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NAME Gil L. Corey *[Signature]* TITLE Water Management Specialist DIV./UNIT DS/AGR/9

PERIOD OF TRAVEL (including dates) October 6- October 31, 1979

ITINERARY Washington, D.C. to Pakistan to Washington, D.C.

(Use attachment for details, including time schedule)

PURPOSE to To participate as team member on assessment of agricultural research in Pakistan.

ORGANIZATIONS AND PERSONS CONTACTED: Pakistan Agricultural Research Council, PARC.

(Use attachment for details.) All major experiment station in Pakistan; All Agricultural universities; Finance, Planning and Development and Agriculture Ministers and Secretaries in all Provinces and Central Government; All Provincial Governors and RESULTS/ACCOMPLISHMENTS: and the President of Pakistan.

- 1.
2. SEE ATTACHED
- 3.
- Etc.

FOLLOW-UP ACTION REQUIRED: Final report will be forthcoming after preparation and (indicate what, by whom, when.) review by the World Bank. Govt. of Pakistan, World Bank and other donors will then consider the recommendations.

OTHER REMARKS:

(May include other information, observations, and impressions of general interest.)

- Attachments: (List)
1. Note on the Review by G.L. Corey
  2. Memorandum to President of Pakistan
  3. Memo to Mission members prepared by team leader.
  4. Report on Irrigation Water Management Research by G.L. Corey

Distribution: World Bank, K. Pranich, A.J. Pritchard USAID/PAK, A. Handley (List) AA/DS, S. Levin DS/DAA/FN, T. Babb DS/DIU, L. Allen DS/PO, A. Silver DS/MGT, M. Thome ASIA/TR, T. Arndt ASIA/TR/ARD, D. Plucknett, D. Lundberg ASIA/PN, R. Thompson ASIA/PD, M. Demetre PPC/PDPR, D. Caton DS/AGR, D. Peterson DS/AGR, J. Wilson, K. McDermott, F. Williams, K. Byergo Soil & Water Mgt. Division

Note on Review of Agricultural Research - Pakistan

by G. L. Corey, 1 Nov. 1979

The Agricultural Research System of Pakistan was reviewed by a group of international scientists during the period October 4 - November 1, 1979. It is my understanding that this was done at the request of the Government of Pakistan.

The team was billed as a World Bank/USAID/CIDA team, however, it is obviously considered a World Bank function and the final report will be a "Sector Assessment" of agricultural research and will be published by the World Bank. The final report will evidently be several months in production since there will be an internal World Bank review prior to final draft. I assume that AID and CIDA will also be afforded an opportunity for review. The World Bank intends to invest in agricultural research in Pakistan, especially as the USAID program terminates, therefore this report will become a basis for the appraisal team when their project is finally described.

The team consisted of the following:

Sir Charles Pereira, Team Leader, British;	World Bank
G. Corey, Water Management, USA;	AID
D. Davy, Education and Extension, USA;	World Bank
G. Gerhardsen, Fisheries, Norway;	World Bank
R. Knight, Plant Sciences, Australia;	World Bank
L. Lovvorn, Research Administration, USA;	AID
B. Nekby, Extension, Sweden;	World Bank
B. Poole, Forestry, New Zealand;	World Bank
A. Pritchard, Agronomy, Australia;	World Bank
W. Pelton, Dry land Agriculture, Canada;	CIDA
G. Uehara, Soils, USA;	AID
M. Walsh, Livestock, Ireland;	World Bank.

The team visited all important research stations in all provinces and held discussions with most key persons within the political and bureaucratic systems including the President, the Governors of all provinces and the Finance, Planning and Development, and Agricultural Ministers of the Central Government of all provinces.

Attached are copies of:

1. A requested set of recommendations to the President of Pakistan.
2. Sir Charles Pereira's memo to mission members which reflected his impressions of the team's thoughts at the end of the mission.
3. My report on water management presented to the World Bank for partial inclusion in the final report.

Sir Charles Pereira

Islamabad, October 30, 1979

His Excellency  
The President of Pakistan  
General Mohammad Ziaul Haq  
Rawalpindi.

Sir:

In response to your request I submit herewith a very brief outline of the conclusions of the World Bank/USAID/CIDA Mission on Agricultural Research, setting out both our recommendations for World Bank support and our suggestions as to actions which your Government could take immediately.

With regards,

Yours sincerely,

Charles Pereira

Enclosure.

Islamabad, October 30, 1979

Measures needed to strengthen the agricultural  
research structure of Pakistan

(A memorandum submitted at the request of the President of Pakistan, General Mohammad Ziaul Haq, outlining the advice which the Mission would be recommending to the World Bank).

1. The Mission considers that Pakistan has natural resources capable of producing more than the national needs of wheat, sugar, oilseeds and milk, each of which is now imported, and also capable of supplying increased exports of rice and cotton, through substantial increases in yield.
2. Many factors which affect agricultural production lie outside the Mission's terms of reference. Pricing policies, market organization, the availability of credit, fertilizers, pesticides, machinery and transport all need attention, but the Mission is concerned with research and development for the improvement of the inefficient farming technology which is widely prevalent.
3. Top priority should go to a radical improvement of extension services. This improvement is the subject of two major projects supported by the World Bank, to enable extension staff to live and to move freely in rural areas and to have subject-matter-specialists living in Districts. This programme should be treated with national urgency. The Mission believes also that there is an urgent need to improve the technologies available to the farmers.
4. Recognizing the importance of provincial research organisations the mission will recommend the strengthening of some provincial institutes with World Bank support for both staff and facilities, by means which will be detailed in the report. They would then act as lead stations for specific crops and livestock.
5. The Mission will also recommend support for some strengthening of agricultural universities, in particular for the promotion of their closer collaboration with research institutes.
6. Immediate steps will be recommended to develop a strong central Agricultural Research Service, capable both of coordinating provincial work on a national scale and of providing much needed technical supporting services to the Provinces. Provincial organisations must continue to carry out most important task of field experimentation \* the and verification and adaptation of technology, including the breeding of crop varieties for local conditions.

