THE IMPORTANCE OF FARM WATER MANAGEMENT IN PAKISTAN

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Abstract

A combination of events have resulted in intensive studies and major programs related to irrigation water management in Pakistan. These studies have all emphasized the necessity of controlling waterlogging and salinity and of increasing irrigation water supplies. The rationale on which all these studies have been based is that most (63 to 85 percent) of the water delivered to the canal outlet (mogha) is stored in the farmer's field and used by the crop. Studies over the world have suggested that such efficiencies may average nearer 40 percent and will frequently be lower.

Data from field observations of farmer practices and watercourse losses in Pakistan suggest that in SCARP areas this efficiency may average as low as 12 percent. Thus, there is great need in Pakistan for a program to improve on-farm water management in order to repress waterlogging and salinity as well as to provide more water for increased crop production. A number of practices that will improve on-farm water management are suggested.

THE IMPORTANCE OF FARM WATER MANAGEMENT IN PAKISTAN

Wayne Clyma and Gilbert L. Corey[1]

Introduction

Water supplies have been and are deficient in Pakistan for a fully productive agriculture. A flow rate of one cusec to supply the demands of over 300 acres is totally inadequate for peak daily requirements even when only half the land is in production. The Salinity Control and Reclamation Projects (SCARP) have increased water supplies to the farmer and decreased waterlogging and salinity conditions. The first objective of this paper is to review the development and status of these major programs and discuss their effects on irrigation water use and management. The second is to suggest that the next logical development step is to improve on-farm water management. Several promising programs for achieving this improvement are outlined.

Pakistan faces the dilemma of many countries. There is a shortage of food as evidenced by imports of wheat averaging about one million tons each year, as well as other food materials. The population growth rate is approaching 3 percent and there is an indication that while total production has increased by 9 percent from 1971 to 1972, per capita production has increased by only four percent.[2] While having the world's largest

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1/ Agricultural Engineer and Chief of Party, Colorado State University Water Management Research Contract/Pakistan.

2/ Department of State, Agency for International Development, Washington, D. C., January 1973, Unpublished Statistics.

contiguous irrigation system of over 30 million acres, yields per acre are among the lowest. Better water management is needed to solve the problems of waterlogging and salinity and to help provide the means whereby critically needed food production can be increased.

The irrigation system in Pakistan was developed beginning in the late 1800's and a feature of the design was that inadequate amounts of water were available to meet perennial water requirements of crops on all irrigable land.3/ The water supply system of reservoirs, link canals for inter-river transfer, and the canal delivery system itself are very extensive. Since 1960 intensive development of ground water has supplemented canal supplies on over six million acres through a public tubewell program and on several million acres through a private tubewell program. The public tubewell program was developed to reduce waterlogging and salinity and to enhance the inadequate water supply. Reclamation of waterlogged and saline areas has met with limited success but new areas continue to become affected.

Previous Studies

A number of studies have summarized the development of waterlogging and salinity control efforts in Pakistan (Mundorff et al, 1972; Kahn, 1972; Leven, 1964; and West Pakistan Water and Power Development Authority, 1961.)

In 1954 modern approaches to waterlogging and salinity control were initiated under a technical assistance program of the United States International Cooperation Administration through investigations of ground water and salinity problems. These investigations led to the Salinity Control and Reclamation Projects. A formal agreement for SCARP I was signed in

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3/ For a more detailed discussion of Pakistan's irrigation system see Corey and Clyma (1973).

1957 and the project was completed in 1961. An expanded program of investigation was initiated with the founding of the Water and Power Development Authority (WAPDA) in 1958 and WAPDA was assisted from 1959 by the following consultants: Harza Engineering Co., International, General Consultants; Tipton and Kalmbach, Inc., consultants in connection with reclamation work in the Punjab; and Hunting Technical Services, Ltd., and Sir M. MacDonald and Partners, consultants in connection with reclamation work in the Sind.

