extent as given in column 5 of the table provided that SAR and the RSC responsible for alkalinity remain well within the permissible limits. More data is, however, needed in this regard. Therefore an intensive research work has been started and is in progress at the Directorate of Land Reclamation in the Laboratory and field stations.

Scope for modification in the concept of Residual sodium carbonate

The extent to which exchangeable sodium accumulates in soils irrigated with high carbonate water depends upon the SAR of the water and the fraction of applied carbonate that precipitates as $CaCO_3$. In order to isolate the effects of RSC and SAR, waters of low salt content with varying RSC and low SAR values well within the permissible limits were passed through soil columns of 16 inches in four sets. The interval between each irrigation was 5 days. The application was made in 4 inches instalments and the total depth of application was 50, 70, 90 and 120 inches in each case. There were two replications of each set.

The analysis results of water quality and soil before and after the treatment of each set are given in table on pages 13—15.

Set No. I.

From the data given it is revealed that the use of canal water with SAR 0.76 and RSC nil has reduced the SAR to about half in the soil columns saturated with 50", 70" and 90" of irrigation applications. With 120" irrigation the SAR (5.25 of soil extract) came down to 1.09. The overall effects of the canal water are quite favourable in respect of the elimination of alkalinity hazard.

TABLE.—*Showing analysis results of water quality used for irrigation and of the soil before and after treatment.*

	Milliequivalents per litre							Parts per Million D. by Evap	EC × 10^3 at 25°C	pH	Res CO^3 me/l	SAR
	Ca+Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Cations Anions					
SET NO. I.												
Water *Quality* (*A*) (Control Canal Water)												
	2.2	0.8	..	0.7	0.3	2.0	3.0	160	250*	8.1	..	0.76
Original soil.												
	6.25	9.25	..	6.32	5.9	3.28	15.5		1.55	8.1	0.07	5.25
Treated soil.												
With 50" of Irrigation ..	3.37	3.17	..	3.37	1.31	1.86	6.55		0.65	..	0.5	2.49
With 70" of Irrigation ..	2.69	3.01	..	2.75	1.5	1.45	5.7		0.57	..	..	2.59
With 90" of Irrigation ..	2.94	3.56	..	2.81	1.5	2.19	6.5		0.65	..	..	2.93
With 120" of Irrigation ..	5.6	1.85	..	5.0	1.75	0.7	7.5		0.75	..	..	1.09
SET NO. II												
Water *Quality* (*B*) (containing no Residual Carbonate												
	4.6	8.4	..	3.7	2.5	6.8	13.0	777	1230*	8.5	..	5.46
Original soil.												
	6.25	9.25	..	6.32	5.9	3.28	15.5		1.55	8.1	0.07	5.25

TABLE.—*Showing analysis results of water quality used for irrigation and of the soil before and after treatment.*

	Milliequivalents per litre							Parts per Million D.S. by Evap	EC × 10^3 at 25°C	pH	Res CO^3 me/1	SAR
	Ca+Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Cations Anions					
Treated soil.												
With 50'' Irrigation ..	4.0	5.62	..	3.25	3.06	3.31	9.62		0.96	..	0.12	4.02
With 70'' Irrigation ..	4.87	9.62	..	4.12	4.75	5.62	14.5		1.45	..	..	6.15
With 90'' Irrigation ..	4.0	10.2	..	4.0	4.0	6.2	14.2		1.42	..	..	7.2
With 120'' Irrigation ..	5.25	5.2	..	4.9	2.6	2.9	10.4		1.04	..	..	3.19
SET NO. III.												
Water *Quality* (C) (containing Medium Residual Carbonate)												
	2.6	6.1	0.7	3.8	1.2	3.0	8.7	493	770*	8.6	1.9	5.3
Original soil.												
	6.25	9.25	..	6.32	5.9	3.28	15.5		1.55	8.1	0.07	5.25
Treated soil.												
With 50'' Irrigation ..	2.87	7.12	..	5.0	3.37	1.62	10.0		1,00	..	2.12	5.87
With 70'' Irrigation ..	2.62	8.32	..	4.0	2.5	4.45	10.82		1.08	..	1.37	7.21
With 90'' Irrigation ..	3.9	7.9	..	5.25	3.0	3.5	11.8		1.18	..	1.4	5.4
With 120'' Irrigation ..	5.0	6.9	..	5.6	2.75	4.3	11.9		1.19	..	0.6	4.4

SET NO. IV.