7. The Mission will recommend:-

- (i) The rationalization of the agriculture research activities of the Federal Government by reserving to the appropriate Ministries the formulation and direction of policy, while allotting to the PARC the full responsibility for Federal action in the generation of improved technology for crop and animal production, fisheries and forestry.
- (ii) In order to rationalize the present fragmented pattern of research effort the Mission will recommend the incorporation into PARC of the agricultural laboratories of the Pakistan Atomic Energy Commission, the Forestry Research Institute, the Cotton Research Institute of the P.C.C.C and the Soil Survey of Pakistan.
- (iii) Establishment plans, for which the Mission proposes to recommend World Bank support, of a Marine Fisheries Research Institute, a Sugar Research Institute and an Institute for Research in the Control of Pests and Diseases, as components of the Agricultural Research Service of PARC. The Council should also make with WAPDA arrangements for the strengthening of the Mona scheme by the introduction of more agricultural technology and the securing of future funding.
- (iv) That PARC should undertake, with suggested support from the World Bank, country-wide technical support services for Library Improvement, Biometrics and Computing, Laboratory Instrument Maintenance, Plant Importation and Quarantine. To continue to improve the national testing scheme for crop varieties.
- (v) To develop, in cooperation with provincial authorities, a network of research units in agricultural economics.
- (vi) That PARC should be charged with the development in cooperation with the Provincial authorities, of objectives and priorities for national research, as a basis for the allocation of Federal resources.
- (vii) That PARC should have responsibility for the organization of Visiting Groups drawn, in consultation with the provinces, from leading scientists throughout the country to review major institutes and programmes at suitable intervals (probably of 5 years).

- (viii) That new institutions and research initiatives which require Federal funding should be appraised and recommended by PARC.
- (ix) That PARC be authorised to establish a national procedure for the selection of outstanding young scientists for overseas training, seminars and study groups. Also, after approval of an overseas training agreement by the Federal Economic Affairs Division of the Ministry of Finance to implement the agreement without the necessity for reference to other Departments.

8. In order to enable the PARC to carry out these heavy responsibilities the Mission will recommend.

- (i) That PARC should have an autonomous constitution on the lines of successful organisations such as WAPDA. In particular PARC needs the power to undertake direct recruitment and to offer career opportunities for able scientists, whose salary scales should be comparable with those of the Agricultural Universities.
- (ii) Although an autonomous body, the Council has an essential role in coordinating all agricultural research into a national effort. The Council, therefore, needs authority to deal directly with Provinces on research matters. The Mission noted that the Indian Council of Agricultural Research has successfully solved a similar problem by giving the Head of Council the status of an ex-officio Secretary to the Government of India for Agricultural Research and Education. The Mission will recommend that the Government of Pakistan should take urgent action to resolve this problem, which is impeding progress at present.
- (iii) That PARC should be authorised to devise and to implement a system of promotion by merit for its own staff.
- (iv) That a system of promotion by merit rather than by seniority should be introduced by provincial authorities for their agricultural research staff as early as possible.
- (v) That PARC should appoint a Member for Soil and Water Management and should give emphasis to the better coordination of agricultural studies with those of irrigation and drainage.

- (vi) That the Government should continue without interruption the provision through PARC of development funds for agricultural research, and that the Provinces should provide more adequate operating funds for their research stations.

Memo to Mission Members

Notes for Introduction

Pakistani agriculture is failing to make effective use of very favourable resources of soil, water and climate, not for lack of scientific knowledge but from lack of management and organization to test and use the knowledge available.

Much time and resources have been wasted by repetitive research redemonstrating in Pakistan agricultural science which has been thoroughly established elsewhere. There are already adequate facilities in many fields for innovative research, but there is an urgent need for "Development with Measurements".

A World Bank Project on a large scale for the development of a strong extension service, in which subject matter specialist officers trained in extension methods are given housing, transport and demonstration facilities, should have top priority for funds and manpower.

The major aim of the Research and Development Service should be to provide "packages" of improved farming practices, drawing heavily on research already accomplished in other countries of similar ecology.

With few exceptions the problems of Pakistan's agriculture have already been solved in other countries with comparable soils and climates. Many of these solutions have been tried out here in research programmes.

Enough is now known to apply on a field scale - but before it can be recommended to farmers it must be tested on a field scale by "measured development", i.e. by implementation, preferably by small farmers, while inputs (especially water) are measured and yields are sampled, diseases and pests are monitored. This requires trained specialists with investigative skills in the field, backed up by laboratories for analysis and identification services.

This type of work we propose that the World Bank should support as an "R&D Programme". It involves extra effort by scientists in field travel and exposure, and should be rewarded by equal or better grades of salary than those in the "air-conditioned" posts, and should be supported by transport and by field allowances.

Memo to Mission Members

Summary of Team Discussions:

(a) Many of Pakistan's difficulties in agricultural research and development are "self-inflicted" by an over-elaborate bureaucracy which causes endless delays and by a rigid Civil Service system of provision in which merit is dominated by seniority; it is therefore, difficult to ensure that any injection of international research funds would be effective in improving agricultural output.

(b) The excessive concentration on provincial affairs renders reinforcement of national effort very difficult. The aim of each province to be self-sufficient is, from a scientific viewpoint, illusory. There is no foreseeable possibility of each province achieving either the capital infrastructure or the trained manpower to succeed alone.