Two activities created further intensification of investigations of the irrigation system in Pakistan. The first was the signing of the Indus Basin treaty in January 1961 which divided the waters of the Indus between India and Pakistan. The second was a visit to the United States in July 1961 by President Ayub, who requested and obtained assistance from President Kennedy for additional studies of waterlogging and salinity in Pakistan. The result of these two activities was the development of plans for utilization and transfer of Indus Basin waters in Pakistan and a detailed report on waterlogging and salinity with recommended solutions.

The 1959 and 1961 events combined to produce a series of inter-related and similar reports. The activities initiated by President Kennedy produced a report with an analysis of the problem and recommended solutions referred to as the Revelle Report (Revelle, et al, 1964). While the White House study was being conducted, Harza Engineering Company, International, was preparing a similar but more comprehensive report in their capacity as general consultants to WAPDA (Harza, 1963). As part of an agreement reached with WAPDA in 1962, Hunting Technical Services Limited and Sir M. MacDonald and Partners prepared a report known as "Lower Indus Report for the Sind... for the optimal development of water resources...

and...for the control of waterlogging and salinity in these lands..." (Hunting Technical Services Limited and Sir M. MacDonald and Partners, 1966). As part of the Indus Basin Treaty, the World Bank commissioned a study of the Upper Indus which began in 1964 and resulted in a detailed study and report for that area. This study, published in some detail by the consultants (Sir Alexander Gibb and Partners, International Land Development Consultants N.V. and Hunting Technical Services Limited, 1966), was also re-evaluated and published by the World Bank (Lieftinck, Sadove, and Creyke, 1968). Tipton and Kalmbach (1967) published their development plan for the Northern Indus with heavy emphasis on future development including a continued SCARP program. The results of hydrologic studies of ground water and salinity made by the United States Geological Survey have also been published as multi-volumed water supply papers and their studies also included an analysis of the problems caused by canal irrigation. (Greenman, Swarzenski, and Bennett, 1967).

Basic Assumptions of Previous Studies

The problems diagnosed by each of these separate groups and the recommendations for solutions were quite similar. The "Lower Indus Report" and the study sponsored by the World Bank involved extensive and intensive studies in the field of farmer practices and field problems. All of these previously cited reports emphasize the necessity for increasing irrigation water supplies. It is true even today that many areas need additional irrigation water for maximum cropping intensity and maximum yields. WAPDA (1961), Harza (1963), Revelle (1964), Hunting Technical Services Limited and Sir M. MacDonald and Partners (1966), World Bank (Lieftinck, Sadove, and Creyke, 1968) and Tipton and Kalmbach (1967) each assumed that the problems

of waterlogging and salinity and water supply augmentation would largely be solved by the SCARP tubewell program. The rationale upon which this was based is related to their analysis of what happens to water applied to the land by irrigation and is perhaps best quoted from Revelle (1964):

> Water applied to the land, either by irrigation or precipitation, was mostly lost through evapotranspiration, and never reached the water table except in those relatively small areas where the ground water stood close to the surface.

This line of thought resulted in the assumption that most of the water applied to fields was stored in the soil and used by the crops. Recent data indicate a need to update and change this assumption. More insight into the details of the assumption can be obtained from this analysis as quoted from Harza (1963):

> For this preliminary analysis, we have assumed that farm losses and waste, deep percolation, and routine leaching will total 25 percent of the irrigation water delivered to the farms. This represents a farm efficiency of 75 percent. Such a high farm efficiency is possible in West Pakistan because the bund (border) system of irrigation is used throughout. The 25 percent is made up of evaporation and seepage from farm ditches, non-beneficial evapotranspiration from ditch banks, water lost to the crops by percolation through the soil to levels below the plant roots due to uneven or excessive applications, low places in the fields, too slow a rate of application, uneven soil permeability, etc.; and waste due to failure or overtopping of the bunds, failure to stop irrigation at the proper time, or other operational factors.
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> The requirements for the passage of water through the crop root zone to flush down salts brought in by the irrigation water (leaching requirement) has been kept in mind in adopting a farm irrigation efficiency of 75 percent. The water application needed for this purpose varies with the nature and concentration of dissolved salts in the irrigation water. An allowance of 10 percent of the irrigation water as the average leaching requirement is reasonable for the waters available for use in the Indus Plains. The leaching component does not have to be applied during each irrigation but can be accomplished by overirrigation of rabi crops. This will permit limiting the water delivery requirements to the bare minimum (farm irrigation efficiency of 85 percent) on most of the area cropped during the months of high demand. This would

minimize difficulties due to limitations on canal capacities. .....Losses in watercourses have been estimated as 10 percent of the amounts delivered to them from canals or tubewells.

