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IRRIGATION PRACTICES SEMINAR

LAHORE, PAKISTAN—1968

FOREWORD

The Seventh Near East-South Asia Irrigation Practices Seminar, jointly sponsored by the Government of Pakistan and the United States Department of State, Agency for International Development, was held in Lahore, Pakistan, from September 25 to October 5, 1968. The proceedings of the seminar are reported in this volume.

Other seminars dealing with irrigation practices in the Near East-South Asia region have been held in Izmir, Turkey 1956; Teheran, Iran 1958; Lahore, Pakistan 1960; Ankara, Turkey 1962; New Delhi, India 1964; and Amman, Jordan 1966. All of these seminars have been sponsored by the United States Agency for International Development.

Delegates to the Seventh Seminar represented the countries of Afghanistan, Ceylon, India, Jordan, Nepal, Pakistan, Saudi Arabia and Turkey, with observers from the United States of America and the United Kingdom. The delegates were selected by their respective governments from the personnel of the organizations having the responsibility for the development and maintenance of irrigation projects and irrigated agriculture in their countries. The delegates dedicated their efforts in the seminar to the problems of providing agricultural soils with optimum moisture to maintain maximum production. Good irrigation practices, integrating the physical resources of the water-soil-plant complex, were suggested as the answer to the world food problem.

A. ALVIN BISHOP, Head
Department of Agriculture and
Irrigation Engineering
Utah State University.
Technical Advisor - USAID

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DELEGATES

Afghanistan

(1) A. Tawab Assifi
Chief Engineer, Helmand Arghundab Valley Authority

(2) Mehrabuddin Formali
Director General, Planning and Investigation
HAVA

(3) Dost M. Noori
Director General, Soil Department
WSSA

(4) Saleh M. Popalzai
Director, Ground Water Studies, WSSA

(5) R. Shinwari
Director General of Irrigation
Rehabilitation, Agriculture and Irrigation Ministry

(6) A. Ghafar Shuja
Director General O & M, HAVA

(7) A. H. Wadin
Irrigation Engineer, USBR

Ceylon

(1) D.J. Ramanayake
Deputy Director of Irrigation

(2) S. Rajendram
Irrigation Engineer

India

(1) G.A. Narasinha Rao
Chairman, Central Water and Power Commission

(2) B.S. Mal
Joint Commissioner, (Engineering)
Ministry of Food and Agriculture

(3) V.P. Kumar
First Secretary, Indian High Commission
Karachi

(4) Eugene Sperry
Engineer, USAID

Jordan

(1) Fahd Natur
Director, O&M Division
Natural Resources Authority

(2) Yousef Attieh
Chief, Agricultural Sector
Planning and Research Division
Jordan Development Board

(3) Saleh Abdul Kadir
Civil Engineer
Directorate of Study and Planning
Jordan River Tributaries Regional Corpn.

(4) Bassam S. Nimry
Director, Bedouin Settlement Project
Ministry of Agriculture

(5) Naim I. Shouka
Head, Credit and Research Division
Agricultural Credit Corporation

(6) Jack A. Griffin
Engineering Advisor, USAID

(7) Richard A. Dangler
Advisor, Natural Resources Authority

Nepal

(1) Tope B. Basnyat
Chief Agricultural Engineer
Ministry of Food, Agriculture and Land Reform

(2) N. K. Agarwal
Deputy Chief Engineer, Irrigation Department
Ministry of Transport, Communication,
Water and Power

(3) B. D. Dahal
Divisional Engineer, Irrigation Department
Ministry of Transport, Communication,
Water and Power

Pakistan

(1) B.M. Abbas

(2) Mehi-ud-Din Khan

(3) Mansur Ahmad

(4) Anis Ahmad

(5) Khalil-ur-Rahman

(6) Altaf Hussain

(7) Malik Sarfaraz Khan

(8) Mohammad Shamsul Haq

(9) Mohammad Serajul Islam

(10) Shamsur Rahman

(11) Sarwar Jan Khan
Secretary of Irrigation and Power
West Pakistan

(12) Mian Alim-ud-Din
Chief Engineer, Irrigation and Power
West Pakistan

(13) Sayid Hamid
Former Chief Engineer, Reclamation
WAPDA

(14) Dr. Mushtaq Ahmad
Director of Research, Irrigation and Power
West Pakistan

(15) Ch. Muhammad Hussain
Director, Land Reclamation

(16) M. Saadat Ali

(17) S. Allah Bakhsh
Chief Engineer, Reclamation
WAPDA

(18) S.S. Kirmani
Chief Engineer
IBRD

(19) Mian Masud Ahmad
Chief Engineer
WAPDA

(20) S. M. Saeed

(21) Munawar Ali

(22) M. S. Minhas

(23) Ch. Abdul Majid
Deputy Director, Irrigation, A.D.C.

(24) M. H. Arain
Chief Engineer, Engineering and Irrigation
Division, A.D.C.

(25) A. Latif Mirza
Secretary
Land and Water Development Board

(26) Majid Hassan Khan
Joint Secretary, Agriculture
West Pakistan

(27) M. Shafi Gill
Director of Agriculture
Lahore Region

(28) Ahmad Mustafa Khan

(29) Abdul Wahab

(30) Dr. Noazesh Ahmad
ADC, East Pakistan

(31) Ahmad Hasan
Vice-Chancellor
West Pakistan Engineering University

(32) Dr. S. Nazir Ahmad

(33) N. D. Yousaf
West Pakistan Agricultural University
Lyallpur

(34) Mazhar Ali

Saudi Arabia

(1) Masud Taji El-Faruki
(2) Saleh El-Humaidan
(3) Wasel Al-Ahmedi

Turkey

(1) Huseyin Yegin
Asst. General Director, Soil Conservation and Farm Irrigation
TOPRAKSU

(2) Ragip Boyaci
Director of Research
TOPRAKSU

(3) Ismail Fikret Celenligil
Head, Agriculture Branch
O & M Department, DSI

(4) Ali Oktay Ersoy
Director, Supervised Agricultural Loans Division, Agriculture Bank

(5) Seref Ozgul
Head of Soils and Drainage Branch
DSI

(6) Teoman Tanrikut
Assistant Chief, O & M,
DSI

(7) Fred Tileston
Engineering Advisor, USAID

United Kingdom

(1) D.J. Fitzgibbon

USA

(1) Dr. A. Alvin Bishop
Head, Department of Agriculture and Irrigation Engineering
Utah State University
Logan, Utah

(2) Leland Anderson
NESA Bureau
AID/Washington

(3) O. H. Folsum
Chief Engineer, NESA
AID/Washington

USAID Pakistan Participants

(1) C.C. Brookshier
Food & Agriculture Officer

(2) Niel A. Dimick
Agriculture Engineering Advisor
West Pakistan

(3) A. B. Enriquez
Agriculture Extension Advisor
West Pakistan

(4) Willet Keyser
Agriculture Extension Advisor
West Pakistan

(5) Leo Mastrofini
Irrigation Engineering Advisor
West Pakistan

(6) Otto Sonntag
Irrigation Farming Advisor
East Pakistan

(7) John R. Stout
Agriculture Extension Advisor
West Pakistan

(8) Earl S. Sumner
Irrigation Farming Advisor
West Pakistan

(9) William Stephens
Irrigation Engineering Advisor
East Pakistan

(10) Theodore Thompson
Irrigation Engineer
West Pakistan

PROGRAM

Monday, September 23

0800 *Registration of Delegates*

1030 *Inauguration*

Recitation from the Holy Quran

Welcome Address by Sh. Ahmad Hasan, Vice Chancellor, W. Pakistan Engineering University

Welcome Address by C.W. Kontos, Director, USAID/Pakistan

Inaugural Address by S.I. Haque, Acting Governor of West Pakistan

Response by B. M. Abbas, Leader, Pakistan Delegation

1400 *Executive Committee Meeting*

Tuesday, September 24

Chairman: B. M. Abbas, Pakistan

0800 *Introduction of Delegates*

0830 *Country Progress Reports* by Afghanistan, Ceylon, Jordan and Nepal

1200 Recess

2000 Dinner sponsored by Habib Bank

Wednesday, September 25

1100 Trip to Batala Engineering Company

1300 Lunch sponsored by Batala Engineering Company

1500 *Country Progress Report* by Saudi Arabia (no written report prepared)

2000 Dinner sponsored by Pakistan Delegation

Thursday, September 26

Chairman: D. J. Ramanayake, Ceylon

0810 *Country Progress Reports* by India, Pakistan and Turkey

1415 TECHNICAL SESSION : *Education and Training*

The Impact of High-Yielding Varieties on Cropping Patterns and Irrigation Practices, India

The Role of Irrigation Foremen in Irrigation Projects, Turkey

TECHNICAL SESSION : *Farm Management for Irrigation Practices*

Soil Moisture as Related to Irrigation, Afghanistan

Survey and Development of Ground Water Resources and Integration with Surface Water Resources, Ceylon

1615 Trip to Packages Limited and Tea

Friday, September 27

Chairman: G.A. Narasinha Rao, India

0800 TECHNICAL SESSION : *Farm Management for Irrigation Practices* (continued)

Estimation of Water Requirements for Various Crops in Different Parts of India, Using Climatological Data, India.

The Influence of Credit upon Water Development and Efficient Use of Water, Jordan

Farm Water Management through Legislative Measures, Credit and Marketing Facilities, Pakistan

The Role of Supervised Credit in Promoting Good Irrigation Practices, Turkey

1050 TECHNICAL SESSION : *Irrigation Institutions —Farm Relationships*

Criteria Relating to Agricultural Aspects for the Design and Operation of Irrigation Systems, India

Water Management as Practiced by the East Ghor Irrigation Project, Jordan

1500 Visit to Badshahi Mosque, Jehangir's Tomb, Old Fort and Pakistan Day Memorial

2000 Dinner sponsored by Siddiqui Construction Company

Saturday, September 28

Field Trip to SCARP-I, Qaderabad-Balloki Link Canal and Chakanwali Reclamation Experiment Station

Lunch by Reclamation Directorate at Chakanwali

Sunday, September 29

Field Trip to Mangla Dam

Lunch at Mangla sponsored by Chief Engineer, Mangla Dam

Monday, September 30

Chairman: Fahd Natur, Jordan

0700 TECHNICAL SESSION : *Irrigation Institutions —Farm Relationships* (continued)

Water Charges and Administration of Systems by Water Users, Turkey

Water Charges in Relation to Benefits Derived in West Pakistan, Pakistan

1045 TECHNICAL SESSION : *Irrigation Practices Research*

Ground Water Investigations, Afghanistan

Water Requirements of Field Crops in East Pakistan, Pakistan

1400 *Panel Meetings*

1630 Visit to Rana Tractor Assembly Plant and Tea

2000 Dinner sponsored by Geotechnica

Tuesday, October 1

Chairman: Tope B. Basnyat, Nepal

0800 TECHNICAL SESSION : *Irrigation Practices Research* (continued)

Recent Researches in the Field of Irrigation, India

Weed and Rodent Control Problems in the Management of Irrigation Systems, Turkey

Irrigation, Soil Salinity and Plant Interactions in West Pakistan, Pakistan

Soil Salinity in Relation to Growth, Yield and Diseases of Crops and Development of Salt-Tolerant Varieties, Pakistan