(c) The organization of agricultural research is fragmented, and "coordination" has not taken the form of assessing of goals and priorities, allocating targets and resources, and leaving the research institutes and commodity stations to pursue these goals. There is instead a bureaucratic process of scrutiny and approval of individual seasonal research proposals. This causes much delay and uncertainty, which has become worse in the largest province, the Punjab, in which a provincial coordinating process also taken the form of scrutiny and approval. For annual crops there is little enough time to analyse and study each season's results and to design consequent experiments before next planting date.

(d) The system of promotion is excessively weighted towards seniority and pays only lipservice to merit and scientific achievement. Promotions are arranged as for the administrative service, so that the head of a station may have no knowledge of the fields of service involved. There is thus no incentive for personal effort.

(e) The scientific discipline and accountability for resources is very slack. Many institutes make no annual reports and grants have been renewed for many years without evidence of results.

(f) Salaries are low and are compensated by excessive security. Rewards for the energetic and ambitious lie only outside the Civil Service. This, with (d) and (e) above, are all factors promoting mediocrity and low scientific output. Much credit goes to the minority of scientists who have achieved real scientific advances in spite of these discouraging factors of the system.

Mission Meeting 08:00, Thursday, October 25

1. Team agreed unanimously that we should propose the strengthening of PARC as a national and unifying force, but <sup>that</sup> we should propose tightening of its terms of reference.
2. The team agreed that Pakistan agricultural research would be unlikely to guide national agriculture into greater productivity while it continued to operate in enclosed and complacent provincial groups.
3. The team will recommend a Project on agricultural research and linkages to extension but will propose essential conditions to be met before the Bank should undertake an IDA loan.
4. The Project will include both the strengthening of named Institutes and the establishment of national programmes of "development with measurements".
5. The Institutes selected for strengthening are as follows:  
Animal Production
  - (a) The Livestock Production Research Institute, Okara, with the associated "Crossbreeding farm" (Punjab).
  - (b) The Poultry Research Institute (Sind).

- (c) A PARC Research Units for AI to support the National network (Punjab).
- (d) The Livestock Research Unit at NARC (Punjab).
- (e) The Vet Research Institute, Lahore should be upgraded to become <sup>a</sup> lead research station with a possible ARC input of a vaccine unit.

#### Wheat Research Stations

There are at present too many wheat breeders and there is inadequate scientific input into building of foundation stocks, multiplication and distribution of certified seed. Only some 6% of wheat seed now planted is from certified stocks.

All wheat breeding requirements could be met by two stations. The Ayub Agriculture Research Institute at Faisalabad should issue rust-resistant varieties while the Agricultural Research Insitute, Tandojam should issue varieties for the rust-free areas. A national strategy for coordinating rust prevention would be necessary.

Both Institutes should test and develop drought resistant varieties suitable for rainfed agriculture or for limited irrigation supplies and should make full use of varieties available through the International Institutes. Varieties should be compared in Coordinated Variety Trials organised by the Wheat Coordinator of PARC for all ecological areas of Pakistan where wheat has current or potential importance.

#### PAEC

PARC, the Universities and the laboratories should contribute valuable inputs to the national pool of wheat germplasm but should

The mission recommends that the Project should include the improvement of facilities at both Institutes and the establishment of a Project fund to enable Post-graduate students from Universities to carry out genetical studies using the enhanced facilities of the Institutes. This fund should not limit students to provincial boundaries. (In the past USAID has provided such a fund but there are very few such students).

The PARC Institute of Cereal Diseases should be strengthened by improved facilities and supported to include virology and nematology.

#### Sugar

The Mission programme did not include visits to sugar research but from reports and discussions we understand that the situation is as follows:-

Experimentation with improved varieties has already demonstrated that cane of low bulk and high sugar content can be grown. Although offered to farmers these varieties are not accepted because the sugar mills buy cane by weight. Farmers then fore grow bulky cane, and cut is daily as they feed the tops to cattle, taking the cane to the mills at intervals. Much of it yields only 7% sugar. The average cane yields are absurdly low in view of the good yields harvested by advanced farmers.

Donors have offered technical aid to provide equipment and training to the mills in order to introduce payment by sugar contents as is normal in other countries. Political influences are too strong to allow the factories to reject low quality cane. The consequent low efficiency is reflected in the high cost of sugar production (which

is between two and three times the cost of imported sugar).

We recommend that the practice of buying cane by sugar content be introduced as soon as possible. Assuming that this change will occurred it appears likely that a further investment in sugar research can be justified and we therefore propose that PARC should set up a sugar research institute.

#### Water Management in Irrigated Agriculture

This is a major weakness in Pakistan's agriculture. At present the lack of organised cooperation for joint development between the water engineers and the agricultural scientists is a costly gap. The agricultural scientists have so casual an attitude to water management that even in studies of crop responses to irrigation the water applications are counted but are not measured.

There is a serious lack of planned rotations of crops and of water scheduling to supply the rotations. Thus leguminous fodder crops play only a small part in Pakistan's irrigated agriculture, whereas in comparable irrigation developments in countries with similar climates these legumes are a major source of soil fertility and structural stability, and the basis of the livestock industry. There is much fallow land between monocropping of cereals, even where water is available. There is also fallow due to lack of water which could be supplied if there were to be joint planning of crop rotation and of water scheduling.

