Impact of Irrigation Research on the Developing Economy of West Pakistan

By

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I. INTRODUCTION

Irrigation was never so important in human civilisation as it is at present. Two thirds of the world is under-fed, that is, the basic sustenance of life is not being made available in adequate quantity to the major portion of humanity. While the possibilities are definitely there to feed all the people we have got to take various steps. Of these, irrigation is perhaps the primary one. Thus forced by sheer necessity and driven by climatic conditions man has developed the art of irrigation over the ages taking advantage of the mighty rivers that were otherwise flowing waste to the sea and of ground water storage which was available underneath. Consequently an extensive network of irrigation systems large and small have sprung up and today the practice of irrigation is a necessity for agriculture under arid and semi-arid conditions.

In West Pakistan which is arid to semi-arid (area) the development of water resources for irrigation was taken in hand long ago, with the result that now we have one of the world's most elaborate and extensive systems of irrigation works. Mighty rivers have been tamed and water diverted into thousands of miles of big and small canals that today serve more than thirty three million acres of land in West Pakistan. These irrigation works utilize almost all the perennial flow of rivers and have turned once barren lands into green fertile fields which are feeding millions of people of the country. The diversion of water from the rivers to the canals and then to the watercourses involved problems of great hydrological importance. The use of this water on the soil which has been left to the cultivators is another equally important aspect of irrigation. In this paper it is proposed to dilate on this latter aspect of irrigation research and to see its effect on our developing economy.

II. ORGANISATION OF RESEARCH IN LAND RECLAMATION

Looking back we find that with the extension of irrigation facilities to unirrigated areas, problems like those of salinity and waterlogging started plaguing our agriculture. Consequently some attempts to study cause of the

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origin and spread of the maladies with the object of finding remedies were started about seventy years ago. It was in 1892 that Sir Thomas Highman started investigations on the rise of open well water level due to rain. The problem of rising water-table had perhaps been visualized by him at that very juncture.

Some sort of organized attempts, however, began in 1917, when the Government of the Punjab established a Drainage Board for carrying out investigations regarding the causes of waterlogging. A few years later, the Board was replaced by another body called the Waterlogging Enquiry Committee to do the work on a more scientific basis. For this purpose one Engineer and one Scientist were included in this organisation. To carry out research a Laboratory was set up in 1927 under Irrigation Department. A separate section within the Irrigation Research Institute was formed a few years later for dealing with problems of Land Reclamation.

Further research on Soil Reclamation and Development was considered necessary and in view of the nature and volume of work involved, a separate Directorate of Land Reclamation was created in 1945. A soil Laboratory was attached to this Directorate for carrying out research as well as routine analytical work in connection with soil problems and quality of waters. The need for soil and water research has been becoming more and more pressing with the high rate of soil deterioration which has resulted from the irrigation practices followed in the areas served by the Indus Valley Canals.

III. RESULTS ACHIEVED BY RESEARCH

Through basic and applied research in the Laboratories and Field Experimental Stations on soil and water problems, the following results have been achieved, which have a great impact on our economy.

1. *Standards of deteriorated and reclaimed soil.*—Fixation of standards of deteriorated and reclaimed soil on the basis of total salt contents and alkalinity. Soils containing soluble salts up to 0.2 per cent and pH less than 8.5 were categorised as normal. Presence of salts above 0.2 per cent and a pH above 8.5 were considered detrimental to crops, resulting in their decline of productivity.

2. *Suitability of water for irrigation.*—An index to determine the suitability of water for irrigation purposes was established. The installation of surface wells and tubewells without caring for the quality of the water could spell disaster to the soils and consequent agricultural productivity. A proper diagnosis of water before its application on soils saved large areas from utter ruination. Besides the electrical conductance and total salts present in irrigation waters, factors like "Salt Index" which have a direct bearing on the relative

proportion of Na^+ to Ca+Mg were also taken into consideration before deciding the usability of a particular water. The latest concepts of 'Residual Sodium Carbonate', 'Sodium Adsorbtion Ratio' and 'Calculated ESP' have greatly added to our knowledge in predicting the effect of irrigation water on a particular soil.