Soil, Water and Plant Relationships, Pakistan

1045 TECHNICAL SESSION : *Farm Irrigation and Drainage Systems*

Practices in the East Ghor Project, Jordan

Design of Farm Ditches and Measuring Structures, Pakistan

1400 *Panel Meetings*

1630 Visit to Shalimar Gardens

2000 Dinner sponsored by H. T. Smith International Drilling Company

Wednesday, October 2

Chairman : Saleh El-Humaidan, Saudi Arabia

0800 TECHNICAL SESSION : *Standards for Irrigation and Drainage Investigations*

Design Standards Afghanistan

Preparation of Irrigation Guides, Turkey

1015 TECHNICAL SESSION : *How to Live with Salinity*

The Scope for Living with Soil Salinity and Alkali Conditions in India, India

The Use of High Salt Waters by Gradual Dilution in the Reclamation of Saline and Alkali Soils, Turkey

1400 *Panel Meetings*

1600 Visit to Irrigation Research Institute

2000 Dinner sponsored by Pak Elektron Limited at their factory

Thursday, October 3

0800 *Panel Meetings*

1400 Panels prepare Reports

1600 Exhibition at Engineering University

2000 Dinner sponsored by USAID

Friday, October 4

0800 Chairman : Huseyin Yegin, Turkey

0815 Report of FARM MANAGEMENT FOR IRRIGATION PRACTICES Panel

0915 Report of IRRIGATION PRACTICES RESEARCH Panel

1030 Report of FARM IRRIGATION AND DRAINAGE SYSTEMS Panel

1145 Report of EDUCATION AND TRAINING Panel

1200 Report of IRRIGATION INSTITUTIONS — FARM RELATIONSHIPS Panel

1500 *Executive Committee Meeting*

2000 Dinner sponsored by WAPDA

Saturday, October 5

1000 *Closing Session*

Chairman: Sarwar Jan Khan, Pakistan

Report of Executive Committee by Sh. Ahmad Hasan, Pakistan

General Resolution by Fahd Natur, Jordan

Seminar Report by Dr. A.A. Bishop, Coordinator

Delegate Appraisal by Huseyin Yegin, Turkey

Observations of USAID by Curry C. Brookshier

Closing Address by Sarwar Jan Khan, Pakistan

Recitation from the Holy Quran

In the name of Allah, the Beneficent, the Merciful.

He it is Who sends down water from the sky for you; it gives drink and by it (grow) the trees on which you feed.

He causes to grow for you thereby crops, and the olives, and the date palms, and the grapes and all the fruits. Surely there is a sign in this for people who reflect.

And He has made subservient for you the night and the day and the sun and the moon. And the stars are made subservient by His command. Surely there are signs in this for people who understand.

And what He has created for you in the earth is of varied hues. Surely there is a sign in this for people who take heed.

And He it is Who has made the sea subservient that you may eat fresh meat from it and bring forth from it ornaments which you wear. And you see the ships cleaving through it, so that you seek of His bounty and may give thanks.

And He has cast firm mountains in the earth lest it quake with you and rivers and roads that you may go aright.

And landmarks. And by the stars they find the right way.

Is He then Who creates, like him who creates not? Will you not then remember?

And if you would count Allah's favors, you would not be able to number them. Surely Allah is forgiving, merciful.

And Allah knows what you conceal and what you do openly.

And those whom they call on besides Allah created naught, while they are themselves created.

Dead (are they), not living. And they know not when they will be raised.

Your God is one God: so those who believe not in the hereafter, their hearts refuse to know and they are proud.

Undoubtedly Allah knows what they hide and what they manifest. Surely He loves not the proud.

Al-Quran XVI: 10—23

Chapter I
OPENING SESSION

Welcome Address

by

SH. AHMAD HASAN
Pakistan

Mr. Governor, Honorable Guests, Ladies and Gentlemen:

It is a great pleasure for me to have the privilege of extending a cordial welcome to the distinguished delegates and guests who have gathered here to participate in the Seventh Near East-South Asia Regional Irrigation Practices Seminar. May I also, on behalf of the gathering, thank Sheikh Ikram-ul-Haque, Acting Governor of West Pakistan, for having very kindly agreed to inaugurate this seminar. We are also grateful to the United States Agency for International Development for their assistance and cooperation in organizing this seminar for the second time here in Lahore. The previous one was held in 1960.

The first seminar was held in Turkey in 1956. Since then it has been a regular feature to hold the seminar every two years by rotation in the participating countries. These seminars have played a unique role in the matter of pooling scientific information and exchanging technical knowledge. Most of the developing countries have the physical potential for increasing their crop production by 50 per cent or even more. The present low productivity is mainly due to the unbalanced proportion of the productive factors. Irrigation is one of the most important factors contributing to the increase of agricultural production. In order that the farmer may have the full advantage of the available water supply, he needs assistance in the proper utilization of soil and water. It involves many skills and considerable knowledge of the soil-water-plant relationship. Most of the irrigation systems of the past failed because of a lack of knowledge of the proper measures for salinity and water-logging control. Remnants of irrigation systems built hundreds and even thousands of years ago can be found today. In most of the arid and semi-arid countries irrigation is an old art—as old as civilization. For the whole world it is now a modern science and the science of survival.

About three-quarters of the earth's surface area does not have adequate natural moisture for successful crop production and needs irrigation facilities. All over the world, more particularly in arid and semi-arid zones, every country with the objective of attaining maximum benefits from its water resources is putting into application numerous irrigation developments. There has been a progressive increase in the irrigated area. In 1880 irrigated land in the world was about 20 million acres, which went up to about 100 million acres by the year 1900. At present the area irrigated is about 402 million acres, or 15 per cent of the 2.7 billion acres of cultivated land in the 44 countries of the world with substantial irrigation systems. The actual cultivated area in the world, however, is 3.4 billion acres, which is about 45 per cent of the potentially arable land area of 7.9 billion acres. Considering the overall figure of cultivated land in the world, the irrigated area is yet only a small percentage. However, when the distribution of irrigated land and arable land over the world is related to the distribution of world population, it becomes apparent that a large segment of the earth's people, living in diet deficient countries, is heavily dependent upon irrigation for food. Nearly two-thirds of the world population lives in diet deficient countries having less than half of the arable land but about three-fourths of the irrigated land.

Of West Pakistan's gross area of about 199 million acres, more than 66 per cent receives an average annual rainfall of less than 10 inches. The large arable plains of the Indus basin are situated in arid and semi-arid zones, and it is only through the construction of an extensive network of canals, with diversion weirs and barrages across the rivers, that it is possible to practice large-scale irrigated agriculture in this region. The importance of irrigated agriculture in West Pakistan can be estimated from the fact that 64 per cent of its wheat acreage, 89 per cent of its rice acreage and 96 per cent of its cotton acreage are located in the irrigated tracts.

The historic mean annual discharge of the Indus system—comprising the Indus with its five major tributaries, the Jhelum, Chenab, Ravi, Beas and Sutlej—is of the order of 168 m.a.f. as it enters the plains. This is gradually being reduced, and West

Pakistan will be left with about 135 m.a.f. by 1970 under the terms of the Indus Waters Treaty of 1960. About 66 per cent of the annual flow in the rivers is concentrated in the three months, June through August, and a good deal of this volume goes waste to the sea.

For over a century now, the Irrigation department in West Pakistan has been engaged in the development of water resources and irrigation practices. Of the 73 million cultivable acres in the province, 37.5 million acres have been covered by irrigation projects comprising about 40,000 miles of main and distributary canals receiving controlled supplies diverted by 18 weirs and barrages built across the rivers. This is the largest single irrigation system in the world.

There has been extensive development of irrigation in the province. At the time of independence in 1947 the total diversion from rivers for irrigation was of the order of 65 m.a.f..This has risen to 96 m.a.f. in 1966-67. The corresponding increase in the area irrigated is from 19 million acres to about 29 million acres. This increase in water diversion and the irrigated area has been achieved by extending irrigation to new projects and improving water supplies to existing ones, and has greatly contributed to the success of the program for self-sufficiency in food.

Though the climate and the soil offer an opportunity for a much higher level of irrigated agriculture, crop yields in West Pakistan are far below those in other parts of the world. The main reason for this is that drainage and related problems were not fully attended to along with irrigation development programs. In the beginning the water table in the areas under canal irrigation was deep, from 40 to 90 feet below the surface. Since the soil profile was deep and permeable, the necessity for drainage was not felt. By 1947, however, when Pakistan came into being, large areas of the western wing were in the grip of salinity and water-logging. The condition became worse due to low irrigation applications, which accelerated the spread of salinity to about half of the total irrigated area.

We were quite aware of the ultimate consequences of this menace. Continuous research since 1925 on soil and water problems had given us a guide line for action. Salinity and water-logging were declared enemy no. 1 by our President Field-Marshal Mohammad Ayub Khan, and the fight was taken up on a war footing in 1958. The government undertook a comprehensive investigation of soil and irrigation problems in the severely affected areas earmarked by the Directorates of Land Reclamation and Hydrology of the Irrigation department of West Pakistan on the basis of annual salinity and water table surveys. Many salinity control and reclamation projects (SCARPs) have since been formulated with the assistance of foreign scientists and technical experts. Some of them have already been put into operation with the financial cooperation of friendly nations and the World Bank. The actual performance of one of these SCARPs will be shown to seminar participants in the course of a field trip.

We have been able also to surmount the hurdle of an uncertain water supply from India in the three eastern rivers by completing various link canals and the Mangla dam, but still remain deficient in irrigation water for some parts of the year. We are therefore now concentrating on fully exploiting our ground water resources. At present tubewells of about 30 m.a.f. capacity installed by the private and

public sectors in West Pakistan are contributing about 11 m.a.f. annually. The diversions into the canals are of the order of 96 m.a.f. The private sector has sunk about 50,000 tubewells with an average capacity of 1 cusec, and 5,600 more have been added by WAPDA under the SCARPs and by the Irrigation department. Installation of another 2,400 tubewells by these two agencies is in progress.

Salinity Control and Reclamation Projects I and II, now in operation, have shown encouraging results in lowering the water table and increasing the intensity of cropping, where scientific principles of land and water use have been applied. At places where the poor quality of ground water has not been kept under proper watch some adverse effects have been observed. This has focused the attention of scientists and farmers on the careful use of such water. It is hoped that during the course of deliberations the seminar will give special attention to this aspect. There are divergent views on the standard of usable water. Discussion may bring out suitable guide lines based on the experience gained in other countries.