The very serious losses of water between the outlets of the minor canals and the crops, estimated by WAPDA at 62% overall (Ref. 1) are due to inadequate construction and maintenance of the village water courses, many of which have become "Linear marshes" with thickets

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Foot note 1: WAPDA Revised Action Program for Irrigated Agriculture, Lahore 1979.

of trees and bushes. The water losses from more than 88,000 village water courses are estimated by WAPDA to total 50 m acre-feet per annum which is equivalent to the flow of the Nile. Research on water-course improvement has been effectively undertaken by a joint WAPDA/USAID programme, the "Mona Project", over the past 8 years. Effective economic solutions have been demonstrated in local villages and have been adopted, with the help of a USAID Project, on some 300 villages so far. The Canadian Government and GOP are planning a similar project in Sind. The need is for a large corps of staff trained to understand both the water needs of crop rotations and the possibilities and limitations of the water supply system.

This is not simply an extension problem: the varying soil types, drainage regions, water qualities and agricultural patterns need investigation and integration in a form of applied on-farm research which is best described as "development with measurements", but needs subject-matter-specialists with some training in measurement and in assessment of evidence.

A combined programme by WAPDA and PARC with support from the World Bank for an accelerated programme of water-course improvement is proposed. Should USAID cease to support the Mona field center, this should be supported by the World Bank. In either case PARC should offer to add agricultural studies. The WAPDA Revised Action Programme for irrigated Agriculture (April 1979) recommends the establishment of a Command Area Management unit for 100,000 to 300,000 acre Command areas, to be headed by a member of the Provincial Agriculture Department "with a staff of 5 to 10 agronomists and engineers" to secure joint rotational planning and water scheduling and to ensure that inputs of seed, water, fertilizer, protection

chemicals and credit are available on time. These proposals are strongly supported by the Mission.

A much more active role by PARC in promoting liaison between agricultural R&D and water engineering is needed. For this PARC should have a Land and Water Management Member on the Executive Council.

### Rainfed (Barani) Agriculture

Over some 15 M. acres the diversity of ecological and economic conditions precludes effective support from a single Institute. A national programme of the developing and testing of known technologies should be supported by the NARC. Plant-breeding should not be the dominant activity; agronomy, soil and water conservation by tillage, land shaping and water harvesting are equally important. The work of ICARDA, ICARISAT and other overseas centers of research and development should be a major source of innovation, and testing by "development with measurements" is at present more essential than research.

### Fisheries

(1) Inland. Present production from lakes, reservoirs, rivers and very few ponds is:

Sind	20,000 t.p.a.
Punjab	8,000 "
NW Fronter	2,000 "

Punjab Provincial Government is making an effort to increase production have been one Zoologists from Faisalabad Agriculture University and sent for training in China. Government has set up a successful 6 m.p.a hatchery with

16

with 3 spp of China carp and is stocking ponds. They claim 90% survival for fry. Punjab is now building a very large 100 m.p.a. hatchery and have increased their aquaculture budget to Rs. 10 m p.a. with a team of young zoologists recruited from Faisalabad.

Sind has large opportunities to do the same, with the additional resources of the brackish waters of the Indus estuary, where milk fish (Chanos chanos) would probably flourish.

Funds are likely to be available from the ADB for development of aquaculture but not for research,

#### Recommended

There appears to be no good case for an inland fisheries research Institute at present, but much need for young graduates to be trained in fisheries extension by visits to other tropical countries (e.g. Thailand and Phillipines) where they can learn the technologies which have already been developed by research.

The Zoology Department of Faisalabad Agriculture University is doing some work with limited facilities on the nutrition of pond-fish and on disease incidence, and a modest development of facilities there might be considered if they could be made accessible to post-graduate students from other universities.

If the proposed developments succeed in creating a substantial market for inland fisheries and the potential for a new industry is demonstrated, then an institute for inland fisheries may well be justified, both to study the population dynamics of indigenous and introduced species in lakes and reservoirs as a basis for management and also to improve the efficiency of aquacultural production and marketing.

## Fisheries

### (2) Marine

#### Production

Pakistan lands 200,000 tones of marine fish p.a. plus about 20,000 tonnes of penaeid shrimps which are exported to Japan bringing in \$ 40 million annually in foreign currency. The "by-catch" of some 60,000 tonnes is thrown into the sea, except for the final day of the voyage, when it is retained and sold. Half is marketable and half goes to fishmeal. The biggest immediate increase in fish landings in Pakistan would be obtained by organizing of boats to collect the bycatch from the shrimps.

#### Research

Research needs are for the survey of the sea fisheries resource and the estimation of the population dynamics and the maximum sustainable yield. This would give a sound guide to both investment and management. Research in processing is already being done by a PCSIR laboratory in Karachi but this needs closer association with the fisheries authorities. The Norwegian Government is giving aid to Pakistan in developing her sea fisheries and a Norwegian Research Vessel spend six months in 1978 in study of the coastal waters. Norway will continue to give advice but Pakistan should continue this work. The Federal Government has built two research vessels (each 95 foot long with a 600 hp diesel engine) but these have done only two weeks work in two years, and have been neglected (and some of the gear "borrowed"). The problem has been the inability of a Federal Civil service organisation to pay the very high present rates for crew

(an engineer earns more than the Director of Research.) However the ADB is in process of advancing some \$ 70 million to develop fisheries and it is quite essential that these research vessels be activated and provide the basic data on the resources for development. (Negotiations by the Federal Ministry to hand these vessels over to the Navy are short-sighted and should be postponed while more effective research use is organised.)

The University of Karachi Zoology Department has an outstandingly good fisheries museum for identification of both juvenile and adult stages of local fish species.

#### Organization

The Federal Government Director of Fisheries has new offices and room to build laboratories at the fish harbour of Karachi. The Provincial Governments of Sind and Baluchistan also have Fisheries Directors in Karachi, less well housed and with few facilities. The Provincial Directors control fisheries to the 12-M limit and the Federal Director beyond this limit. The latter has rather a light task.