Similar conclusions, based on similar assumptions and logic, were also reached in the other studies. Table 1 was prepared from statements in these reports concerning the effectiveness of water use from the canal outlet (mogha) through the farmer's field.

Table 1. Water Loss Estimates from the Canal Outlet through the Farmer's Fields as Assumed by Various Studies.

Source	E_i	E_c	E_a
Lower Indus	67.5 (although the measured value was 50-60)		
Revelle Report	85 1/		
Harza	68	90	75
Tipton & Kalmbach	70	90 1/	78 1/
Gibb	65		
World Bank	63	90	70

E_i = irrigation efficiency = $(\frac{E_c}{100} \cdot \frac{E_a}{100})\ 100$

E_c = water conveyance efficiency = $(W_c/W_{co})\ 100$

E_a = water application efficiency = $(W_{et}/W_a)\ 100$

W_c = volume of water delivered by the conveyance system

W_{co} = volume of water delivered to the conveyance system

W_{et} = volume of irrigation water stored in the soil and removed by evapotranspiration.

W_a = volume of water applied to the area ($W_a = W_c$)

1/ Derived from statements or calculations.

The day-to-day farmer practices were studied and discussed in the extensive volumes prepared by Sir Alexander Gibb and Partners, et al (1966). However, they state:

> It is unfortunate that no measurement could be made of water channel losses on the watercourse. This has meant in practice that we can only show the total water available to a watercourse and the manner in which that quantity was allocated to the crops grown. It is not possible to state the amount of water received by the crops.

The Lower Indus study also involved a detailed study of farmer practices in Pakistan. The primary conclusions related to farm water management are given as follows (Hunting Technical Services and Sir M. MacDonald and Partners, 1966):

> Bearing in mind the deficient applications in some areas present overall efficiencies lie somewhere between 50 and 60 percent. For optimum yield they are nearer the former figure. Efficiencies are low at present owing to inadequate plant populations, poor field leveling and bund maintenance and general lack of attention to water distribution in the canals. Farmers tend to make over-frequent applications when water is freely available and sometimes unnecessarily late applications when the crops are mature and do not need water.
>
> Various figures are quoted for farm efficiencies in the literature. Experimental work on level contour borders yield an efficiency of 66 percent in the United States. Basin irrigation as practiced in Pakistan should be slightly more efficient than this with the same management practices. Messrs. Harza Engineering Company International has adopted a figure of 67.5 percent for the Northern Zone and it is therefore proposed to adopt this figure for the Region for the ultimate future in order that water requirement calculations for both zones are on the same basis.

Some measurements of water past the mogha were made. The report suggested that wastage of water did occur and farm efficiencies were much lower than the 50-60 percent reported. These lower efficiencies apparently, however, were not measured.

The data in Table 1 are the values for efficiencies used to plan and

implement the SCARP programs in Pakistan. If these values for efficiencies are valid, then they should be near the values measured on SCARP watercourses today. SCARP 1 was in operation in 1961 and some of the studies on which additional SCARP programs were based were conducted on supplemented watercourses.

The high efficiencies given in Table 1 indicate that these reports and studies of the irrigation system of Pakistan were based on the assumption that farmers were doing a good job of irrigating. All the reports were uniform in this regard. In the summer of 1962 a team of consultants to Harza made the following recommendations (Hansen, Bower and Williams, 1963):

> The magnitude of irrigation efficiency is not only extremely variable but difficult to appraise for the future. Even though consumptive use is calculated with considerable accuracy, the water requirement to the field involves application efficiency. The losses occurring in conveyance must also be considered when determining diversion requirements.
>
> Thus, it is important that sufficient field studies be conducted to obtain a reasonable estimate of the water application efficiency that can be expected under different cropping conditions. Likewise, the losses in conveyance by seepage, evaporation, and plant use should be determined for the enitre water distribution system.