According to the Indus Waters treaty of 1960 between Pakistan and India, the waters of the three eastern rivers—the Ravi, Beas and Sutlej—have been allocated to India, and the waters of the three western rivers—the Indus, Jhelum and Chenab—have been left to Pakistan. The treaty was signed through the good offices of the International Bank for Reconstruction and Development after protracted negotiations between India and Pakistan extending over a period of eight years, and ended a 13-year-old dispute. The irrigation systems taking off from the three eastern rivers before partition are now being switched to the three western rivers. This is being achieved by the construction, under the Indus Basin Replacement plan of inter-river links aggregating 578 miles in length with capacities ranging from 4,000 cusecs to 22,000 cusecs. A major part of the work is already complete. The remaining work is likely to be completed by 1970. This project has involved the huge task of constructing six new barrages and seven new link canals, and remodeling a number of existing canals and barrages with their auxiliary works.

In East Pakistan there is ample rainfall during the summer but a severe deficiency of soil moisture in winter. Because of this shortage of winter moisture approximately 60 per cent of the cultivated land is idle during that season and the balance produces low yields. About 13 million acres have been earmarked for eventual irrigation, involving the application of about 40 m.a.f. of irrigation water. Plans are under way to extend irrigation through gravity canals and lift pumps. To acquaint farmers with the technical know-how, demonstration farms have been opened for practical training in the technique of irrigated agriculture.

The proper use of irrigation water is of the utmost importance for achieving maximum production. This aspect is now being given more attention by following scientific irrigation practices in conjunction with the application of other agricultural inputs. This has enabled us to attain self-sufficiency in food production. The cooperation and response by the farming community in making the government's program of food self-sufficiency a great success deserve special mention.

In the end, I once again extend a hearty welcome to you on behalf of the Government of Pakistan. I wish you all a very pleasant stay in Lahore, 'Hilal-e-Istiqlal'—the historic city of Pakistan, and fruitful deliberations.

Welcome Address

by

C. WILLIAM KONTOS
Director, USAID/Pakistan

The United States Agency for International Development is pleased to join with the Government of Pakistan in extending a hearty welcome to the delegates to the Seventh Near East-South Asia Regional Irrigation Practices Seminar. We are happy to welcome you to Lahore. You will find in Pakistan harvests of unprecedented size and crops now in the ground that demonstrate that in this country we are on the verge of a revolution of farm production aptly called "the green revolution".

Pakistan's growth rate represents an annual increase of about 8 per cent in the gross national product, with agriculture responsible for nearly half of this extraordinary accomplishment. We are certain that additional irrigation has to a great degree contributed to this advance. While here, you will have the opportunity to see and discuss some of the recent developments in the irrigation field. The government and the people of Pakistan can be justifiably proud of their achievements and we know they are determined to improve far beyond present standards.

The world has within its grasp an opportunity of immense proportions—nothing less than the solution of the problem of enough food to meet the needs of fast-growing populations. The basic question is whether this promise will be achieved—whether food production in the developing world will continue to accelerate and become a permanent order of things. Those of us who have been observing the breakthrough in Pakistan's agricultural growth see it as a quantum jump in farm yields that is here to stay.

This is the Seventh Irrigation Practices Seminar in the Near East-South Asia region and the second time you have met here in Pakistan. When this seminar met in 1960, the Salinity Control and Reclamation Program (SCARP for short) was still in the planning phase. We now have six years of operation of the first

project (SCARP-I) of 1.2 million acres and 2,056 tubewells behind us. Study, organization and investment have brought farmers to the threshold of dramatic production success in areas which until now were water-logged and salinized beyond economic use. We in USAID are proud too of the association of the U.S. Government with this massive reclamation effort.

Seven years ago President Ayub asked President Kennedy for American assistance in combating what appeared to be an insurmountable problem. Although many other studies contributed, the report prepared by a team of U.S. scientists headed by Roger Revelle actually launched the SCARP approach.

Twenty-five SCARP areas of approximately one million acres each have been mapped out for a 25 to 30-year program. Six of these areas—providing in time about 7,000 wells—are now in various stages of development. Over 40,000 smaller private wells in West Pakistan have been put in by farmers themselves, following the benefits demonstrated by the SCARP program. The U.S. is assisting in four of the six SCARP areas. To date USAID has provided over $60 million to help finance feasibility studies, engineering supervision, and tubewell construction and electrification. Significant contributions have been made also to road construction and other related works in SCARP-I, the first area put into operation.

At present nine USAID technical advisors are working with the Agriculture and Irrigation departments in SCARP-2. They are launching an intensive educational program among water users, building up on the SCARP-I experience. This program most certainly will be recorded as a significant cause of Pakistan's imminent breakthrough in farm production—a victory for the "green revolution".

While the increase in agricultural production has been phenomenal, we are sure a further increase of 50 per cent can easily be made by improved irrigation practices. We use the liberal definition of irrigation practices as any practice that will increase the efficiency of available irrigation water.

Water use management involves a number of technologists : hydraulic and construction engineers, agriculture engineers, agronomists and plant breeders. Such factors as reservoir management, canal lining, watercourse maintenance, land leveling, methods of irrigation, drainage, improved varieties, fertilizer, tillage and many other practices all contribute to the efficient use of the water.

Science will continue to make improvements in all phases of agriculture, but it is from the irrigated areas that huge increases in food production must come in order to feed increasing millions. The countries taking part in this seminar represent 32 per cent of the irrigated lands of the world. The Near East-South Asia region can become a food exporting area. The resources of land and men are there. With the help of knowledge accumulated from experiences around the world these countries can rise to the challenge.

I again welcome you on behalf of USAID/Pakistan. I wish you every success in your deliberations and discussions. I hope you will take the time during your visit to see some examples of the successful use of water that has made West Pakistan a model of irrigation practices.

Inaugural Address

by

S. I. HAQUE
Acting Governor of West Pakistan

I am grateful to you for having invited me to inaugurate the Seventh Near East-South Asia Region Seminar on Irrigation Practices. It is a matter of great pride for us that this is the second time that the historic city of Lahore has been selected as the venue for this seminar. The city of Lahore, which is rightly known as the heart of Pakistan, is the focal point for coordinating our massive development effort in West Pakistan.

International seminars play a fruitful role by facilitating the exchange of experience and knowledge. The developing countries, by their very nature, have to be on the lookout for every opportunity of sharing the fruits of research by the technically advanced countries. In this era of increasing international cooperation such seminars not only facilitate the exchange of technical information, but also play a vital role in creating a sense of common human goals.

The economies of most of the developing countries of the Near East-South Asia region depend heavily on agriculture. It not only contributes a major portion of their national produce, but is also the predominant occupation of the people dispersed in the pastoral vastness of the region. Any betterment in the lot of this multitude of people, as one of the fruits of independence, can come only through improved agricultural standards as a result of the introduction of modern techniques.

Agriculture in the Near East-South Asia region is beset by many problems. These have commonly been recognized as: outmoded techniques, fragmentation of holdings, a land tenure system devoid of motivation for the tiller and a general shortage of irrigation facilities and inputs. Although all these inputs are crucial, no less than the man behind the plough, some of them acquire a special significance against the background of the natural features of the region. Availability of suitable water is one such factor, since water is essential for the growth of all plant

life. As rainfall in some of the areas comprising the Near East-South Asia region is scanty and in others ill-distributed over the year, artificial irrigation has come to hold the key to the problem of low agricultural yields.

We in Pakistan have a long tradition of artificial irrigation. We have learnt to harness our mighty rivers and have developed one of the most sophisticated canal systems in the world. In developing this irrigation network which is our pride, we have also come face to face with some major problems. One such malady associated with canal irrigation which we are now learning to counter effectively is water-logging and salinity. With the twin purpose of fighting water-logging and salinity while adding to our scarce water resources, we have recently been paying increasing attention to the exploitation of our ground water potential. With a motivated peasantry heralding an agricultural revolution in the country, the demand for irrigation is growing rapidly and water is becoming a rare commodity. It is here that irrigation practices come to acquire an importance which transcends the mere academic pleasures of research. An adequate water supply is the basic requirement of the major industry of the country, and naturally people want to apply water only where it can produce the best results. Traditionally, our agriculture has been based on the assumption of abundant water and cheap labor. Present circumstances have invalidated this assumption. For us it is now a problem of the highest national importance to devise means for the economic and thrifty utilization of costly irrigation water, and simultaneously to maintain the fertility of the soil and avoid the hazards of water-logging and salinity.

This ever-increasing problem of water-logging and salinity had been till recently the biggest hurdle in the way of a breakthrough in agriculture in West Pakistan. In the Indus valley about 33 million acres are under command of the irrigation system. As many as 11.3 million acres were water-logged and 4.8 million acres severely affected by salinity, with an estimated 100,000 acres being lost annually. This was a problem of gigantic proportions and great urgency.

To match the magnitude and urgency of this problem, an institutional change had to be introduced in our management of irrigated agriculture. The issue was tackled through integrated efforts to improve all aspects of irrigated agriculture within clearly demarcated project areas of optimum size. The soil was freed from surplus water, ensuring better drainage. Adequate water was supplied to meet the requirements of various crops and to wash down the salts. Key agriculture inputs were provided to allow full interaction of the productive factors. A new autonomous body called the Land and Water Development board, under the administrative control of a project director, was created to coordinate and integrate the diverse operations involved.

Salinity Control and Reclamation Project No.1 is a typical example of the success of the system. This area of 1,200,000 acres was among the worst affected of our irrigated lands. As many as 425,000 acres had wholly or partially gone out of cultivation. The crop yield in other parts had fallen due to a rise in the water table, the accumulation of salts in the root zone and a shortage of irrigation supplies.

A battery of about 2,000 tubewells started functioning by the end of 1962.

The objective was not merely to lower the water table and thereby drain the soil, but also to produce such conditions as would double agricultural production. The results have been extremely satisfactory. The entire project area is now free from water-logging. The water table has been lowered to an average of 20 feet. Additional irrigation supplies of about 2 million acre-feet per year have become available, increasing the irrigated area by about 400,000 acres. There has also been a considerable increase in yield per acre. The major crops of the area—wheat, rice, cotton, sugarcane and maize—have registered yield-per-acre increases of almost 100 per cent. Of the 425,000 acres out of production, 260,000 acres have already been reclaimed and restored to normal productivity. This is a major achievement of great credit to our engineers and agriculturists. I am glad to learn that you have planned a visit to this project. We would be only too glad to listen to the advice any of you may like to offer in connection with the economic management of such projects.

Similar projects in other affected areas have already been planned and are at various stages of execution and completion. By the end of the Third Five Year Plan the number of public sector tubewells should go up to 8,000 and the operational area should increase to 4.5 million acres. The tubewells will not only free these areas from water-logging, but will be supplying about 10 million additional acre-feet of water per year for crops and reclamation.