#### Recommendation

That a Federal Fisheries Research Institute be set up at Karachi Fish harbour, to be closely associated with both Karachi University and the PCSIR laboratories. The main objective of the Research Institute would be study of the marine resource, of methods of improving the size and quality and marketing of marine fish.

A Fleet Management Unit should be a component of the Research

Institute and this Unit should be set up immediately and funded to operate the two research vessels. To avoid the civil service problems of employment of commercial marine crew the Research Institute could with advantage, be a unit of the PARC and this is recommended.

The Fisheries Research Institute and the University should be given resources to undertake joint socio-economic studies of the constraints on production caused by the present marketing arrangements. Close cooperation with Karachi University Biology Department and full use of the fisheries museum should be included in the terms of reference of the new Institute.

## WATER MANAGEMENT RESEARCH - PAKISTAN

G. L. Corey AID/Oct. 79

Pakistan has a tremendously large and high quality natural resource base of soil and water. Couple this with the highly favorable climatic resource and potential for agricultural production defies description.

Soil and water resources are usually and erroneously viewed as mere inputs to agricultural production and since they occur naturally it is not uncommon to assume that man has less control over their management and they often become the most neglected field in agricultural research or production. This general statement applies throughout the world and Pakistan is certainly no exception in having neglected water management research.

Water is the life blood of agriculture. It is not an input which can be purchased at the market place on demand. Its management requires an intricate, precise, coordinated set of systems, laws and procedures handled by governments, legal and operational institutions, farmer organizations, and individual cultivators. To provide irrigation water in proper amounts and at proper times without excessive waste is the most complicated aspect of irrigated agriculture. Perhaps, it is this fact that causes governments to ignore water management as long as possible. It is only natural to want to solve simpler problems first. Agriculture is however a dynamic process - a way of life - and its problems are never all solved, creating the possibility of never getting down to working on soil and water problems. This can finally result in complete destruction of the agricultural system. There are many examples which dramatically verify that this has happened in many locations throughout the world. Surely these bitter lessons of previous water management neglect need not be repeated.

### The Irrigation System

The irrigation system in Pakistan is unique and requires a brief explanation in order to understand some of the water management problems associated with it. Irrigation water is supplied from a five river system (the Indus, Jhelum, Chenab, Ravi and Sutlej) through a vast and extensive system of canals, minors, distributaries and watercourses to something more than 25 million acres. There are 39,000 miles of canal within the system.

The canals supply water to what is referred to as a "watercourse" area. There are 88,000 of these. The water passes to them through an opening in the canal (mogha) which is not gated. In other words, when there

is water flowing in a canal each watercourse area will be receiving its share of the canal water through its particular mogha.

The size of a watercourse area varies from 3 to 800 acres and will be operated by from a few to as many as 100 farmers depending on the size of land holdings.

The canal system of Pakistan was built to distribute irrigation over a large area rather than to produce food in the most economic and efficient manner. The system therefore covers much more acreage than the available water can irrigate at any one time. This merely means that all the land under the canal command cannot be under crop all the time. There is not enough water. In fact, some canals do not deliver water on a year around basis. The designed "duty" of water for the various canal systems varies over a wide range. Some of the rice canals provide one cubic foot per second for each 50 acres while many of the large systems supply water at the rate of one cubic foot per second for as many as 350 acres. Due to limited river storage, canal flow receives only limited regulation and is more or less dictated by the natural river flow. On the watercourse (that system below the mogha) the farmers use the flow on a turn by turn basis (warabundi) with each farmer taking the full flow during his particular turn.

Such a system is not designed to meet the demand of a particular cropping pattern. Irrigation water is supplied on a rigid schedule with a given quantity being available on a regular basis for a fixed time interval. Even if a particular farmer, at a given time, has no crop planted he will be required to use the water during his turn since there is no provision to store water on the watercourse system. Crop water demands are not met by the planned operation of the system but by the farmers' attempt to manipulate his crop species and acreages to match his rigid water supply. In so doing, he plants an acreage he thinks he can adequately irrigate during periods of peak demand. The result is that the farmer may have a surplus of water for that acreage during a portion of the season.

The distribution system (watercourse) from the mogha to the field is farmer maintained. The Government maintained and operated system ends at the mogha. The method of irrigation common on the Indus Plain is level basin and requires that the irrigation field be precisely level. The farmer with primitive tools is only able to partially accomplish precision by keeping the fields small. Therefore, the irrigation units are usually no larger than one-fourth acre and many are smaller than one-eighth acre. A tremendously extensive watercourse system is necessary to conduct water to each field. It is not uncommon to have at least one mile of watercourse channel for each twenty acres.

These watercourse channels are usually poorly maintained. Trees, weeds and shrubs are allowed to grow in the channel and on the banks. Debris and vegetation slow the flow until silt is deposited and the condition is aggravated. This all results in a great deal of precious water being lost in conveyance from the canal to the crop field. Losses from 30 to 50 percent are not uncommon.

In spite of the fact that the turn (warabundi) system is rigid, there is trading and selling of water on the watercourse. This indicates that the farmer does have a knowledge of consumptive crop demands and he tries to put some flexibility into the system. The problem, of course, is that one usually only has excess water during periods when no one else needs it.

#### Waterlogging and Salinity

Waterlogging and salinity are potential problems within any irrigation system. The severity and types of problems vary but always where water is artificially placed on soil for crop production there is danger of salinity, sodicity, and/or waterlogging.