This advice was evidently too late to be of use in the preparation of the reports. Since most of the water applied to fields was assumed to be consumptively used by the crops, the solution to on-farm water management problems was simply to provide more water. The actions for implementation of these programs was more tubewells and dams.

Worldwide Irrigation Practices

Irrigation water use efficiencies are, even today, rather low in almost all areas of the world. Erie (1968) reported on a cross section of 22

irrigation projects in the USA and stated that "the overall project use efficiency from the dam to the final irrigation process is 36.1 percent "and" of the amount delivered to the farm, 42 percent is lost through the irrigation process." Langley and Robb (1969) showed that in Colorado application efficiencies ranged from 8 to 71 percent during the season and averaged 40 percent. In another Bureau of Reclamation (1968) study, farm efficiencies ranged from 24 to 53 percent and the three farm, 4 year average was 33 percent. The International Source Book on Irrigation and Drainage (1973) in discussing conveyance losses stated that "...for preliminary estimates, it may be assumed that in typical earth channels under usual conditions, about one third of the total water delivered will be lost by seepage, operational waste and evaporation."

These rather recent studies have shown that irrigation efficiencies with border irrigation and earthen channels are, in fact, rather low all over the world. Applying a typical farm efficiency from the Western United States of 40 percent to the 67 percent delivery pattern for earth channels mentioned above results in an estimated efficiency of 27 percent from the mogha through the field.

Present Water Management Practices

Losses along the watercourse from the mogha to the field are high in Pakistan, especially on tubewell augmented watercourses. These losses (seepage, wastage and evapotranspiration by non-beneficial plants) frequently range from 30 to more than 50 percent of the flow at the mogha. Seepage is considered here to be that water which infiltrates from the channel cross section down into the soil profile and eventually to the

water table. Wastage is the loss occurring to the ground surface either by overtopping, slow seepage through the side, breakage of the bund at nakkas or weak areas and operational losses. Evapotranspiration is that lost to the atmosphere. Corey and Clyma (1973) have detailed many of the physical causes for watercourse wastage. These include leaky nakkas, inadequate hydraulic capacity, thin channel walls, channels below ground, inadequate freeboard, obstructions such as trees, weeds, debris and sediment, poor alignment and an excessive ditch system required to serve the many small fields.

Clyma, Arshad and Ashraf (1974) have presented data from flow measurements on watercourses and have shown that seepage may range from 1 to 100 cusecs per million square feet of watercourse perimeter and wastage in many instances exceeds the seepage. They found that water delivery efficiencies range between 50 and 90 percent with an average near 60 percent for many watercourses. An additional disadvantage of wastage is that the greatest loss occurs when the farmer needs are the greatest. Since a SCARP tubewell frequently doubles the flow when added to the canal water already in the channel, wastage will increase. The period of peak water use is when the tubewell is operated. Crop yields are greatly reduced if excessive moisture stress occurs during the peak water use period.

Application of water in the field is usually very inefficient in Pakistan. Table 2 presents data from Clyma, Arshad and Ashraf (1974b) on measured field application efficiencies. Almost three-fourths of the measurement gave efficiencies of less than 30 percent and over one-half of the measurements resulted in efficiencies of less than 20 percent. These low efficiencies are a function of many factors and Corey and Clyma (1973) and Clyma, Arshad and Ashraf (1974b) have discussed these factors

Table 2. Irrigation application efficiencies[1/] observed at Mona on traditionally farmed fields (from Clyma, Arshad and Ashraf, 1974b)