Through these measures we have been able to achieve near self-sufficiency in food grains and to reduce our dependence on imports proportionately. We hope to sustain and intensify our efforts so as to achieve complete self-sufficiency and perhaps even a surplus for export.

Gentlemen, I assure you that your deliberations will be of interest not only to the government of this country but also to the vast multitude of its agriculturists. With these remarks I have great pleasure in inaugurating this Seventh Irrigation Practices Seminar and wishing its deliberations every success.

Response

by

B. M. ABBAS
Leader of the Pakistan Delegation

Mr. Governor, Ministers, Leaders of Delegations and Gentlemen:

It is very appropriate that the Seventh NESA Seminar on Irrigation Practices is being held in Pakistan this year and at this time as we are now celebrating the decade of progress. The last ten years have indeed seen a remarkable development in Pakistan in all sectors of the economy.

West Pakistan, which has the largest expanse of land under irrigation in the world, has had to face many problems. The Indus irrigation system is more than a century old. It started with inundation canals which captured river flows at high level. Then perennial irrigation was gradually introduced through a series of river barrages and canal headworks. As the winter flow in the rivers was inadequate for the requirements of agriculture, dams were built to store surplus monsoon flows for utilization in the dry months. Lack of proper drainage and the inadequate application of water, however, created a serious problem of water-logging and salinity. This problem is now being tackled through a comprehensive program of tubewells and drains, which will pump out and drain saline water, lower the water table and at the same time provide additional fresh water for agriculture. Satisfactory results have been achieved through this program, and it is expected that nearly five million acres of water-logged land will have been reclaimed and developed by 1970.

The Indus Basin project is a landmark in the development history of West Pakistan. This $ 2,000 million project consisting of two major dams, huge link canals and new barrages is being executed with great speed. The additional water being made available from the Mangla reservoir has made a tremendous impact on food production and, in association with increased use of fertilizer and improved agricultural practices, has brought about a revolution in West Pakistan's agriculture.

In East Pakistan also considerable development has occurred in the last ten years. This region was neglected and no major development of any kind took place

before independence. Though East Pakistan has big rivers and a heavy rainfall, cultivation of the main crops is confined to a few months of the year, taking advantage of the rainfall and river spill. Most of the cultivable land lies fallow during the rest of the year for want of irrigation water. The high density and rapid growth of the population has made irrigation essential in East Pakistan too.

The control of floods during the rainy season is not within our reach, as the headwaters of the big rivers which bring the floods lie outside Pakistan. Flood protection is being provided, however, through construction of marginal embankments and the improvement of river channels. The water development program for East Pakistan provides both for irrigation and flood protection. During the last decade, East Pakistan has had its first hydro-electric project completed and put into commission at Kaptai. The first modern irrigation project has been constructed and brought into operation in the Ganges-Kobadak area. This project, which provides irrigation by pumping water from the Ganges, will be turned into gravity supply when the Ganges barrage, now under planning, is constructed. In the last decade a deep tubewell and low-lift pump irrigation project has also been executed. All these have ushered in an era of irrigated agriculture in East Pakistan. While there was practically no irrigation in 1958, irrigation facilities are now provided to 425,000 acres of land. On the flood protection side, a major embankment has been constructed along the right bank of the Brahmaputra. It is 135 miles long and protects more than 600,000 acres of land. A big embankment project has been undertaken in the southern districts of East Pakistan to save lands from inundation by saline sea water coming up from the Bay of Bengal. This is one of the largest undertakings of its kind in the world and will protect 3.4 million acres of potentially fertile land in the coastal area of East Pakistan. To date more than 1,600 miles of this embankment have been constructed, reclaiming about 1.5 million acres.

We are keenly aware of the value of research on irrigation practices. The government has set up an irrigation research council to organize, coordinate and promote research in the fields of hydraulics, irrigation, drainage, reclamation, tubewells and flood control. The council has taken over a number of studies in the existing hydrology research laboratories and in the engineering universities. It proposes to set up a flood control research station in East Pakistan and a special study of the problem of water-logging and salinity in West Pakistan. Two institutes of hydrology, one in each wing, are also under consideration.

I invite you to visit these works and many more, if you can spare the time to do so. You will find in Pakistan the entire gamut of water problems and some of the solutions. It is an area of contrasts, from the sophisticated irrigation works of the Indus basin to the unbridled rivers of East Pakistan, from the desert of Sind to the delta of the Brahmaputra, from the tubewells of the Punjab to the fractional pumps of the Ganges. In Pakistan you can see the mammoth and the miniature using water to bring multiple benefits.

We are indebted to the Governor, who in spite of his heavy schedule of engagements has spared the time to inaugurate this seminar and thereby encourage us in our deliberations. I thank him on behalf of all of us here, especially the delegates to the seminar. I thank you, gentlemen, for taking the trouble to come and participate in the inauguration of this seminar. I also thank the organizers of the seminar, the Government of West Pakistan and USAID.

Chapter II
RECOMMENDATIONS

Panel I Education and Training

Chairman :
HUSEYIN YEGIN
Turkey

Recommendations of the previous seminars have been reviewed by this panel. The lack of adequate education and training for all types of technical personnel is admitted, and this panel concurs with this opinion expressed in the past. While appreciating the high value of the recommendations, the panel would like to make further suggestions in specific fields so as to achieve the desired results.

Proper education and practical training are the keystone to the success of the irrigation development of a country, especially for the NESA countries, where irrigation has to play a dominant role in the fight against hunger. The general prosperity of a developing country depends primarily on the development of its irrigation. The science of irrigation has been developed through experience. It is therefore necessary that through proper training the researches and advances in the field of modern irrigation technology be conveyed to various levels for application in order to help realize optimum crop yields.

The panel is aware of the considerable progress made in technical education at the school and university levels, and it is hoped this would be adequate to supply the qualified personnel required for the ever-increasing development needs of irrigation. A major effort is deemed necessary in the field of in-service training at all levels, now generally lacking. We live in an age of specialization, where the requisite skills for the job cannot be acquired from a university education alone. While placing emphasis on the recommendations of the previous seminars, the committee therefore takes this opportunity to make the following recommendations and suggestions :

I. Policy

(A) A policy must be adopted which will satisfy the education and training requirements of personnel at every level and achieve this objective. The agencies utilizing manpower should be closely associated with the bodies connected with curriculum and policy-making decisions at the college and university levels.

(B) Personnel inventories from the project level up should be made to determine the qualified manpower requirements in a balanced way and for a reasonable time in advance.

(C) Maximum effort should be exerted to educate and train personnel by local means, although external facilities may be temporarily employed in the early stages.

(D) Education and training systems should be planned in such a manner that a self-generating, chain reaction effect will be established and maintained. The educated and trained personnel should be used, in addition to their routine activities, for the education and training of others. The in-service trainees should be trained in academies specially set up for this purpose.

(E) Specialized knowledge should be encouraged, and personnel engaged in research and design work should be given a special status to attract suitable talent to this field.

(F) To make the education and training of farmers attractive to them, as it is to project authorities, the whole irrigation development program, including education and training, should be seen and dealt with in one perspective. This will help provide the incentives, such as markets for the products, credits, etc., which are indispensable to the success of efforts in education and training.

II. Planning

(A) Education and training in relation to irrigation should cover the employees of related agencies as well as farmers.

(B) A job description for every level of the related agencies should be prepared, and the training programs of basic irrigation institutes should try to meet the requirements of these job descriptions. Such training as cannot be given by the institutes could be carried out by centers or academies for in-service training.

(C) Education and training programs of basic education training centers and academies should be dynamic enough to meet the changing conditions and demands of the country.

(D) Specialization in particular fields should be encouraged, and special incentives should be given to irrigation workers.

(E) At the stage of irrigation projects where water is applied to the fields, either a strong coordination between engineering and agriculture should be maintained or special training programs should be designed for this purpose.

III. Implementation

(A) Basic education of professional personnel should be mainly the responsibility of ordinary educational institutes. However, agencies engaged in irrigation activities should provide active support to these educational institutions, and should be associated with curriculum planning bodies.

(B) Specialized education of professional personnel should be mainly the responsibility of related agencies. However, active coordination with educational institutions should be maintained, and the possibilities of higher educational institutions should be used for specialization until the agencies develop their own specialized training and educational systems.

(C) The training activities should be diversified and extended to all levels in order to have the needed flexibility. For this, the committee recommends the following :

(1) The training of personnel, including extension workers, may be progressively carried on simultaneously by : (a) on-the-job training; (b) short courses at the job site under the conduct and supervision of more experienced and highly trained personnel of the project; (c) periodic

refresher and specialization courses at the job site; (d) intermediate-term development courses at regional or central training centers; (e) highly-specialized short-term courses, including management training.

(2) The training of farmers should be mainly on a demonstration basis, but every farmer should have the chance of learning the necessary "know-how" on his own field with the help of the extension workers. Audio-visual aids should be used. A comprehensive demonstration system should receive the utmost attention. Full use should be made of the means and ways already available to, or that could be provided by, the farmers. Complementary measures should also be elaborated.

(3) In addition to the above general suggestions the committee recommends the following, with particular regard to farmers :

(a) In order to overcome the shortage of extension workers, training of farmers through cooperatives or farmers' associations should be encouraged, and experienced farmers should be employed for assisting extension technicians.

(b) Field trips to research stations, model demonstration farms and progressive farms should continue as a means of informing farmers about new crop varieties and improved techniques of irrigated farming.

(c) Farmers should be motivated to try better irrigated farming through incentive programs.

IV. Coordination

The committee is of the opinion that NESA countries can actively and successfully cooperate in their training efforts. The experience and achievements of one country may save the other countries from repeating the same trials and errors. Consequently, the committee deems it useful to establish a routine for the regular exchange of experience and information among NESA countries through the exchange of publications and experts. Also, joint programs in particular parts of education and training, such as highly specialized short-term courses, may be launched.

To establish and maintain the above coordination the committee recommends the designation of a liaison officer in each country. The chairman of each country is requested to let the other country chairmen know the name and address of the designated officer at the earliest possible time.

PANEL I. Education and Training

Panel II Farm Management for Irrigation Practices

Chairman :
B. S. MAL
India

The panel discussed in detail various problems relating to farm management for irrigation practices. The committee realized that inadequate farm management for optimum utilization of available soil and water resources was one of the most important factors causing low crop yields in the NESA countries, compared with those being obtained in other developed countries. It was, however, appreciated that recently there has been some improvement in this respect in the NESA countries, where agricultural production has consequently shown appreciable increases.

The position with regard to the recommendations adopted at the Fifth and Sixth Seminars on the subject of farm management for irrigated agriculture was reviewed by the committee. It was found that they were very exhaustive, and covered either directly or indirectly almost all aspects of the problems involved. A list of these recommendations is attached as a supplement to this report.