Some of the natural features of the Indus Plain relate directly to these problems and need to be understood, otherwise one can easily confuse a natural condition with an irrigation created problem.

The Indus Plain in Pakistan is arid and although the mountainous areas of the North have rather high rainfall and there are often monsoon floods, basically within the agricultural areas the precipitation only averages 20 inches annually in the north and a mere 3 inches in the south. The soils therefore are naturally not well leached and contain considerable salts in their natural state.

The Indus Plain is also unlain with ground water which is highly saline. This water approaches sea water in its salt content. Whether it originated from the ocean or resulted from precipitation through soils over the ages is not especially important. It does exist and at varying depths throughout almost all of the basin. There is, of course, a layer of good quality water lying above the highly saline water. The thickness of this layer also varies depending upon its source and amount of recharge. This deep salty groundwater overlain with sweet water is also a natural phenomenon of the Indus Basin. It was there long before man started cultivating the area extensively.

The irrigation system and the resulting agriculture has greatly affected this natural system. The extensive canal and watercourse systems have provided opportunity for more fresh water to be leached down to the underground supply. Irrigation in the fields has washed out natural salts as well as also added to the groundwater. The obvious result of

the irrigated agricultural system is a rise in the water table and a lessening of the quantity of the fresh water lens which rides atop the denser salt water base.

The degree of damage done in the past, presently being done, and expected in the future seems to be the subject of much debate. There is no question that water tables did rise after irrigation and there is no question that sodium is increasingly becoming a problem as underground waters become more affected by the leached salt.

The Salinity Control and Reclamation Projects (SCARPS) initiated in the late 1950s were designed as a partial solution to the water-logging problem. This program was essentially a project to drill large wells into the good quality water and pump that water into the farmers watercourse systems. Although many of the wells have been abandoned due to decreasing water quality, most are still operating and have resulted in a general lowering of the watertable in areas where they now have been placed.

Other than the SCARP and private tubewells there is essentially no internal soil drainage anywhere in the agricultural areas of Pakistan. Surface drainage is marginal. Several large open drains have been constructed over the past 50 years but in general surface drainage is rather haphazardly placed and one often sees vast areas of standing stagnant water in a countryside where water is a highly precious resource. Essentially what has happened is that many main drains have been constructed but feeder drains to these mains are practically non-existent and certainly not well maintained where they have been constructed.

#### On-Farm Water Management

Management of water on the farm by the farmer is, in general, not well understood by the Pakistani farmer. He does a good job given his constraints and knowledge but in general he has been given practically no help in this area. His techniques have evolved over time by trial and error methods of survival while operating within his physical, social, institutional and economic environment.

Groups of irrigation farmers are provided a theoretically constant supply of water by the irrigation system. This supply is used by the groups by passing the flow from farm to farm on a turn basis. Equitable sharing is therefore highly dependent on cooperation among the farmers on the watercourse system.

As in most engineer designed and operated irrigation systems, the assumption was made that the farmer would somehow be able to effi-

ciently and effectively use this water in the production of crops. This assumption was adopted by Pakistanis and world consultants alike and has persisted until only recently when actual and thorough measurements made by WAPDA at the Mona Reclamation Experimental Project conclusively showed otherwise. Water use efficiencies between the canal outlet and the cropped field are, in fact, quite low in Pakistan - certainly no better than irrigation systems worldwide as had previously been assumed because of the short supply of water and the level basin method which has no run-off.

When one understands the operation of the Pakistan irrigation system he realizes that the individual farmer has few options or choices in how he uses the water. It is presented to him at a specified time but the amount is totally dependent on the total flow in the supply canal and the state of maintenance of the watercourse system above his farm.

The reliability of this supply at his field, to a great extent, dictates his cropping patterns and the amount of land he cultivates during any given season. The only information available to him is his and his neighbours experience with the system. Couple this with the rather large wastage of water along the watercourse, and it is not difficult to understand why the farmers are not presently interested in using modern cropping rotational systems which theoretically would optimize production on his land. He cannot afford the risk of insufficient water at critical crop stages and logically operates within the survival system he has evolved.

#### Irrigation Water Management Development Programs

There are several donor assisted irrigation and drainage programs in water management either underway or in the planning stages. These need to be mentioned because future research and training orientation should take account of the informational and technological needs they will create.

These development projects, proposed or in progress, are either designed to increase the water supply to farmers, provide for equitable distribution of water, insure a more reliable farm supply of water, create more efficient water application methods, remove excess drainage water and/or reclaim salt affected lands. Most of these projects are based on the realization that there is a large waste of water in the present watercourse irrigation system and that waterlogging and salinity are problems which will continue to threaten the agricultural system. Technologies applied or planned under these programs include watercourse rehabilitations, land leveling, irrigation system management under a canal command area concept, provision of irrigation water

through tubewells or new canals, and waterlogging reduction by either well or open channel removal.

Based on the wasteful water use findings at Mona, mentioned above, the U.S. Agency for International Development and the Government of Pakistan developed a five year pilot program to establish capacity within government agencies, private contractors, and farmer groups to plan and carry out activities necessary for efficient on-farm water management. Salient features of the project design include (a) demonstration of watercourse improvements, precision land leveling, watercourse maintenance and improved structures in large project areas within each province; (b) building the institutions essential for a subsequent nationwide water management program; (c) direct farmer involvement in planning work and in financing the project by contributions of labor and cash; and (d) aggressive promotional efforts to elicit farmer participation generally.

The project is in its third year and has suffered the usual and some unusual implementation set backs. Overall, however, the program is showing promise and is accelerating rapidly especially in the Punjab and Sind Provinces. Especially attractive to farmers is the assistance with improvement of their watercourse systems after which they report being able to irrigate a given plot faster, irrigate more land during their waribundi turn, and to increase cropping intensity and production generally.