The standards for quality of water worked out in the Laboratories of Land Reclamation Directorate are as under:—

CLASSIFICATION OF IRRIGATION WATERS

(*i*) Conductance E.C. $\times 10^6$ Quality

0 — 750		Good
751 — 1750		
1751 — 3000	1:1	Dilution
3000 — 4500		
Above 4500		Unfit

(*ii*) Sodium-Adsorption-Ratio $SAR = Na \sqrt{\frac{Ca+Mg}{2}}$

SAR	Quality
Less than 10	Good
10 — 20	1:1 Dilution

SAR IS INTERPRETED JOINTLY WITH CONDUCTANCE

(*iii*) *Salt Index*

(Total Na—24.5)—(Total Ca—Ca in $CaCO_3$) $\times 4.85$

S. I.	Quality
Negative—Ve Salt Index	Good Water
Positive+Ve Salt Index	Bad Water

All values are expressed in ppht.

Interpretations of salt index are limited up to 1200 ppm of dissolved solids. Magnesium is added to Calcium for calculating the Salt Index.

(*iv*) *Residual Sodium Carbonate.*

Res. $Na_2 CO_3 = (CO_3 + HCO_3) - (Ca + Mg)$

Res. Sod. Carbonate		Quality
Less than	1.25	Good
1.25 —	2.50	Marginal
More than	2.50	Unsuitable

All values are expressed in millequivalents per litre.

(*v*) *Calculated ESP*

$$ESP = 2\ SAR + 2\ SAR\ (8.4 - pHC)$$

ESP		Quality
Less than	10	Safe
10 —	20	Marginal
More than	20	Hazardous

(*vi*) *Boron*

Boron greater than 1 ppm is injurious to many plants.

3. *Technique for reclamation of saline and alkali soils.*—Technique for the reclamation of saline and alkali soils was evolved which is now in practice with the cultivators all over the province. The soils of the province are of alluvial origin and have salts distributed in the profile. The canal irrigation system is designed to provide considerably less water to the land than is required to keep it free from accumulation of salts and the irrigation practices have resulted in the creation of a zone of accumulation of salts which rise up to the soil surface and have turned once fertile lands into saline-alkali lands unfit for crop production. Before undertaking reclamation operations, salinity survey (Thur Girdawari) is carried out.

The reclamation is carried out by providing excess water for 3 years for leaching down the salts. This additional supply is given at the rate of one cusec for forty five acres of land which is six times the normal allowance of water for cultivated areas of the province except SCARP I. The cultivator is required to level the field, construct dykes for holding water in quarter acre plots and to apply water after every seven days during summer. He has to sow either paddy or the legumes such as Sesbanea Aculeata during the summer and irrigated Egyptian clover or unirrigated gram during the winter. Where there is abundance of soluble salts in the soil in addition to high alkalinity, rice is grown

during the first 2 and 3 years to wash away the salts. The rice is followed by deep-rooted Sesbania Aculeata. Where high alkalinity is manifested without high salts the legume is introduced from the very beginning and the paddy follows afterwards. This method of reclaiming land is chemically, agriculturally and economically sound. Based on this method an area of 584270 acres has been reclaimed from 1945 to 1965.

4. *Correction of alkali soils.*—The research work carried out both in the Laboratories and at experimental stations suggested the solution for the correction of alkali soils. Vast tracts of undeveloped alkali soils exist on various canal systems which were considered unreclamable as a result of experimentation by the Agriculture Department at Bara Farm, Montgomery. The Projects for the reclamation of alkali soils declared unreclaimed by the Agriculture Department were drawn up by the Irrigation Department in 1943-45 and implemented in Government waste lands in various districts with great success. About forty thousand acres of alkali soils have so far been corrected without the use of any amendments.