Application Efficiency Interval (Percent)	Crop				Total for Interval	Percent of Total Number of Observations	
	Wheat	Sugarcane	Fodders	Misc.		Interval	Accu
0 < 10	2	4	4	3	13	20	20
10 < 20	8	5	2	2	17	26	46
20 < 30	2	8	4	2	16	25	71
30 < 40	2	2	3		7	11	82
40 < 50		1		1	2	3	85
50 < 60			2	1	3	5	90
60 ≤ 70		1			1	2	92
70 ≤ 80							
80 ≤ 90							
90 < 100		4	1		5	8	100
Total	14	25	16	9	64	100	

1/ Application efficiency = $\frac{\text{amount of water stored in the root zone}}{\text{amount of water applied to the field}}$

in detail. Primary among these are unleveled fields, an irrigation canal delivery system that supplies water at a constant rate independent of the needs of the crop and a lack of knowledge by the farmer about the water requirements of his crop. Some under irrigation does occur. Three instances of under irrigation were obtained in the 54 measurements. The common practice appears to be overirrigation resulting in average field application efficiencies of near 20 percent.

There is a wide range in efficiencies of water delivery and water application in Pakistan. The above conclusions about water delivery and water application efficiencies are based on limited data and limited geographic sampling. An understanding of the hydraulic principles of water delivery and water application suggest that the results so far obtained generally represent the results that would be expected for most of Pakistan. Hunting Technical Services Limited and Sir M. MacDonald and Partners (1966) in their study of the Lower Indus suggested that somewhat similar results occurred there. Quantitative data were not presented, however.

Table 3 was developed to illustrate the importance of on-farm water management in Pakistan. The delivery and application efficiencies used in Table 3 are those given by Clyma, Arshad, and Ashraf (1974a and 1974b). The efficiencies, while perhaps not valid for all seasons and locations in Pakistan are useful to illustrate the nature of the water management problem. In SCARP areas in general, the public tubewells have doubled the effective water supply of the farmer. The water supply at the mogha was also doubled, but because of the low delivery and application efficiencies,

Table 3. A hypothetical delivery of water assuming realistic efficiencies for Pakistan.

Source	Quantity of Water Supplied (Vol./ unit area)		
	Mogha	At Field[1]	In Root Zone[2]
Canal	1	0.6	0.12
Tubewell	1	0.6	0.12
Total	2	1.2	0.24[3]

1/ Assumes an average delivery efficiency of 60 percent as given by Clyma, Arshad and Ashraf (1974a).

2/ Assumes an average application efficiency of 20 percent as given by Clyma, Arshad and Ashraf (1974b).

3/ The resulting overall efficiency is 12 percent.

most of the additional tubewell water is lost. Furthermore, only 12 percent of the tubewell water or the total supply is effectively used. This low efficiency suggests why the SCARP program has not been completely successful in lowering the water table. Much of the pumped water as well as the canal water goes to the ground water to maintain a relatively high water table. Much of the initial ground water decline after initiation of SCARP pumping resulted from a redistribution of the water surface as a result of pumping.

The authors wish to emphasize again that the SCARP program objectives of reducing waterlogging and salinity by lowering the water table and increasing water supplies both by pumping are correct and worthwhile. We do conclude, however, that (1) Farmers are not doing an efficient job of managing water from the mogha through their fields as has been previously assumed. (2) Improving on-farm water management will make more water

available for plant growth than any other similarly priced investment, and (3) Hazards of waterlogging and salinity will be concurrently reduced.

A New Water Management Program

Water supplies created by development of additional reservoirs or tubewells will effectively add little water for growing crops unless something is done to improve delivery and application efficiencies. The greatest increase in water supply can come from rehabilitation of watercourses to reduce delivery losses and improvement of field application efficiencies through land leveling and adjustment of irrigation to more nearly meet the requirements of crops. This increase in the effective use of water would result in reduced waterlogging since inefficient use of irrigation water is the cause of waterlogging and ultimately of salinity in Pakistan. Increased food production would also result because of increased yields and the increased area which could be irrigated with the water saved.