The program is managed by water management departments created within the provincial agricultural ministries each of which include operating field teams who work with farmers, a training unit to train new teams and an extension unit to develop demonstrational plots to indicate to farmers, methods of effectively using the increased water supply. The Punjab Province also has created a Demonstrational and Research Farm near Lahore to demonstrate the improved practices and test new techniques.

The achievements through June 1979 under the project are 228 watercourses improved, 24,900 acres of land leveled and 2,466 personnel trained. These certainly do not represent any significant portion of the 88,000 watercourse areas in Pakistan; however, it is a significantly impressive start especially since the institutional machinery is in place, functioning and at an accelerating rate. For example during the first 18 months period only 17 watercourse areas were improved and only 4,700 acres of land was leveled. There are presently 15 field teams operating in the Punjab, 12 in the Sind, 1 in NWFP, and 1 in Baluchistan. The number of teams increase as new trainees pass through the 3 month training courses.

The program also provides for its own extension system in that Extension Specialists are given a 4 month training course at the University of Faisalabad and then assigned to the Water Management team. These specialists work with farmers after the watercourses have been improved to help them make better use of the water. The course is taught by an interdisciplinary group of professors at the University. Three such courses have been taught to date.

If nothing else, this program provides evidence that the government of Pakistan is very much interested in irrigation water management improvement and that they intend to work toward improving the situation. Such a development will create a fertile atmosphere for the necessary research which must accompany such massive farm level programs if optional results are to be achieved.

WAPDA in April 1979 developed a Revised Action Programme for Irrigated Agriculture which proposes vast and numerous projects to modernize agriculture. Most of the suggested projects deal with water management. In summary, the programs include:

1. Credit for new private tubewells.
2. Transittion of SCARP tubewells to the private sector.
3. Watercourse living program in unusable groundwater areas.
4. Water use extension and reclamation programs.
5. Irrigation and drainage system rehabilitation.
6. Basin and canal command water management programs.

These would be accomplished through sub-surface drainage, surface drainage, canal remodeling, canal extension, flood control, and regional development complexes.

This panacea of programs and projects undoubtedly will not be all approved by the Government of Pakistan, however the fact that such a study has been made indicates that there is strong interest in implementation of water improvement projects and surely some of the programs will be initiated.

#### Existing Research

There are no organizations devoted entirely to soil and water management research in Pakistan and very few agricultural research centers devote any effort whatsoever to the subject. This is either an indication of the low priority given to these natural resources or a continuation of the past assumption that farmers will manage these resources effectively and efficiently without help. This attitude must be reversed if Pakistan's irrigated agriculture is ever expected to achieve anything other than a fraction of its potential.

Most research done in the area of water management during the past 20

years has related to crop consumptive use, irrigation requirements for specific crops, and the effects of water table depths and salinity on these factors. The Land Reclamation Directorate in Lahore is an agency which existed before the birth of Pakistan. Most of its work has been accomplished by using various types of lysimeters.

There has been considerable research done on reclamation methods by the University at Faisalabad, the Land Reclamation Directorate, Ayub Research Institute, WAPDA and the Mona Reclamation Project. These studies have provided Pakistan with a fair working knowledge of the soil salinity and sodicity reclamation problems and remedial measures to temporarily remove them.

All three of the Nuclear Institutes have at times accomplished research related to water management. The work is usually rather sophisticated and basic and not readily applicable in the near term to the farmers day to day water management problems.

All of the crop Research Institutes have often accomplished research relating to number of irrigation, irrigation timings, and fertilizer/water interactions for various crops. Unfortunately these studies are usually done without measuring the water applied and often treatments are used which farmers, operating under the present irrigation system, have no hope of duplicating.

The Irrigation Research Institute is a part of the Punjab Irrigation Department. Its major activity is in the field of hydraulics and it has done significant work in hydraulic modeling for the many dams, barrages and structures which make up the major canal systems. Other work done by the Institute includes development and testing of tube-well strainers and lining materials for earthen channels. Although the Institute is a part of the Punjab Irrigation Department its work has application country wide.

All of the above described research is related to water management and the use of water by crops. However, as described earlier, water management involves more than using water as an input to production and useful on-farm water management research must include the manager of the water; the farmer. His problems with the irrigation systems operational procedures, rules and regulations, conveyance of water to the farm and field, application to the field, and removal of water from the field must all be incorporated if research results are to be meaningful to him. In other words, in water management research it is necessary to understand and work within the farmers physical, economic, social and institutional framework.

This type of interdisciplinary research was initiated at the Mona Reclamation Project in 1972 and has been ongoing since. Many types of

studies have been carried out including watercourse improvement by various methods, land shaping by leveling and formation of soil beds, maintenance of watercourses, development of improved watercourse structures, groundwater management and conjunctive use with surface waters, tubewell operation and maintenance, and the effects of these practices on production, cropping intensity and effective water use.

This program has received assistance from a U.S. Agency for International Development grant which provided operational funding support as well as a team of advisors from Colorado State University. The AID contract with Colorado State has now ended but most of the field work is being continued at present.

The Government of Canada is considering providing assistance for a similar experimental arrangement in the Sind Province. Certainly such a program is logical since irrigation system operation, water supplies, cropping patterns, and size of land holdings are sufficiently different to warrant establishment of a center at another location.

The Mona Reclamation Project in the Punjab and the proposed new one in Sind are unique in that they are not experiment stations in the usual sense. Their laboratory is the irrigation system and the farms and fields which make up a portion of entire canal command. Therefore the research accomplished must be done with the farmer, within his environment.