Water *Quality* (*D*) (containing High Residual Carbonate)

	2.0	8.9	0.7	5.5	1.2	3.5	10.9	640	1000*	8.8	4.2	9.07
	Original soil.											
	6.25	9.25	..	6.32	5.9	3.28	15.5		1.55	8.1	0.07	5.25
	Treated soil.											
With 50'' Irrigation ..	2.5	7.87	..	3.87	2.87	3.62	10.37		1.04	..	1.37	7.36
With 70'' Irrigation ..	2.25	10.12	..	5.0	2.5	4.81	72.37		1.24	..	2.75	9.51
With 90'' Irrigation ..	3.19	11.19	..	5.25	3.9	5.2	14.35		1.44	..	2.06	8.76
With 120'' Irrigation ..	3.9	7.1	..	5.9	2.4	2.7	11.0		1.1	..	2.0	5.5

*EC $\times 10^6$

Set No. II.

In this set the water quality was of EC 1230 micromhos/cm, RSC nil and SAR 5.46. The maximum increase in SAR of soil extract was from 5.25 to 7.2 in 90 inches irrigation application while 120 inches irrigation treatment showed reduction to 3.19. No signs of any alkalinity hazards are evident.

Set No. III.

Water quality used in this set had EC 770 micromhos/cm, SAR 5.3 (against 10 of the permissible limit) and RSC 1.9 against 1.25 me/l prescribed for water of good quality. The maximum increase in SAR of soil extract is from 5.25 to 7.21 with 70 inches irrigation application which is still well within the permissible limits. Evidently there is no sign of alkalinity hazards with use of water of this quality.

Set No. IV.

The water used in this case had EC 1000 micromhos/cm SAR 9.07 and RSC 4.2 me/1. The maximum increase in SAR of soil extract is from 5.25 to 9.51 in 70 inches irrigation applications which seems to be in equilibrium with SAR of irrigation water and still within the permissible limits.

The data collected in the experiment clearly indicate that so long as the EC and the SAR of the irrigation water are within the permissible limits, the RSC up to even 4.2 me/1 do not show any alkalinity hazards in the soil. As such in the evaluation of the quality of water with respect to the presence of RSC the salt content and SAR of the water should also be simultaneously considered. If the salt content and SAR are within the prescribed permissible limits there is ample room for raising the RSC limits to the extent even up to 4.0 meq/1 for medium textured *non-saline* and *non-alkali soils*.

Effect of RSC of Water under high leaching regime

In another set the water quality with EC 1400 micromhos/cm, RSC 7.2 and SAR 6.9 when passed through in containers having known analysis of the soil has also given interesting results as shown in the tables on page 17.

From the examination of the results it is revealed that the SAR of the soil after treatment has increased from 7.8 to a maximum of 9.0 in case of the container cropped with rice and 10.0 in case of uncropped one. The SAR of treated soil has shown some increase as compared to the original soil, the effect being a bit higher in case of the uncropped containers.

TABLE.—*Showing the analysis of water used for irrigation.*

	Ca	Mg	Na	HCO_3	Cl	SO_4	Total Cations Anions	EC × 10^6 at 25°C	pH	Res CO_3 me/l	SAR
	1.70	2.5	10.0	11.4	1.9	0.9	14.2	1400	8.3	7.2	6.9

TABLE.—*Showing the analysis of soil before and after irrigation application.*

Soil pre-irrigation treatment.

	Ca+Mg									
	4.00	11.0	3.0	5.0	7.0	15.0	1.5*	..	..	7.8

Soil after irrigation treatment.