From the discussions at panel meetings, the reports of the participating countries and the papers presented at the Seventh Seminar, it is encouraging to note that the NESA countries have made vigorous efforts to follow the recommendations of the two previous seminars, with necessary modifications to suit local conditions and traditions. This is also confirmed by the marked, though gradual, improvement in farm management and irrigation practices in these countries as reflected by increased production. More important than increased production, however, is the consciousness which has developed, both in the governments and the people of the area, of the need for improving farm management for irrigation practices on proper scientific lines. As a result, farm management for irrigated agriculture is now receiving due attention in all these countries. The panel took note of these trends towards better farm management for irrigation practices, and urges the governments of member countries to take still more interest in this field.

The panel therefore recommends the following :

(A) Each NESA country should review the actions taken and progress made on each major recommendation of the last two seminars in the field of farm management, and take the necessary steps to accelerate the pace of further implementation.

(B) In addition to follow-up action on the previous recommendations as suggested above, special and specific emphasis should be laid on the points enumerated below :

(1) Widespread use of sprinkler irrigation as one of the improved water management and application methods, depending on local climatic, soil and economic conditions and the limitations of available water.

(2) Relaxation in the imposition of water charges for the first two or three years after introducing irrigation, especially in the case of minor irrigation schemes, in order to encourage quick development of the area and utilization of the irrigation potential created.

(3) Top priority for land preparation in the command of new projects.

(4) Strengthening the extension service to guide farmers on the proper cropping patterns and crop rotations, the amount of water for each irrigation and the time of application with reference to the stages of growth of each crop (especially in the case of new improved varieties being adopted in many countries), and the use of fertilizer.

(5) Encouraging farmers, especially in areas where new minor irrigation projects are proposed, to form irrigation associations or cooperatives, and giving priority to those projects where such associations agree on cost-sharing programs. These associations could function as intermediate agencies between the farmer and the government. Recoveries of payments could be spread over a long period, say 15 years, after completion of the project.

(6) Supervised credit programmed on a large scale and provided in all irrigation projects for quick agricultural development.

(7) Special attention to afforestation as a soil and water conservation measure in the project areas and in the catchments of reservoirs.

(8) Encouragement for laying out grazing grounds in the command of projects where rainfall is very scanty.

(9) Urging progressive farmers to maintain correct accounts of inputs and production, both quantitatively and financially. Simple forms which do not involve complicated and detailed entries could be designed for the purpose. These accounts would be useful in analyzing farm economies.

(C) The panel feels that the necessary coordination between various government and public agencies concerned with farm management for irrigation practices is very often lacking. This coordination, especially between irrigation, agriculture, cooperative and credit agencies at all levels, is very important and should be brought about.

Supplement

List of major recommendations regarding Farm Management for Irrigation Practices in the Fifth and Sixth Seminars.

FIFTH SEMINAR

(1) Adopting sound irrigation methods on a scientific basis in relation to crop, soils, climate, stream water discharge, etc., and proper preparation of fields according to the methods adopted.

(2) Introducing improved implements suited to the draft power available locally.

(3) Advising cultivators on proper scheduling and depth of irrigation applications.

(4) Evolving and popularizing simple methods which the cultivators may conveniently adopt for knowing when to irrigate and how much to irrigate.

(5) Introducing intensive cropping patterns and scientific crop rotations suited to irrigated agriculture.

(6) Achieving the best possible coordination between the irrigation demands of the cropping pattern and the supplies made available on the irrigation systems.

SIXTH SEMINAR

(1) The committee notes that in some countries certain traditional methods of irrigation result in low efficiency of irrigation and waterlogging. It is therefore recommended that governments should help the farmers in adoption of improved water application methods.

(2) To maximize benefits from irrigated farms, farmers should be induced to adopt improved cropping practices, such as using improved seeds, fertilizer, plant protection, etc., and to adopt better techniques of farming through demonstration, education and incentive programs.

(3) Governments should promote farm planning, especially for irrigated agriculture where the capital investment is very high, and yields should be raised to the maximum. Emphasis should be given to land preparation.

(4) In many countries, inadequate and/or poorly maintained watercourses result in heavy water losses. Agencies responsible for water distribution should, where necessary, carry out down to the farm level watercourse construction and betterment programs in cooperation with, and at the cost of, the farmers.

(5) Farmers should be encouraged to develop ground water resources within existing regulations, especially where existing supplies from other sources are inadequate or nonexistent.

(6) It is resolved that the land should be owned by the cultivator. The governments may implement proper measures for the selection of the optimum economical size of holdings, in addition to other assistance. In case of small fragmented holdings which lead to improper utilization of resources, land consolidation should be enforced.

(7) Motivation of farmers to improve their farming methods must be studied and incentives established. This may take the form of guaranteed minimum prices on farm products, subsidies, assistance in developing farm mechanization and processing industries, and special credit facilities. Land taxes should not be relaxed on land left uncultivated.

(8) Inasmuch as improper operation and maintenance of farm distribution systems lead to nonuniform diversion and utilization of resources, policies should be adopted governing the responsibility of the operation and maintenance of farm distribution.

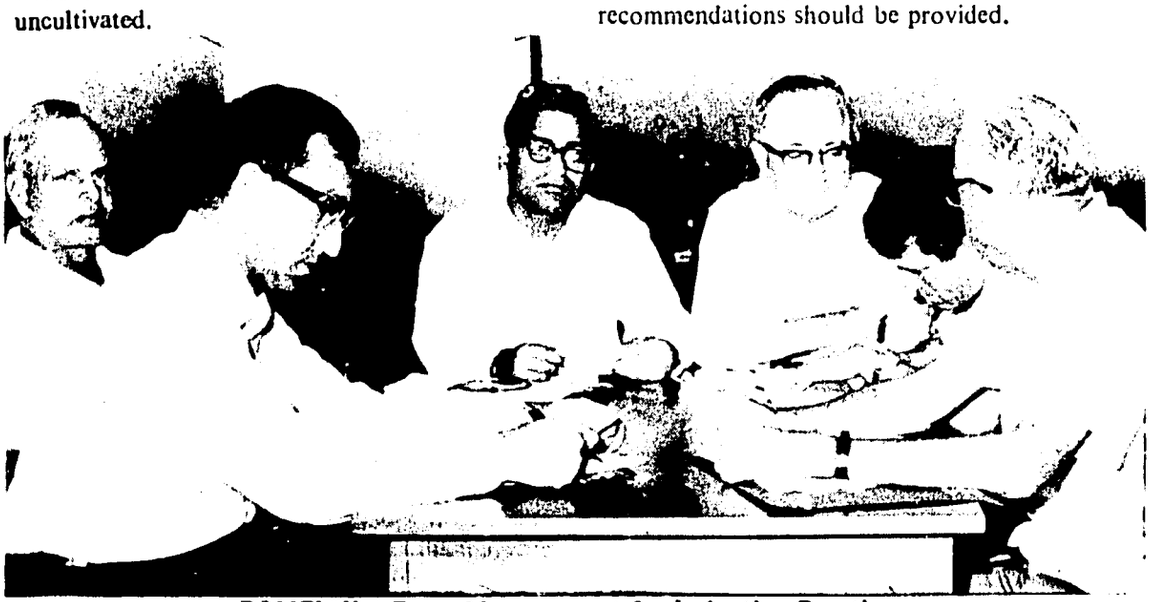
(9) To achieve the most efficient use of water, especially in areas suffering from a shortage of irrigation water, the charge to farmers should be changed to volumetric basis, and where this is not feasible, to an area and cropping basis.

(10) All governments are urged to establish communications within irrigation projects. This includes farm-to-market roads, electricity for irrigation pumps and other uses, and telephone connections between all irrigation facilities and villages.

(11) Agricultural cooperatives should be promoted to make credit, irrigation and marketing facilities available to farmers on the farm level.

(12) Education and training of farmers by institutions or governmental agencies should be promoted.

(13) Necessary legislative measures and institutions to implement the above mentioned recommendations should be provided.



PANEL II. Farm Management for Irrigation Practices

Panel III Irrigation Institutions - Farm Relationships

Chairman :
FAHD NATUR
Jordan

I. Objectives

The objectives of this panel were: to discuss, examine and recommend the pattern of irrigation institutions that will conveniently handle water management to the optimum benefit of the water users; to recommend institutional measures with respect to water rights, water use, water charges and water delivery; and to assess the feasibility or otherwise of forming irrigation associations and transferring the management and operation of parts of the irrigation, flood control and drainage systems to these organizations of beneficiaries.

II. Discussion of Problems

The members of this panel discussed the following institutional problems which are found to be common in the NESA countries.

(A) *The Need for Laws and Regulations Regarding Water Rights, Water Use, Land Reforms and Cropping Patterns.*

(1) Most of the NESA countries either have incomplete or no laws and regulations regarding water rights, water use, land reforms and cropping patterns, with the result that the water users do not receive optimum benefits.

(2) In some countries rules and regulations regarding water rights and water use are enforced without taking the beneficiaries into confidence. Likewise, the beneficiaries in most cases do not cooperate for the success of the project due to this lack of information.

(3) Utilization of water is hampered in some cases due to the absence of a right-of-way for field channels to the land of the beneficiaries.

(4) The absence of proper operational manuals for irrigation projects is a hindrance to the delivery of the right amount of water at the right time and the right place.

(5) Some countries need land consolidation, land ownership reform, and cropping pattern laws and regulations in connection with irrigation development.

(B) *Water Charges in Relation to Benefits Derived.*

(1) Water charges in most cases are fixed without a detailed study of the benefits derived from irrigation.

(2) Some countries do not have price-cost computing divisions connected with irrigation projects. Such divisions are necessary to determine the operation and maintenance costs of irrigation projects so as to assess the water charges correctly.

(3) In some countries water charges are assessed on the basis of the area commanded, whether irrigated or not.

(4) In some countries water rates are fixed on a crop basis. These countries face difficulties in realizing water charges, and since the beneficiaries do not receive demand notes in

time, they face problems in payment.

(5) The collection of water charges is a problem in most NESA countries.

(C) *Irrigation Institutions, Formation of Irrigation Associations and Their Role and Responsibilities.*

(1) Most of the countries in the NESA region do not have farmers' organizations for optimum utilization of water at the field level.

(2) In some countries where farmers' organizations exist they do not have elaborate working procedures.

(D) *Transfer of Management Operation and Maintenance of Irrigation, Drainage and Flood Control Schemes to Organizations of Beneficiaries.*

(1) Some countries face problems of transferring small irrigation schemes to organizations of beneficiaries unless a contract agreement of transfer is signed before execution of the schemes.

(2) Some countries feel that parts of the irrigation and drainage projects should not be hastily transferred to organizations of beneficiaries until and unless they are sufficiently trained to operate and maintain those parts.