The present average cropping intensity over the irrigated area of Pakistan is undoubtedly not more than 75 percent, less than one crop per year. The climatic resource is such that two or three crops or a cropping intensity of from 200 to 300 percent is possible. Water, however, is one of the limiting resources; yet an intensity of at least 150 percent is feasible with proper management. Of course, water is not the only input needed to increase acreages but certainly the effective cropped acreage can be greatly increased with a coordinated water management program. There is, of course, the added benefit that better management also increases yields. This improvement can be accomplished within the present irrigation distribution system which although rather rigid does have advantages which can

be utilized.

There are several technologies which, if adopted, would greatly improve irrigation water management in Pakistan. Full benefit can only be realized by adopting and utilizing all of them together. Irrigation water management is a system and though any one practice has some benefits, full benefit comes only by adopting the entire system. Only research and testing will determine how much of the system is physically feasible and socially and economically adaptable.

The following practices have been used elsewhere and are worthy of strong consideration for adoption in Pakistan:

1. Field Reshaping and Leveling - Efficient use of water within the root zone cannot be accomplished unless the field itself is precisely designed to fit the particular irrigation method. The level basin method requires that fields be precisely level. Otherwise much water is wasted in the low areas while attempting to cover the high spots, which become salinized unless they are sufficiently covered with water during each irrigation. While leveling the land, the fields may be reshaped into a more efficient design so that the length of the watercourse serving the fields can be greatly reduced. This has the double benefit of eliminating a wasteful watercourse and increasing the acreage of crop land.
2. Watercourse Rehabilitation and Irrigation Structures - Equitable distribution of water cannot be accomplished without an improved distribution (watercourse) system from the mogha to the fields. Regardless of what else is done, effective use of the irrigation

water resource in Pakistan will be impossible without improving the watercourse channels. The present channels are, in many cases, of insufficient size to carry the design flow. There are no distribution structures and leaks abound. The only farmers receiving a full share of water are those whose farms are adjacent to the mogha. When this improvement is coupled with precision land leveling and the introduction of proper irrigation structures such as siphon tubes, portable dams, permanent gates (nakkas) and measuring devices the distribution system becomes complete. Only then will it be possible for irrigation efficiencies to approach those mentioned previously in much of the descriptive literature on Pakistan's irrigation system. It is the author's opinion that watercourse improvement along with improved field irrigation practices could do more to increase food production in Pakistan than any other water management program including the building of any number of Tarbela Dams.

3. Scheduling Irrigation to Meet Crop Needs - Modern technology provides the knowledge to estimate, from climatic factors, the amount of water each given crop uses. Such estimates can be made on a daily basis using meteorological data presently available in Pakistan. With such a service the farmer could be told when to irrigate a given crop and how much water to apply. Couple this service with an improved system resulting from accomplishing 1 and 2 above and a system which efficiently applies and utilizes no more water than is needed by the crop results. The rather rigid warabundi system does not allow for com-

plete adoption of a scheduling program; however, other technologies could be adopted which would ultimately make it possible to achieve it within reasonable limits. These are described in 4, 5 and 6 below.

4. Discharge Augmentation by Tubewell - There is a tremendous quantity of water available for irrigation below the ground surface in Pakistan. This water is usually close to the surface so the energy cost of pumping it is reasonable. Since the supply though extensive is limited, it should be exploited on a controlled basis. The holdings of many farmers are too small to warrant a private tubewell; however, groups of farmers could beneficially own one. In fact, all users on a watercourse system could feasibly construct a tubewell or several tubewells strategically placed within the system to augment the canal flow during periods of peak crop demands. This additional water resource would provide some control of the flow since the tubewells could readily be switched on or off. Small discharge wells would undoubtedly prove more effective than large ones because of smaller individual power units, better water control, and in many areas good quality water is only available in small quantities and must be "skimmed" from atop underlying salty water.

5. Water Storage on the Watercourse - A small amount of storage space on a watercourse system would be highly advantageous because there are times when the mogha is flowing and there is absolutely no need for water anywhere in the system. Many villages already have such

an area, but it is not a planned part of the irrigation system nor is water pumped for reuse. This storage could be utilized as a village pond with fish production, livestock water and the usual uses for such a resource. In fact, the tubewells described above could be placed near such a pond to ensure sweet water production. In such a manner, the storage could be used to augment the water-course flow during peak demands and during emergency canal closures.