5. *Consumptive use of water.*—In the past the crop pattern and water allowance in various irrigation projects were determined simply in the light of experience gained on the projects without adequate scientific surveys. For dependable and profitable agriculture it is necessary to determine the optimum water requirements for soil conditions obtained at site. Consequently studies on irrigation requirements and consumptive use of water by crops were taken in hand and data were compiled. Knowledge of optimum water requirements for different crops under variable soil and meteorological conditions is essential to grow successful crops. In order to supply these requirements it is also essential to use the most efficient irrigation practices so that there may be the minimum waste of irrigation water. The water requirements for crop production are generally considered to consist only of the moisture requirements for growth of plants. The soil problems that arise in arid regions have shown beyond doubt, that for sustained crop production the water requirement consists also of the requirements of the soil. Consumptive use of water by different crops has been determined by the following methods:

(*i*) Lysimeter methods.

(*ii*) Soil moisture studies.

(*iii*) Statistical methods based on meteorological data.

(*i*) Lysimeter studies were conducted under controlled conditions at a water-table of 10.5 feet. Accordingly it was possible to work out the water use of various crops. The experiment was previously conducted with the individual

crops and later on water use of crop rotations was determined. The data were compiled for the following crops:

(*a*) Reclamation Rice.
(*b*) Ordinary Rice.
(*c*) Berseem.
(*d*) Sugarcane.
(*e*) Maize.
(*f*) Wheat.
(*g*) Cotton.
(*h*) Gram.
(*i*) Wheat-Cotton-(Senji)-Sugarcane.
(*j*) Wheat-Wheat-Toria-Cotton.
(*k*) Wheat-Cotton-Fodder.

The observations taken at a fixed water-table of 10.5′ are as under:—

CROPS TRIED

Crop	Total surface application inches.	% Accretion or Depletion	Accretion or depletion in fraction
Reclamation Rice ..	62.06	34.8%	1/3
Ordinary Rice ..	57.16	24.5%	1/4
Berseem ..	19.35	28.2%	1/4
Sugarcane ..	51.36	10.7%	1/10
Maize ..	22.02	40.1%	1/3
Wheat ..	16.95	1.58%Depl.	1/50
Cotton ..	38.76	14.0%	1/7
Gram ..	10.06	0.29%Depl.	1/30

The results show that in case of rice there is accretion to water-table from 24 to 34 per cent, while in case of Berseem the average accretion is 28%. Sugarcane and Maize also cause accretion to the water-table. The crops which cause depletion to the water-table are wheat and gram.

(*ii* and *iii*) In addition to it the consumptive use of water, by crops in different areas of West Pakistan, was investigated using soil moisture studies and the statistical method of Blaney and Criddle. This investigation covered the former Punjab, N.-W.F.P. and Bahawalpur areas. From this data the amounts

of water consumptively used, the amounts supplied by precipitation and the net amount that must be supplied by irrigation were calculated. To prevent the recurrence of salinization some excess water was suggested to flow past the root zone to depress the injurious salts. These experiments helped the experts in designing cropping patterns for different types of soils at different stages of deterioration. From the experimental results, it was concluded that with a water allowance of 1 cusec for 150 acres successful cropping can be done without causing any deleterious effects on the soil. This water allowance has now been adopted in different project areas. Although by no means it is the last word on the subject yet keeping in view the available resources it is a sound recommendation for adoption in the initial stages of development and reclamation.

6. *Drainage of land.*—In order to solve the waterlogging problem it was considered that the adoption of suitable drainage system such as open drainage, tubewells or combination of both is essential. By this means the water-table is kept away from the root zone of the crops and is not allowed to interfere adversely the crop growth. In one of the reclamation farms wherein open drainage system was adopted, the soils were successfully reclaimed. It was inferred that with a system of field drains discharging themselves into collector drains even if the water-table is not depressed to any appreciable depth from its natural level all crops can be grown successfully as long as the drainage system is maintained properly. The success of this method depended upon the continuous removal of the water from the natural surface of the soil through soil profile and finally to the drainage system. As a result of these measures some three thousand acres of waterlogged-saline lands were reclaimed which resulted in the increase of agricultural production.