1. Cropped with Rice ..	2.50	10.38	6.5	3.5	2.88	12.88	1.16	8.3	4.0	9.2
2. Cropped with Rice ..	2.50	10.37	6.5	2.5	3.87	12.87	1.32	8.3	4.0	9.2
2. Uncropped with Rice	1.75	9.38	5.0	1.0	5.1	11.13	1.10	8.5	3.25	10.0

*EC 10^3

From the water applied and leachate collected the input and output of RSC were calculated which are given in table below:—

TABLE.—*Showing the input and the output of RSC.*

Container No.	Cropped or uncropped	Water applied (litres)	RSC added (gms)	Leachate collected (litres)	%age of leaching collected over the water applied	RSC collected in leachate (gms)	RSC retained in the container (gms)
1.	Cropped with rice ..	47.6	28.788	25.33	53.20	22.006	6.782
2.	Cropped with rice ..	47.7	28.861	27.90	58.47	22.308	6.553
3.	Uncropped ..	47.2	28.547	34.23	72.52	24.312	4.235

From the above results it is observed that the retention of RSC from the irrigation water is of the order of 6.5 gms. in case of the cropped containers and 4.2 gms. in case of the uncropped one. It is also noted that the leaching percentage in case of uncropped container was 75% as compared to 55% of the cropped ones and on this account there was comparatively more reduction in EC of saturated extract of soil and so with Na and Ca+Mg contents. The results, however, give indication that in spite of heavy leaching in a small column of soil there is trend in the increase of alkalinity more than the contents of irrigation water and of the untreated soil. This leads to conclude that with even high leaching, to the extent of 55—75% which kept the soil column, almost at saturation level during the currency of treatment the alkalinity hazard due to R. S.C. could not be completely eliminated. Obviously the lesser retained quantity of RSC in soil should have lesser deleterious effects but it is just the reverse as indicated by SAR results probably due to the changes in the calcium content. The field conditions, however, where many other factors are introduced by farming the effect of these waters might be quite different. Also the same quality of water will produce different effects on normal as compared to saline alkali soils.

Summary

Cropping area and crop yields can be increased in rain-fed and active flood plain areas by using proper conservation practices and improved soil management.

Mechanized farming will contribute considerably to the economy of the country. Bullock-power is under-utilized and not economical and efficient.

Reduction of seepage losses from the water conveyances will save considerable water which can be used for irrigation.

Ground waters will contribute to the size and yields of irrigated areas. Quality standards of water as used now will have to be revised especially with respect to the limits of soluble salt and the residual sodium carbonate content. Results show that RSC limit might be higher than 2.5. The SAR limit might have to be raised also.