6. Canal Regulation for Climate and Cropping Patterns - It appears that some canal regulation to meet crop consumptive demands would be feasible. During certain periods water demands on the entire canal system are slack but the climate of Pakistan is varied enough that this doesn't happen on all commands at the same time. In other words, water not needed on a given system could be shifted to another and vice versa. It may even be feasible to schedule crop planting dates such that consumptive demands will not be at the peak on all commands at the same time. This approach of some canal regulation for crop needs is, at least, worth study. If it could be combined with the tubewell and storage augmentation described above, a great deal of flexibility could be built into the presently rigid system.

7. Soil Management for Moisture Control - Traditional methods of agriculture common in Pakistan leave much to be desired with respect to moisture conservation through soil management. The surface soil in most areas is practically structureless. Over-working by repeated plowing adversely affects infiltration rates and irrigation water is observed standing on the soil surface sometimes for days before

it can penetrate into the root zone and be useful to the plants. Much water is lost during the planting season by irrigating and then working the soil so many times that most of the moisture is lost to the atmosphere. Many cases have been observed where the farmer loses so much moisture that it is necessary to re-irrigate thus losing most of the first irrigation and wasting much of the second. A major research program should be launched to study soil and water management as it relates to plant growth. Surely many improvements are possible and worthwhile even within the traditional agricultural system. This research should be combined with that which is necessary to fully develop the technologies described below in 8 and 9.

8. Precision Planting - Modern agriculture has long since discovered that investment in precision seed planting is economically worthwhile. Great pains are taken to place the correct number of seeds precisely at the required depth and with the soil firmly packed around the seed. Rather complicated and expensive machinery is involved for some crops yet the economic feasibility is unquestioned. This is not to advocate expensive planters for Pakistan; however, the problem is worthy of study because poor plant stands are a major constraint in many areas and the rather simple seeding techniques could be improved. Even hand planting can be precise and undoubtedly would be if the benefits were fully known by the farmers.

9. Crop Cultural Practices - Moisture conservation and control is not limited to the irrigation system itself. Many cultural practices

are inter-related and important to optimum production. Weed control, cultivation, mulching, deep tillage, organic matter incorporation and minimum tillage are all practices worthy of study because of their proven potential for improving crop production through their effect on moisture movement and use. Other methods of irrigation should also be evaluated under Pakistan's climate, soil and cultural conditions. Applying irrigation water through furrows has many advantages over the level basin method. Trickle irrigation is a rather new technology which may have application in Pakistan. All of these practices need study to determine their degree of acceptability and to define their economic feasibility.

10. Maintenance of the System - If the improved water management system or any portion thereof is adopted it will require maintanance to keep it operating at maximum efficiency. Just as a delicate machine needs constant care and careful maintenance so does any system of production. Leveled land will become unlevel, improved water channels will deteriorate, developed soil structure will be lost, soil-salt balance will be destroyed without continuous and diligent maintenance of the system. This process is referred to as management and the practices necessary to maintain the system are similar to those necessary to improve it. No system worth developing will maintain itself without inputs from those utilizing it.

Implementation

Utilization of all or a portion of the technologies described in the previous section could create a greatly improved water management system

in Pakistan and thereby reduce waterlogging and salinity, save water, and increase food production. Much benefit can come from any one of the ten practices recommended and it is not necessary to adopt all as a package. Each is a component and if properly implemented and maintained has benefits within itself. While investments in each of these components has been productive in other countries, the sophistication with which they should be implemented in Pakistan can only be determined under local conditions. It is not necessary or possible to predetermine what the best final system will be. No one can predict what will be socially and economically best of available technology and modification of it. The best water management system for Pakistan will be a result of field evaluation to fit existing conditions. It is likely that once the improvement process starts it will continue on into technologies and procedures not now known.