7. *Salinity control and reclamation project No. I.*—In order to reclaim saline soils and to supplement the existing canal supplies a tubewell programme was initiated sometime past. The object of this programme was to raise the water allowance which would not only reclaim the salinized soil but would provide sufficient water for the development of new areas and keep the soil in permanent protection from salinization. It also served the purpose of drainage. A well coordinated programme of irrigation-cum-agriculture was taken in hand in the Salinity Control and Reclamation Project No. I of Rechna Doab, where 2,154 tubewells were installed. The objectives of the programme were:—

(*i*) Leaching the soil free of salts by providing adequate additional water supply through installation of tubewells. The tubewell supply pooled with canal water is provided at the rate of I cusec

for 150 acres. The tubewells also help in lowering the water-table.

(*ii*) Efficient open drainage system for disposal of surplus surface run-off and seepage of surplus moisture from land.

(*iii*) Formulation of scientific cropping patterns based on the results of soil capability and classification surveys.

(*iv*) Establishment of an Extension Service Organisation to educate cultivators in approved techniques of soil and water management. This service is also required to place the problems of cultivators before the experts and seek their solutions.

(*v*) Setting up of reclamation-cum-experimental farms for demonstrating modern techniques and recognised agricultural and irrigation practices.

Out of a total area of 12,35,182 acres the area which had gone out of cultivation at the time of start of these schemes was 4.25 lakh acres. The reclamation operations are now in full swing in all the schemes and so far 2.27 lakh acres have been brought back under cultivation up to September, 1964 which is 57 percent of the total area.

As a result of tubewell working there has been appreciable effect on the sub-soil water level. On account of increase in the water allowance from about 350 acres per cusec to 150 acres per cusec, overall cropping intensity has been increased. By the reduction of salines from the rootzone of the soil, and by following suitable cropping patterns, the fertility status of the soil is being gradually rebuilt. The lands thrown out of cultivation on account of salinity or paucity of water supply are brought back under cultivation and cropping. About one sixth of the uncultivated area is now regularly put under crops. This has resulted in increase of the value of the crops and the overall income in the project area.

8. *Irrigation practices.*—Studies were also initiated on improved irrigation practices which would increase the crop production, control salinity and economize irrigation water. The findings are that salinity control can be exercised to a great extent even under our 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 moisture in the root zone is uneven application of water over the surface of the land. This also has the effect of subjecting the crop to considerable variation in soil moisture stress over various parts of the plot. The results of the irrigation

practices with different layouts indicate that 1/8th acre plot with watercourse on one side and inlets in the centre gave the maximum yield. In case of wheat an increase by 52% and in case of cotton an increase from 65 to 72% was obtained. No salt appearance was observed in case of 1/8th acre plot as compared to one acre plot where salt patches were quite visible. The penetration of moisture was much more uniform in 1/8th acre plot as compared to the plots of bigger sizes.

In order to meet the peak needs of crops during short supply periods, a system of heavier irrigations was suggested. In the month of October the canal supplies subside and there is a keen demand for water for maturing the standing kharif and for sowing of the following rabi crops. In case normal irrigation practices are followed, cotton requires one more irrigation in the month of October which is a short supply period. The results of the experiments indicated that if heavier irrigations such as 6" irrigation is applied in the last week of September, enough moisture can be stored to meet the peak needs of water in the short supply period.

Similarly it was established that by changing the system of flat cultivation by sowing a crop like cotton and maize on ridges or in furrows, it would be possible to spread the same amount of water on a lesser area and diminish evaporation losses to achieve deeper penetration of all moisture without affecting the yield of the crop.

9. *Crop rotations and cropping patterns.*—The crop rotations and cropping patterns were suggested keeping in view the following factors:

(*i*) Water allowance.