III. Recommendations

This committee, having discussed the problems mentioned above and realizing the important role of institutions and laws in water use and water management, recommends the following :

(A) *Laws and Regulations*

(1) Laws, rules and regulations governing the use of water by beneficiaries should be enacted in connection with every irrigation project. These laws and rules should fit the needs and preferences of the farmers as far as possible, and should be drawn up after the farmers' views, have been considered and evaluated.

(2) Water rights upstream, downstream and within an irrigation project should be settled before it is constructed and begins to operate.

(3) Laws for land ownership reform, land settlement, land consolidation and right-of-way should be enacted in connection with every irrigation project constructed by the government to insure the efficient distribution of water.

(4) Every irrigation project should have a detailed cropping pattern scientifically studied to give the greatest economic returns. This pattern may be enforced by whatever means the government may see fit.

(5) Operation manuals for irrigation projects should be prepared by the appropriate authority to safeguard against the misuse of water and to insure proper delivery and optimum utilization.

(B) *Water Charges*

(1) Water charges to cover operation and maintenance costs and all or part of the capital cost should be collected from water users.

(2) To promote efficient water use, charges should be based on the actual water supplied to the farmer. It is recommended that water charges be levied on a volumetric basis wherever practicable.

(3) Water charges should be fixed at a certain percentage of the additional benefits derived by the water users, thus leaving a reasonable percentage of the benefits to the farmers as an incentive. This should be done after a thorough economic study of pre-irrigation and post-irrigation benefits.

(4) Laws and regulations should be set up for the collection of water charges.

(C) *Irrigation Institutions and Farmers' Associations*

This panel very strongly feels that the optimum utilization of water can never be achieved unless there are well-defined government irrigation institutions and well-organized farmers' associations. With this aim in view, the panel recommends that :

(1) Governments should encourage co-operation and close coordination among the different institutions responsible for the development of irrigation projects.

(2) Governments should encourage, through publicity, extension work and mass communication media, the formation of farmers' associations. The size and setup of these organizations would depend on the varying conditions prevailing in each country. These farmers' associations should have rules, regulations and elaborate working procedures. The government should provide training facilities for the members of these associations and all the help necessary for them to carry out their responsibilities.

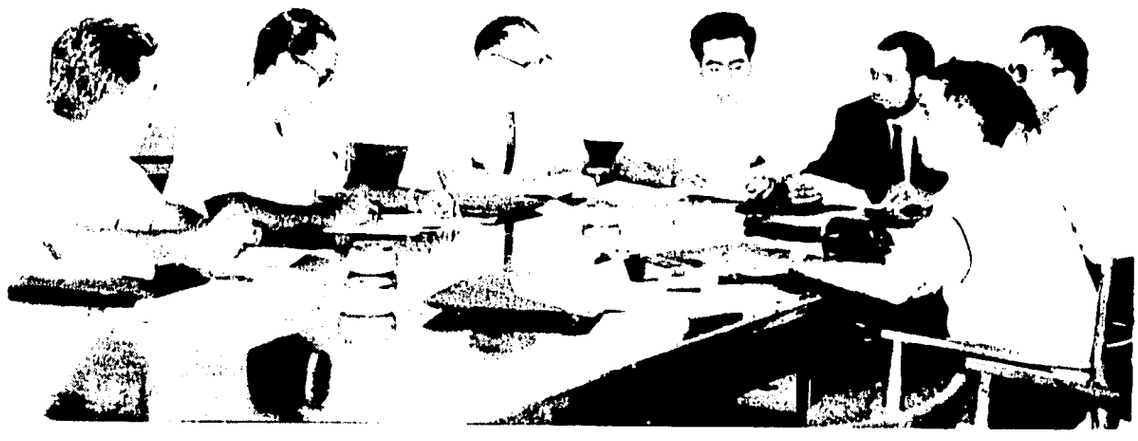
(D) *Transfer of Management, Operation and Maintenance of Irrigation and Drainage Projects to Beneficiaries.*

(1) The operation and management of irrigation distribution systems and drainage projects, or portions of them, should be gradually transferred to the beneficiaries through their own self-organized associations, if and when the state considers them qualified. Such organizations should be of a nature, size and pattern as will best fit the needs of the particular project or project entity. Operation and maintenance costs and collection responsibilities should also be gradually transferred to the beneficiaries.

(2) The state should assume responsibility for operation and repairs of such installations as large dams and reservoirs, major canals, hydro-electric plants and multipurpose structures, where large public interests are involved.

IV. Conclusion

This panel feels that more emphasis should be placed by the different countries of the NESA region on the organizational, institutional and water management aspects of irrigation development in order to achieve the optimum utilization of water.



PANEL III. Irrigation Institutions - Farm Relationships

Panel IV Irrigation Practices Research and Soil Salinity

Chairman :
CH. MUHAMMAD HUSSAIN
Pakistan

Introduction

Irrigation is now recognized as a modern science, a science of survival. The subject of irrigation includes the methods employed for the conveyance of water from the point of supply to the point of application and its actual use in the field. This needs coordination between engineers, soil scientists, agronomists, plant pathologists and extension workers. The subject of drainage is part and parcel of irrigation and in some projects is even more important.

Part I

(A) The panel feels satisfied at the publication of the proceedings of the Sixth Seminar well in time and recommends that the proceedings of this seminar should also be published early. In addition, the panel strongly recommends that the participating countries should submit within three months the topics taken up for research as suggested by the panel, and as soon as possible before the next seminar, a broad outline of the results achieved.

(B) Great difficulty has been experienced due to a lack of the requisite equipment. The panel repeats the recommendations of the previous seminar that adequate funds should be earmarked by the government of each participating country for the timely procurement of equipment needed both in the laboratory and the field.

Part II

The panel has reviewed the recommendations of the previous seminar. In view of the inclusion of soil salinity as a part of the area of deliberation, it has considered the whole subject under the following heads in suggesting topics for research :

(A) *Irrigation Practices*

(1) Methods for the determination of consumptive use and irrigation water requirements of different crops under varying soil and climatic conditions.

(2) Comparative studies of the economics of various irrigation methods on the farm under specific conditions.

(3) Determination of irrigation water losses and economical methods for their control.

(4) Causes of sedimentation and erosion in farm ditches and suggested methods of control.

(5) Determination of the standards of field irrigation practices for specific soil and crop conditions, with reference to the length of run, size of stream, infiltration rate and slope, etc.

(6) Determination of frequency of irrigation for different crops under different soil and climatic conditions by employing various soil moisture measurement devices.

(7) Role of frequencies and amounts of irrigation on the osmotic pressure of soil solutions.

(8) Studies of the methods of soil moisture preservation in the field.

(9) Water measurement.

(B) *Land Drainage*

(1) Evaluation of drainage coefficients for the layout of suitable drainage systems in a particular area.

(2) Comparative study of the practical applicability of various measuring devices for soil permeabilities in the field.

(3) Comparative study of the different types of drainage systems *i.e.* open drain, tile drain, mole drain and vertical drainage by means of tubewells.

(4) Economical material for use in the tile drain, strainers and blind pipes of tubewell installations under different soil and water quality zones.

(5) Optimum depth of water table for different crops under different soil and climatic conditions.

(C) *Salinity Control*

(1) Physico-chemical properties of the soil, quality of water to be used for irrigation and their interaction.

(2) Leaching requirements of the soil with respect to chemical composition of soil and irrigation water.

(3) Optimum water table under various soil and climatic conditions to eliminate the influence of evapotranspiration for salinity control.

(4) Reclamation and other ameliorative methods, including the use of amendments and biological methods and simple leaching under specific conditions.

(5) Influence of exchangeable sodium on yield and chemical composition of plants.

(6) Organic matter, nitrogen, carbon-nitrogen ratio of soils as affected by crops and cropping systems during the processes of soil reclamation.

(7) Soil moisture studies both in the field and in the laboratory to see the movement of the salts under saturated and unsaturated conditions.

(8) Effect of high water table creating anaerobic conditions on the developing roots of the plants and ultimate yield of the crops.

(D) *Water Quality*

(1) Standards employed for the evaluation of quality of water suitable for irrigation, based on the chemical properties of the soil and water with specific reference to CEC, HCO_3 contents, SAR, ESP and boron content.

(2) Prediction of the interaction of water and soil on the basis of soil and water analysis.

(3) Improvement of water quality by mixing it with good water in various proportions.

(4) Changes in the composition of the soil solution as effected by kinds and amounts of ions in irrigation water.

(5) Effect of irrigation water on the quality of drainage water and its suitability for irrigation.

(6) Influence of the use of fertilizers with irrigation water of various qualities.

(E) *Soils*

(1) Appraisal of the physico-chemical characteristics of soils in relation to different irrigation practices.

(2) Development of devices for soil moisture measurement both in the laboratory and the field.

(3) Suitable farming practices for the improvement of soil structure and soil and water conservation under different soil and climatic conditions.

(4) Study of micro-nutrient status of the soil under different water table conditions.

(5) Study of the formation and improvement of hard pans in irrigated soils.

(F) *Crops*

In order to get the optimum return from soil and water resources, special attention should be given to the study of : (a) salt tolerance of crops; (b) suitable crop rotations and cropping patterns; (c) high-yielding varieties; (d) sowing time, seed rate, preparation of seed-bed, frequency and time of irrigation and total irrigation requirements; (e) application of deficient plant nutrients.

(G) *Fertilizers*

(1) Determination of the response to the macro-nutrients (N, P and K) and micro-nutrients (copper, zinc, iron, boron) when applied alone or in combination. Suitable suggestions for fertilizer requirements, mode and time of application, method of irrigation and time of irrigation for the maximum yield under irrigated or dry conditions.

(2) Recommendations on the basis of yield data and soil tests as an aid in developing suitable measures for fertilizer use.

(H) *Weed Control*

The serious problem of the weed is in the canals, drainage channels and cropped fields. Herbicides for the control of weeds at these places will differ in nature. This aspect should be given greater attention as the weed problem is assuming serious proportions, the more so when the water used is silt free. Special attention should therefore be directed to finding suitable types of herbicides for different problem areas.

(I) *Pest Control*

Pest control is now being paid serious attention as the failure of crops is sometimes 100 per cent despite favorable conditions for optimum growth. Research on effective control measures therefore needs to be pursued vigorously.

PANEL IV. Irrigation Practices Research and Soil Salinity

Panel V Irrigation and Drainage Systems

Chairman :
MIAN KHALIL-UR-RAHMAN
Pakistan

The panel recognizes that irrigation was never so important in human civilization as it is at present. To meet the food needs of the fast-expanding population of the world irrigation has to play the most urgent role. Thus the need for improving the overall efficiency of irrigation schemes can hardly be over-emphasized. The objective of any irrigation project, it will be recognized, is to deliver adequate irrigation supplies at suitable intervals to the farms for profitable agriculture, and at the same time to keep the soils healthy and fit for continuous agricultural use. As such, all irrigation schemes should be planned, designed, executed, operated and maintained with an eye on the needs and the good of the farmers.