Actually, there are no physical constraints in achieving the technologies mentioned. Farms can be leveled, fields properly reshaped and the watercourse system improved to any degree desired including permanent lining. Tubewell technology is known and certainly providing some flexibility in canal regulation is possible. Entire canal commands could be placed on computerized scheduling for irrigation. Planting dates for the various crops could be programmed for each command sub-area. After planting the "scheduling service" could keep inventory of the consumptive water needs by monitoring the existing climatic conditions. Farmers could be advised on the proper time to irrigate each crop and the irrigation system could be managed to provide the necessary water.

Obviously to put this sophisticated system together requires time

and a great deal of technical input. If it is to be done in the near future, the process needs to start soon. There are several aspects to be considered. The physical system including land leveling, watercourse rehabilitation, tubewell and watercourse storage construction can technically be readily accomplished. The optimum soil and crop management practices are not as well defined but research can be initated on a systematic basis so near optimum soil and plant management practices can be recommended by the time the present system constraints are removed. The institutional structure to handle the system is perhaps the most difficult part of the process. The farmers themselves should be organized into workable water user units to facilitate improvement in the system and to improve the procedures for operation. The assistance of governmental agencies will be needed to provide technical and financial assistance to construct the system and, just as important, to help the farmers with the maintenance of the system. This eventually would mean a different concept of agricultural extension than presently exists in Pakistan.

It is difficult to know what the first step or steps should be in order to most efficiently develop this water management system; yet it is essential that the development process be started by taking some first steps. The needs are imperative and the potential for improvement too great to not place improved on-farm water management on a very high priority. Success would benefit Pakistan and much of the world.

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The Importance of Farm Water Management in Pakistan

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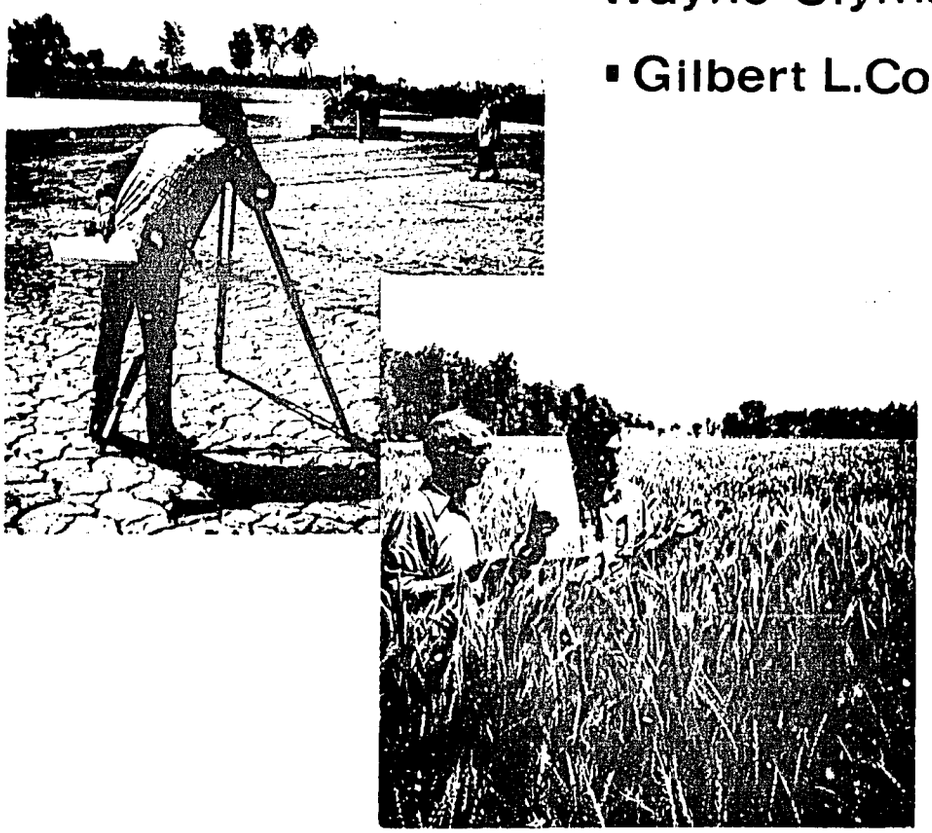

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