(*ii*) Soil conditions, the presence of salinity and the depth of water-table.

(*iii*) Labour requirements. These cropping patterns can be practised by the farmer of a 12.5 acres holding with his own resources of domestic labour and bullock labour which resulted in the appreciable increase of gross and net income of the farmers. The cropping patterns can be managed with an overall water allowance of 1 cusec of irrigation water for 150 acres in Rechna Doab. Further work in this connection is in progress in different regions of West Pakistan and a special sub-committee has been assigned the work by the Governor of West Pakistan.

10. *Effect of salinity on crop yield.*—In order to keep the soil in fertile condition, extensive study was undertaken on the movement of moisture in soil profiles. To begin with, the experiments were carried out in the laboratory in

glazed pipes and later on, the work was taken in hands in lysimeters of larger sizes. The experiments were also conducted in the fields on a bigger scale wherein different crop rotations were tried which could control the movement of salts. Studies have also been carried out to know as to what extent different crops can tolerate different degrees of salines in irrigation waters. The main cause of the decrease in yield is the accumulation of the salines in the root zone of the crops. There appears an appreciable effect of the increase in cropping intensity on the formation of salines. The observations of Punjab soil profile indicates that with a water-table of 5 feet the land develops salinity after 3 years under the prevalent high water duty in West Pakistan, land having 10′ and beyond 10′ water-table may remain under production for 5—8 years respectively.

Laboratory and field scale experiments in the reclamation farms were carried out during the last two decades to see the effects of salinity and water-logging on agricultural production.

The salt tolerance studies undertaken in the Laboratories showed that 0.2% of total salt contents commonly taken as the critical value between good and deteriorated soil by no means holds true for all salts and all crops. For wheat variety C-591 the critical value of sodium chloride at germination stage was 0.3% of salt on dry soil basis and for sodium sulphate this value was 0.7% and 0.8%, with 1:1 mixture of sodium chloride and sodium sulphate the value was between 0.4% and 0.5%.

For the mineral contents of irrigation water applied on semi-field conditions it was found that there was decrease in yield with the increase in the conductivity of irrigation water. At lower conductivities up to 1,500 micromhos per cm the yields were not affected to any great extent. At higher conductivities the relation was well established. In case of wheat the water of 3,000 to 3,500 conductivity decreased the yield by about 10%. A decrease of 6% was noticed in case of cotton at a conductivity of 1,500 and a decrease of 60% has been observed in case when water of 8,000 conductivity was used. The yield of sugarcane was affected by 6% at a conductivity of 1,500 and a 50% reduction was observed when saline water of 8,000 conductivity was used. Berseem like sugarcane is a high delta crop. Decrease in this case was noticed at 4% at a conductivity of 1,500 and at 52% at a conductivity of 8,000. Gram and Barley behaved almost similar so far as the decrease in their productivity was concerned. At 1,500 conductivity a decrease of 5% had been observed and at the highest—of 10,000 the yield was reduced by 55%. At the end of the growing season it was observed that accumulation of salts in the soil was maximum in case of Berseem and least in case of Gram and Barley. The other crops were intermediate.

With the installation of a large number of tubewells in SCARP I and other areas serious problems of water quality have sprung up. Keeping in view the variable nature of the tubewell water and its possible effects on soil, experiments were laid by the Directorate of Land Reclamation to observe the influence of saline sub-soil water on the salinity status of the soil. Assuming that irrigation water up to a maximum electrical conductivity (E.C.) of 3,000 micromhos per cm can be used by mixing with canal water in the ratio of 1:1 without causing any deleterious effect, experiments were conducted with the application of this water in specially constructed pits under semi-field conditions. The effects of such water were investigated on following crops:

Wheat, Cotton, Sugarcane, Maize, Rice,

Berseem, Senji and Chari.

Definite water delta was fixed up for irrigating the crops keeping in view the consumptive use of water of different crops as well as the soil requirements. It was noticed that the resultant water if applied in suitable amounts having a water allowance of 1 cusec for 150 acres would not have any adverse effect in fine sandy loam type of the soil. This soil occupies most of the areas in old canal colonies of West Pakistan.