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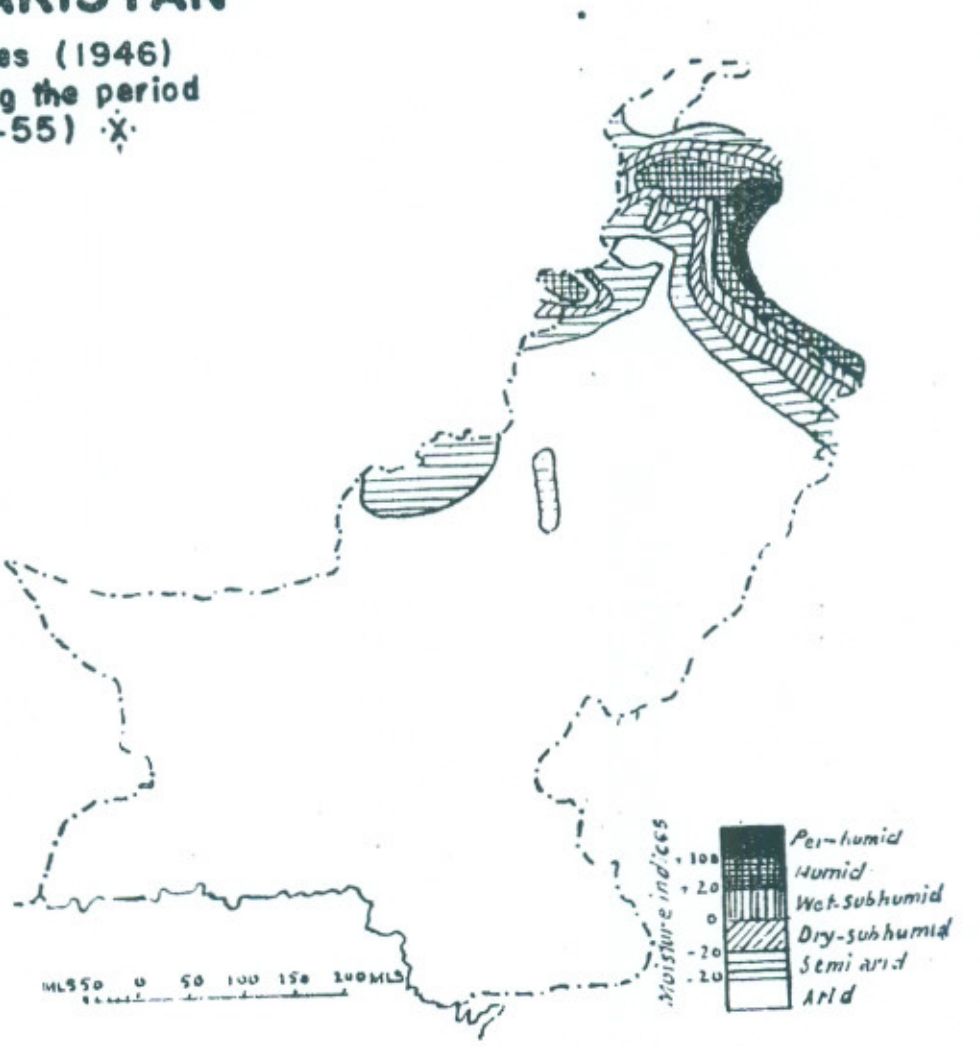
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APPENDIX I

WEST PAKISTAN

Moisture Types (1946)
Driest Year-during the period
(1930-55) ·X·



·X· Ahmad and Khan ! variation of soil moisture syumposium on soil erosion and its control 1960.

APPENDIX II

MOISTURE DATA FOR SELECTED STATIONS*

	Yearly water need (cms.)	Summer concentration of T-E%	Yearly precipitation (cms.)	Water surplus	Water deficiency	Surplus percentage of need	No. of months with surplus	Deficiency percentage of need	No. of months with deficiency	Moisture index
1	2	3	4	5	6	7	8	9	10	11
Badin ..	158.2	38	24.2	0	135.0	0	0	85	12	—51
Bannu ..	134	42	27.7	0	106.7	0	0	81	10	—47
Chaman ..	104.8	50	25.0	3.0	83.2	3	1	79	6	—44
D. I. Khan ..	139.5	42	22.7	0	116	0	0	81	10	—50
Drosh ..	94.0	53	45.1	12.4	62	13	2	65	6	—26
Fort Sandeman ..	111.4	48	20.0	0.0	86	0	0	70	8	—41
Gilgit ..	92.5	54	12.9	0	80	0	0	83	10	49
Hyderabad ..	154.7	38	17.7	0	137	0	0	88	12	—53
Jacobabad ..	152.2	38	9.0	0.0	143	0	0	94	12	—56
Kalat ..	72.5	60	17.4	0	54.8	0	0	76	7	—45
Karachi ..	148.4	40	19.2	0	129	0	0	87	12	—52
Khushab ..	140.3	42	37.9	0	103	0	0	73	10	—43