After due consideration of the recommendations of the previous seminar, the panel makes the following comments and recommendations on the various aspects of the subject:

I. Investigation and Planning

The investigation of an irrigation project is made up of many interrelated surveys and studies. To facilitate these, an investigation plan summarizing the existing conditions and needs of the area and the various aspects to be covered by the investigation should invariably be drawn up. The various elements that may be involved in the investigation of an irrigation project are listed below :

(A) *Water Resources*

(1) Available water supply—surface and ground water—and its reuse.

(2) Water quality.

(3) Water rights, including international obligations.

(4) Hydrology and flood studies

(5) Sediment studies.

(6) Meteorology.

(7) Water requirements.

(8) Uses other than irrigation.

(9) Watershed programs of the area.

(B) *Land Resources*

(1) Soil classification

(2) Land classification.

(3) Land use and capabilities.

(4) Drainage requirements.

(5) Land acquisition, right-of-way and land ownership.

(6) Land development policies and plans.

(C) *Engineering*

(1) Surveying and mapping.

(2) Geological investigations.

(3) Availability of materials.

(4) Anticipated construction problems.

(5) Anticipated operation and maintenance problems.

(6) Replacement problems.

(7) Plan formulation and costs.

(D) *Economic and Financial Considerations*

(1) Economic justification.

(2) Regional and national impact.

(3) Budget requirements and finance.

(E) *General*

(1) Human resources and sociological problems.

(2) Organizational requirements.

(3) Farm cooperatives and credit needs.

(4) Public relations.

II. Design

(A) The irrigation system should be designed for optimum farm efficiency and agricultural production, and should be capable of delivering an adequate quantity of irrigation water at a desirable frequency, keeping in view the farm size, type and profile of soils, cropping pattern, farm layouts, method of irrigation, etc.

(B) The drainage system should be regarded as an essential part of the irrigation project right from the planning stage. The execution of the drainage system can, however, be phased well before the necessity arises. The irrigation project should be designed for maximum operation and maintenance efficiency.

(C) The irrigation and drainage systems should be designed with due regard to considerations such as ;

(1) Topography.

(2) Hydrology.

(3) Size, shape and elevation of the fields.

(4) Types and profiles of soils, and field permeability.

(5) Depth of water table and natural drainability.

(6) Salinity and alkalinity of the soils.

(7) Quality of surface or ground waters.

(8) Water requirements of crops, domestic uses, industrial uses, etc.

(D) While determining the capacity of the irrigation system, special attention should be paid to the following factors :

(1) The increased requirements of irrigation supplies in dry years.

(2) The proposed delivery pattern of the irrigation supply, with due regard to the minimum farm requirements and simplicity of operation.

(E) As far as possible, the system should be able to command the area proposed for irrigation by gravity or other economical means.

(F) The irrigation system should be provided with adequate structures, measuring devices, etc., for efficient operation of the system and control and regulation of deliveries at crucial points.

(G) Adequate number of drainage and road crossings and other communication facilities should be provided.

(H) Where necessary, the irrigation channels should as far as economically feasible be suitably lined to conserve the water resources and reduce the hazards of water-logging and salinity.

(I) The system should be so designed that subsequent modifications, such as enlargement of the canals and drains or regrading of the slopes of the channels, can be accomplished at a reasonable cost.

(J) The choice of the proper drainage system such as open drains, tile drains, tubewells or a combination of these, should be decided upon after taking into account the local conditions of soil, topography, stratigraphy, drainage requirements, etc., and the relative advantages, disadvantages and economics of the system.

(K) Where necessary, the project should be constructed in phases such that complete blocks could be developed for agricultural production as soon as possible.

(L) The irrigation project should be designed for the optimum possible efficiency.

(M) In designing the irrigation system, due consideration should be given to simplicity of operation and economical maintenance.

(N) The irrigation system should be provided with adequate communication facilities, including telephone and telegraph facilities, to assure accessibility to farm units and quick transmission of urgent messages between the field staff and the controlling authority.

III. Construction

(A) The construction of the various components of an irrigation project, including the fieldworks, should be so organized that irrigation water can be used as soon as it becomes available.

(B) The drainage system should be constructed as soon as necessary. The construction of the main drains and the branch drains should be given priority over the construction of the field drains. The construction may be phased according to the needs of the project area.

(C) The activities of the various agencies handling the construction of the headworks, irrigation channels, drains, etc., or dealing with land allotment, land preparation, etc., should be properly coordinated and synchronized to achieve the desired objectives.

(D) In the construction of an irrigation project, maximum possible use should be made of the locally available materials.

(E) All new earthen embankments should as far as possible be provided with suitable protection against erosion.

IV. Operation and Maintenance

(A) Due consideration should be given to the operation and maintenance of irrigation projects both at the planning and the design stages. Persons who have operated and maintained projects at all levels of activity and have valuable information and experience on actual performance of the system in the field should be consulted, and their suggestions, where necessary, incorporated in the scheme. Many a time complicated design problems concerning the operation of a project could be more easily solved in consultation with the field staff. Serious maintenance problems could be eliminated if the suggestions of the operation and maintenance staff are given due consideration while planning and designing an irrigation project.

(B) Responsible public and government agencies should set and maintain minimum operation and maintenance standards at all levels. To facilitate this work, operation and maintenance manuals should be prepared.

(C) Periodical inspection of important hydraulic structures should be carried out by responsible engineers.

(D) For proper maintenance, hydraulic surveys of the channels must be regularly carried out. Water table depth and ground water quality records and the records of the cost of operation and maintenance activities should be properly maintained for periodical analysis, with the idea of further improving the operation and maintenance methods.

(E) Operation and maintenance of the completed parts of a phased project during the construction period should be adequately provided for.

(F) Special attention should be paid to the timely training of the staff needed for operation and maintenance.

(G) The people and farmers benefiting from the project should be encouraged to participate in and assume a greater share of the operation and maintenance responsibilities, through the formation of cooperatives and associations.

(H) Arrangements should be made for frequent contacts between the operation and maintenance personnel and the farmers for a thorough exchange of ideas with a view to improve the operation and maintenance methods.

V. General

The panel strongly recommends that each country planning a large irrigation and drainage project should create adequate research facilities for solving problems of design, construction, operation and maintenance.

PANEL V. Irrigation and Drainage Systems

Membership of the Panels

PANEL I—Education and Training

Huseyin Yegin, Turkey, CHAIRMAN
Yousef Attieh, Jordan
Basu Dev Dahal, Nepal
Saleh M. Popalzai, Afghanistan
Altaf Hussain, Pakistan
Mohammad Serajul Islam, Pakistan
A. G. Kausar, Pakistan
M. Afzal Kazi, Pakistan

PANEL II—Farm Management for Irrigation Practices

B. S. Mal, India, CHAIRMAN
Mehrabuddin Formali, Afghanistan
D. J. Ramanayake, Ceylon
Naim I. Shouka, Jordan
N. K. Agarwal, Nepal
M. S. Minhas, Pakistan
Ahmad Mustafa Khan, Pakistan
Saleh El-Humaidan, Saudi Arabia
Ali Oktay Ersoy, Turkey

PANEL III—Irrigation Institutions—Farm Relationships

Fahd Natur, Jordan, CHAIRMAN
Shamsur Rahman, Pakistan
Tope B. Basnyat, Nepal
Kemal Ertunc, Turkey
A. G. Shuja, Afghanistan
Muhammad Iqbal, Pakistan

PANEL IV—Irrigation Practices Research and Soil Salinity

Ch. Muhammad Hussain, Pakistan, CHAIRMAN
Dost M. Noori, Afghanistan
Bassam S. Nimry, Jordan
M. Saadat Ali, Pakistan
Noazesh Ahmad, Pakistan
Wasel Al-Ahmedi, Saudi Arabia
Ragip Boyaci, Turkey
Ismail Fikret Celenligil, Turkey

PANEL V—Irrigation and Drainage Systems

Mian Khalil-ur-Rahman, Pakistan, CHAIRMAN
A. Tawab Assifi, Afghanistan
R. Shinwari, Afghanistan
S. Rajendram, Ceylon
Eugene Sperry, India
Saleh Abdul Kadir, Jordan
Mushtaq Ahmad, Pakistan
Mohammad Shamsul Haq, Pakistan
William L. Stephens, Pakistan
Teoman Tanrikut, Turkey
Seref Ozgul, Turkey
Fred M. Tileston, Turkey

Executive Committee

Chapter III
CLOSING SESSION

Chairman :
SARWAR JAN KHAN
Pakistan

Report of the Executive Committee

by

SH. AHMAD HASAN
Pakistan

I. Continuation of Seminars

The executive committee recommends that the Near East-South Asia Regional Irrigation Practices Seminars be continued. It holds the view that continuation of the seminars will further benefit irrigation agriculture in the NESA region.

II. Scope and Objectives of Future Seminars

Future seminars concerned with irrigation practices should continue to focus attention on the problems of achieving sound water management and efficient use of water on the farm. Participating countries should pool their efforts to realize this objective.

The executive committee endorses the recommendations of the panels and recommends that the next seminar give priority to the following specific areas :

(A) FARM MANAGEMENT FOR IRRIGATION PRACTICES

(1) Land preparation for irrigation.

(2) Sprinkler irrigation as an improved irrigation application method.

(3) Providing extension services, with special emphasis on water requirements of different crops and the dosage and frequency of irrigation.

(4) Encouraging desirable cropping patterns, wherever feasible, through incentives.

(5) Importance of providing supervised credit to farmers for agricultural development.

(6) Encouraging maintenance of farm accounts by progressive farmers.

(7) Improving coordination between agriculture, irrigation, cooperatives and credit agencies.

(B) IRRIGATION INSTITUTIONS – FARM RELATIONSHIPS

More emphasis should be placed by the different countries of the NESA region on the organizational, institutional and water management aspects of irrigation development in order to achieve the optimum utilization of water. Points of discussion should include the following :

(1) Laws and regulations for water management, water rights, land consolidation and cropping patterns.

(2) Water charges in relation to benefits derived from irrigation and water charging systems, rules and regulations.

(3) Formation of irrigation associations, their setup, responsibilities and authority.

(4) Transfer of operation and maintenance of irrigation and drainage systems, or parts of these, to associations of beneficiaries, including timing and procedures. This should also include the responsibilities and authority to be given to these associations.

(C) FARM IRRIGATION AND DRAINAGE SYSTEMS

The objective should cover the farm delivery for continued profitable agriculture in all phases of planning, design, operation and maintenance by means of :

(1) Adequate planning based on detailed investigations.

(2) Planning and engineering formulation of projects with drainage as an integral part of the system.

(3) Financial and organizational requirements.

(4) Design of the system for optimum farm efficiency and agricultural production.

(5) Construction :

(a) Phased for full utilization and agricultural production of completed parts.

(b) Coordination of various agencies handling the work.

(6) Operation and maintenance :

(a) Consultation with experienced operation and maintenance personnel planning and design phases.