Further experimental work in the Laboratories of the Land Reclamation Directorate has established that when there is scarcity of irrigation water, the saline sub-soil water of tubewells up to a conductance of E. C. 3,000 can be used for a certain period of time in light soils under special irrigation practices for raising of crops like Wheat, Cotton, Sugarcane, Maize, Berseem and Sorghum, as long as the salinity contents in the soil profile does not exceed the permissible limits of 0.2 per cent. Gram and Guara, however, are very sensitive crops.

11. *Soil surveys.*—The crop yields in West Pakistan are far below those attained in other parts of the world whereas climate and the soils offer an opportunity of a much higher level of irrigated agriculture. The obvious reason for the low productivity is the unbalanced conditions of the production factors. The presence of deletrious salts in the soil body and the rise of sub-soil water to the root zone have accentuated the problem. Adverse physical, chemical and biological changes wrought in the soil stamped germination, development and finally the maturity of crops. Low yield and poor quality crops are the logical outcome of the unhealthy associations under such environmental set-up. To combat the menace it was stressed that scientific-cum-drainage plans be initiated. The former programme was visualized to arrest further deterioration of land and the latter to restore the unproductive land to normal agricultural use.

An all-out effort in this direction called for an inventory of the land and water resources of the country. Unfortunately data of any great significance was not available and little time could be wasted in brooding over the past omissions and commissions. An action programme designed to collect the required data preliminary to the formulation of reclamation and drainage schemes, as hitherto recommended by the experts, was immediately desired.

The soil survey of the former Punjab was undertaken with the help of I.C.A. (now AID) of USA to prepare such an inventory and to assess the economic potentiality of the area contemplated to be brought under irrigation.

The soils were studied with the help of aerial photographs and other means. The soil profiles were examined up to a depth of 120″ with the help of augers and pits, and classified into the following five soil series group which are based primarily on the overall texture up to 72″ from the natural surface. These soils differ from each other in texture, structure, density, permeability, etc.

	Texture group	Textural class	Nomenclature
1.	Coarse textured soil.	Sands & loamy sands.	Jhang.
2.	Moderately coarse textured soils.	Sandy loam, fine sandy loam.	Farida.
3.	Medium textured soil.	Loam, silt loam, silt.	Buchiana.
4.	Moderately fine textured soils.	Sandy clay loam, clay loam, silty clay loam.	Chuharkana.
5.	Clayey or fine textured soils.	Sandy clay, silty clay and clay.	Nokhar.

The information regarding soil substratum from 72″—120″ which is essential for drainage and reclamation planning was also evaluated and expressed by qualifying the soil series with the letters normal, (A), (B), (C) and (D).

The work was initiated in 1955 and by now almost the whole of former Punjab and former Bahawalpur areas, have been surveyed. This survey would be useful for planning irrigation programmes, irrigation practices, crop rotation, order of reclamation and drainage and would result in the increase in agricultural productivity.

IV. CONCLUSIONS

As a result of long and continuous research work the following basic and important conclusions have been drawn for further planning work:—

(*i*) that the existing water allowance for irrigated lands in the Indus plains is not adequate to meet the consumptive use and moisture requirement of crops;

(*ii*) that the problem of soil salinity has resulted from low water delta use for irrigation and improper levelling and the unscientific use of the available water supplies;

(*iii*) that for keeping the soil free of excess of salts and to maintain the permanency of the irrigated agriculture it is necessary that about 10-20% of water over and above the consumptive use requirements should be provided for soil leaching requirements.

(*iv*) that the existing water delta of 2′—3′ which is used at present should be increased by about 100% for sustained agriculture and for keeping the soil free from harmful salts; and

(*v*) that for proper crop production equal attention should be paid to efficient drainage system and the sub-soil water must be maintained below the root zone depth of the crops.

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