#### Research and Development Needs

As discussed above, there is strong evidence that the Government of Pakistan will continue to develop and implement programs which will provide for more efficient operation of its sophisticated irrigation system. These improvement programs will result in more water for individual farmers, water on a more timely basis, less drainage problems or, in other words, a more reliable and sufficient supply of irrigation water.

There are two problems associated with implementation and operation of large scale improvement programs to improve water management. First, there is the problem of knowing what to do in an improvement program and second there is the problem of knowing what to do with the additional water obtained by making the system more efficient. A well coordinated national research and development program is essential to handle both problems.

Regarding the first problem - more and better data are needed so scientists, planners, and consultants can make rational economic and logical decisions concerning what the development priorities should be.

Past priorities too often have been based solely on the discipline experience or promotional biases of the consultants or decision makers. In order to successfully organize, implement and operate improvement projects in water management a great deal needs to be known about the physical social, and economic system under which the crops are grown. This diagnostic or clinical approach to problem solving is usually not referred to in the scientific community as research but it is absolutely necessary in order to improve any management system on a systematic basis. This type of "research" is not well understood or appreciated by agricultural scientists and they usually want to leave it to extension specialists, anthropologists, or economists. Whoever does it, if done thoroughly and properly, it can be highly rewarding and result in a very high economic return. Pakistan in recent years, through the Mona project, has learned much about operational problems within the on-farm water management system. As programs for improvement are implemented, however this monitoring and evaluation of the farm situation must continue so further improvements can be made and programs adjusted to fit the real world situation of the farmer.

The second problem of knowing what to do with additional water saved through improved management relates directly to research in the usual sense. Much more research needs to be done under conditions faced by the farmer within his irrigation system constraints. As problems are solved and technology improves he will have more water. What should be done with it? As these answers become clear the chances of his doing a better job and using water even more effectively will be real and the economic benefit increased. Without help, however, the farmer views an increased supply as a temporary thing and he will not use it effectively. He will not trust it.

Several possible research topics come to mind when one contemplates what the farmer at the end of a watercourse should do if he suddenly received a more reliable supply of water.

1. Cropping systems research - what crops and cropping patterns make economic sense given the reliability of the supply.
2. Soil management research to improve soil structure and increase infiltration rates and water holding capacities.
3. Yield effects of inundation of root system of various crops over various periods of time. With low soil infiltration rates many crops in Pakistan suffer from standing water for several days during monsoon flooding and even during regular irrigations. The effects of this does not appear to be readily quantifiable without research.
4. Irrigation methods research coupled with soil management to

- learn best techniques of water control for various crops. The flooded basin method surely is not the best method for all crops.
- .5. There will undoubtedly need to be research on the institutional and procedural arrangements presently functioning within irrigation systems. Farmer water user organizations, the warabandi system, watercourse sub-division, fractional tubewells are all aspects which if altered would change the reliability and quantity of water received by farmers. The inter-relationship and possibilities for change are too numerous to be left to chance and interdisciplinary research must be applied.
  6. Development of water monitoring systems to know precisely how irrigation systems were operating at any given time would be highly desirable to maximize use of the water. This is especially true since the system is so large, intricate, and with minimal true storage capacity.

### Suggestions

There is a strong need for a national program in irrigation water management research and development. The water system is not limited by provincial boundaries and its effective and efficient use must be a national concern. Programs to increase acreage through new canals, to reclaim salt affected land, to drain water logged land, and to rehabilitate watercourse and canal systems will all need to be provided data and methodologies in order to optimize investments.

On-farm water management is especially critical in Pakistan. This refers to the portion of the irrigation system existing from the canal outlet down to and including the farmers fields. This watercourse system is virtually a "no man's land" since the Irrigation Department delivers water to the canal outlet and the Agricultural Department provides assistance on farm fields. The Water Management Cells within the Department of Agriculture have recently been giving assistance to farmers on rehabilitation of the watercourse system but its job is too great to be expected to also handle research efforts or even the training efforts necessary to complete the job.

The sensible approach is to institute the on-farm water management research program at the Federal level where the irrigation and agriculture interface can be readily linked and where inter-provincial coordination can take place.

The following are recommended:

1. That PARC develop and manage a national program of irrigation water management research.
2. That this program be linked with WAPDA and include funding, coordi-

nation and linkage mechanization to all water management research and development programs in Pakistan.

3. That the Land and Water subject be given much higher priority by PARC. Direction should be removed from under Plant Sciences and given full member status.
4. That interdisciplinary (Mona type) water management research be encouraged and funded.
5. That development programs to improve irrigation system management be monitored by PARC, or uninformed firms contracted by PARC, so that operational data and knowledge will be centrally available to planners and implementors of projects. Systematic collection and interpretation of data are essential to continued improvement.
6. That PARC carefully monitor on-farm water management research projects to insure that they are directed to existing farmer problems and that proposed solutions are within the farmer's capacity to implement.
7. That PARC publish and distribute results from all water management research and development efforts. As a start, PARC could presently prepare a very useful on-farm water management manual based on all past and on-going research.
8. That PARC provide water management equipment, training, and techniques to research centers wanting to do water-crop related research. These crop oriented centers should either do no water/plant related research or be assisted in doing it properly.
9. That PARC seek an expatriate advisor for at least two years to assist the land and water member with initiation of this complicated program. The Advisor as well as the member should be professionals with strong experience in irrigated agriculture who understand and appreciate the physical, agronomic and socio-economic aspects of water management.
10. That the Social Sciences member work closely with the Land and Water member in development of studies which will provide solutions to the complicated social problems associated with groups of farmers using water cooperatively.