Lahore	.. 133.8	43	48.0	0	80	0	0	60	10	—37
Las Bela	.. 150.9	40	20.9	0	120	0	0	86	10	—51
Lyallpur	.. 135.9	42	30.1	0	107	0	0	78	10	—47
Miranshah	.. 115.9	48	27.8	0	88	0	0	76	7	—46
Montgomery	.. 140.8	41	25.0	0	150	0	0	82	10	—49
Multan	.. 144.4	40	17.6	0.0	127	0	0	88	12	—52
Murree	.. 70.9	62	148.4	82	0	0	7	0	0	115.7
Nokkundi	.. 134.0	42	4.8	0.0	129.3	0	0	93	10	—58
Panjgur	.. 120.1	46	12.0	0	108	0	0	90	9	—54
Pasni	.. 140.0	42	15.4	0	126	0	0	90	10	—53
Peshawar	.. 127.0	44	33.9	0	94	0	0	74	7	—44
Quetta	.. 80.1	58	23.6	0.8	58	0	2	72	7	—42
Rawalpindi	.. 122.6	44	90.8	2.3	33.9	22	2	28	5	14.7
Sialkot	.. 130.7	44	79.5	0	53	0	0	40	6	—24
Sibi	.. 151.9	39	14.0	0	132	0	0	87	10	—52
Sukkur	.. 151.3	39	9.2	0	144	0	0	94	12	—56
Parachanar	.. 80.6	58	73.1	14.5	20.1	17	3	25	6	— 3

*As calculated by Ahmad and Khan. (11)

APPENDIX III

YIELDS OF COTTON OF TREATED AND UNTERATED PLOTS AT RAHIMYARKHAN

Sr. No.	Sq/Killa	Size of plots (acre)	Treatment per acre			Yield (Mds/ acre)
			Gypsum (lbs.)	Ammonium sulphate (lbs.)	Triple phosphate (lbs.)	
1.	226/13/25 ..	0.5	450	224	112	25.825*
2.	267/13/15 ..	0.5	360	224	112	19.875
3.	286/2/7 ..	1.0	450	224	112	19.625*
4.	286/2/8 ..	1.0	360	224	112	18.250
5.	266/13/24 ..	0.5	450	224	112	15.825*
6.	266/14/21 ..	1.25	360	179	89	15.471
7.	267/13/4 ..	0.5	360	224	112	13.950
8.	226/16/24 ..	0.5	360	224	112	13.650
9.	266/16/12 ..	1.0	360	224	112	13.350
10.	266/13/4 ..	1.0	450	224	112	13.075*
11.	266/16/4 ..	0.5	360	224	112	12.862
12.	267/16/10 ..	1.0	360	224	112	12.631
13.	286/7/19 ..	1.0	360	168	112	12.210
14.	287/3/16 ..	0.5	360	168	112	12.025
15.	268/13/10 ..	0.5	360	224	112	10.625
16.	286/3/25 ..	1.0	360	224	112	8.140
				Average		.. 14.837

NOTE:— The average yield of the non-treated fields in this area works out to 6.67 maunds/acre.

*Treatment carried out under the supervision of staff.

APPENDIX IV

NUMBER AND AREA OF FARMS IN WEST PAKISTAN BY SIZE

Farms Size	Farms		Farm area		Cultivated area	
	Number	Percent	Total	Percent	Total	Percent
	in thousand		in thousand acres		in thousand acres	
Under 1.0 acre	742	16	334	1	267	1
1.0 to under 2.5 acres.	856	18	1,345	3	1,154	3
2.5 to under 5.0 acres.	806	16	2,911	6	2,535	7
5.0 to under 7.5 acres.	581	12	3,546	7	3,127	8
7.5 to under 12.5 acres.	759	16	7,357	15	6,489	17
12.5 to under 25.0 acres.	729	15	12,533	26	10,710	29
25.0 to under 50.0 acres.	286	6	9,468	19	7,387	20
50.0 to under 150.0 acres.	87	2	6,539	13	3,886	10
150.0 acres and over	14	(*a*)	4,896	10	1,694	5
Total ..	4,860	100	48,929	100	37,249	100

(*a*) Percentage less than 0.5

Source: 1960 Pakistan Census of Agriculture, Vol. II, West Pakistan Agricultural Census Organization, Ministry of Food and Agriculture.