(b) Operation and maintenance standards, manuals and inspection.

(c) System performance and cost records and feed back to planning and design.

(D) IRRIGATION PRACTICES RESEARCH AND SOIL SALINITY

Stress should be laid on concentrating research work in the following fields :

(1) Irrigation practices.
(2) Land drainage.
(3) Salinity control.
(4) Water quality.
(5) Soils.
(6) Crops.
(7) Fertilizers.
(8) Weed control.
(9) Pest control.
(10) Water measurement.

(E) EDUCATION AND TRAINING

(1) Correlation between the job descriptions of different levels in related agencies and the training programs of basic education institutes.

(2) Education of personnel who work at the stage of irrigation projects where water is applied to land.

(3) In-service training of personnel through training centers and on-the-job training.

(4) The role of cooperatives and farmers' associations in training the farmers.

(5) Importance of coordination among related agencies in training the farmers.

(6) Intensive extension network in irrigation projects.

(7) Motivation of farmers for better irrigated farming through incentive programs.

III. Modifications Desired

It is recommended that the following modifications be introduced in the program and procedures of the next seminar :

(A) The duration of the seminar should continue to be two weeks.

(B) The scope of the seminar should be limited to the aforesaid recommendations made by the executive committee.

(C) The seminar leader should contact Near East-South Asia countries six to nine months prior to the seminar to determine what technical papers would be most appropriate.

(D) The country reports present progress since the previous seminar in the field of irrigation and related problems. These should be prepared according to the outline given below :

(1) Brief description of the country and the present status of irrigation development.

(2) Accomplishments since the last seminar.

(3) Progress in water supply development, mainly as related to farm irrigation.

(4) Development of institutions and procedures for improvement of farm irrigation.

(E) The total number of technical papers to be discussed should be limited to 30.

(F) The papers to be presented at the next seminar should be in the hands of the delegates for proper study well in advance. This can be done if the participating countries send their papers at least one month ahead of the seminar to their respective USAID offices. The USAID offices should see that these papers reach the host country and are distributed to delegates in folders on the opening day. The inauguration of the seminar and the formation of the executive committee should take place the next day.

(G) Each paper submitted for presentation must have a synopsis of the subject matter at the beginning.

IV. Responsibility for Organizing and Conducting Future Seminars

It is recommended that :

(A) The United States Agency for International Development should continue to take leadership responsibility for organizing and conducting future seminars.

(B) An invitation to participate in the next seminar should be extended to all NESA countries and interested U.N. specialized agencies.

Resolution

prepared and read by

FAHD NATUR
Jordan

and adopted by the seminar

Mr. Chairman, Dr. Bishop,

Gentlemen:

It gives me great pleasure to take this opportunity to express, on behalf of the delegates to the Seventh Irrigation Practices Seminar, our thanks, appreciation and deep gratitude to our host, the Pakistani Government, for their unmatched hospitality, for their assistance and for all the great efforts they have put into co-sponsoring this seminar, without which this seminar could not have been successful.

We also thank the advisor to this seminar, Dr. Bishop, who gave so much time and effort before the seminar and during the sessions, and much valuable advice that made the holding of this seminar possible and made it one of the most successful so far.

We also thank our colleagues from the Pakistani delegation for their sincere help to the delegates. They really went out of their way to extend help and friendship to the rest of the delegates and to make their stay in Pakistan delightful. We have all had a very rewarding and delightful stay in Pakistan, and I am sure that every one of us will take back with him memories that will be cherished for the rest of our lives.

We thank the U. S. Government and the USAID program for co-sponsoring and financing the seminar.

Fellow delegates, I now propose that a resolution be adopted by this seminar to extend our thanks and gratitude to our host Pakistan, to our advisor Dr. Bishop and to the USAID program.

Seminar Report

by

Dr. A. ALVIN BISHOP
Technical Advisor

Mr. Chairman, Delegates and

Fellow Workers:

I am very happy at this time to make a brief report of another successful Irrigation Practices Seminar, the seventh. Some of you may not know that the seminar series for the NESA region had its beginning in Izmir, Turkey, in 1956. A review of the proceedings of that first seminar reveals that considerable emphasis was placed on the scientific aspects of irrigation, for example, the use of water by crops, the soil as a water storage reservoir, water measurement, drainage and salinity. Likewise, the second seminar held in 1958 at Teheran, Iran, maintained the focus on irrigation science and the need for disseminating the available knowledge to all countries so that the most modern and efficient methods of irrigation could be adopted.

The emphasis of the third seminar held here in Lahore in 1960 was slightly changed to focus more sharply on the farm irrigation problems. It was realized that the most sophisticated scientific and intricate designs are of no value unless proper application of water takes place on the farm. The fourth seminar at Ankara, Turkey, in 1962 maintained this sharp focus on "good irrigation practices on the farm" and explored methods and ways to achieve it. Problems of education and training of farmers received attention along with farm credit, farm irrigation systems, operation of projects and research.

The fifth seminar at New Delhi, India, in 1964 and the sixth at Amman, Jordan, in 1966 further emphasized the importance of having the farmer intimately involved. All of the science of irrigation, the careful planning and building of large dams and canal systems, improved crop varieties with fertilizers and related inputs are of no value unless the integration of knowledge and physical resources takes place on the agricultural soil to produce crops.

We have come to realize that irrigation is complex, necessary, and perhaps the most important single discovery that has been made by man. No longer is irrigation considered to be solely a requirement of arid regions. Today irrigation is known to be beneficial in arid, sub-humid and even humid regions, for nature cannot be depended upon. Nature is whimsical, capricious and seldom provides the right amount of water at the right place at the right time. Thus, to maximize agricultural production in any climatic region of the world, irrigation can be depended upon when nature fails.

The past seminars have been designed to make irrigation more effective in the NESA region. The seminar objectives have been carefully planned to determine the problems and exchange ideas regarding their solution. The objectives were carefully thought out. The emphasis continued to be directed toward "on farm irrigation problems". The papers and discussions focused upon the problems of providing the right amount of water at the right place at the right time to be used to maximum advantage by the agricultural crop.

The discussions here at the Seventh Seminar have provided a free exchange of knowledge in an atmosphere of cooperation among the delegates from the countries of the NESA region. The hard-working panels tackled their assignments with enthusiasm and dedication. Thus excellent reports and spirited discussions are ample evidence of their diligent efforts.

It was difficult at times to maintain the focus on "farm irrigation practices" for it was realized that these are often subject to practices beyond the farm. For example, institutional practices, management practices, legal practices and design practices all influence the manner in which the water is used on the farm. These practices can be influenced by the farmer only to the degree of his involvement. The discussions also pointed up the complex nature of the irrigation system, which includes the engineering structures for conveyance and delivery of irrigation water and the collection and disposal of drainage water. These systems are designed primarily as hydraulic systems, but with an underlying purpose to provide the right amount of water at the right place at the right time, or provide drainage to maintain water tables at desired levels and reduce the salinity hazard. The sound management of water was recognized as requiring a thorough understanding of the water-soil-plant complex, integrated with fertilizer, variety and cultivation practices, to produce maximum yields. The theme of the seminar to "keep the focus on irrigation practices" was thus maintained.

In evaluating the seminar one must pay attention to three sets of conditions generated by the seminar. First, in my visits to the NESA countries during January and February an enthusiasm was generated to prepare papers and a country report.

Thus a situation was created within each country to write papers and exchange ideas about irrigation problems. Second, participation in the seminar itself, where country reports have been presented, technical papers discussed and a free exchange of ideas has taken place in panels and general meetings. Third, the delegates, armed with new knowledge and enthusiasm, can return to their home countries and approach the many irrigation problems with renewed vigor. These three situations—planning for the seminar, participating in the seminar and putting into practice the ideas of the seminar—all have value, and the value depends upon the degree to which each delegate involves himself in each situation.

In all, 25 technical papers and eight country reports have been presented. As one considers the numerous subject matter titles, one is impressed with the broad area covered by irrigation science and the complexity involved in integrating all related disciplines into a scientific treatment of irrigation problems.

The executive committee in formulating its recommendations for a future seminar has outlined the goals to seek in promoting and improving irrigation practice. It is hoped that these recommendations will be given due consideration when another seminar is planned.

I now wish to congratulate the local committee here in Pakistan for the great effort it has put into arrangements, facilities and program to make our visit here profitable and enjoyable. Special thanks should be extended to Mr. Earl Sumner, USAID/Pakistan, for his untiring efforts in behalf of the seminar and the welfare of the delegates.

The field trips were planned to show the broad scope of irrigation in Pakistan, the local visits and tours added to the enjoyment, and, I should say, we have dined most royally. All in all I believe the seminar has been highly successful, and our thanks should be extended to the Pakistan Government and the USAID Mission in Pakistan for all of their efforts and a job well done. Thank you!

Delegates' Appraisal

by

HUSEYIN YEGIN
Turkey

Mr. Chairman, Dr. Bishop, Mr. Hasan, Distinguished Delegates and Friends:

It is a great pleasure for me to present the delegates' evaluation of the Seventh NESA Regional Irrigation Practices Seminar.

It is necessary to increase agricultural production in the NESA countries to meet the demands of the increasing population and to raise the standard of living. Irrigation is one of the most important factors in increasing agricultural production in areas where climatic conditions are unfavorable and land resources are limited. But irrigation is not an easy task. It requires proper institutions, laws, qualified personnel, sufficient funds and extensive knowledge covering every phase of irrigation, starting from the water resource and ending with the marketing of agricultural products. Successful irrigation can be achieved only by combining science with the art of administration. Because of the complex nature of irrigation, NESA countries are facing many problems in their fight against hunger. Fortunately they are not alone in this fight. In the NESA irrigation seminars we are learning from one another the necessary tactics of this fight.

Two weeks ago scientists, administrators and experts from Afghanistan, Ceylon, India, Jordan, Nepal, Pakistan, Saudi Arabia and Turkey and advisors of USAID gathered in Lahore to report their achievements in the last two years and to learn from each other. Two weeks have passed like a day. Now we are concluding our meetings. Eight country reports and 25 technical papers were presented.

Suggestions were made for the future by five different panels after discussing mutual problems and reviewing the achievements of countries.

As you know, if it were not for the helping hand of Pakistan, there would not have been any Seventh NESA Irrigation Seminar at all. The decision to have this seminar in Pakistan was taken only a few months ago. Preparation for such a seminar requires two years of planning, organization and arrangement. We highly commend the chairman of the seminar managing committee, Mr. Hasan, and the Pakistani agencies for accomplishing all this work in only a few months and yet making this seminar one of the most successful held so far. I think the seminar was very successful because we were provided with a very modern meeting place, all of the reports were presented and discussed thoroughly and a proper time was given for panel discussions. Field trips to SCARP-I, Chuharkana reclamation farm, Chakanwali experiment station, a model farm and the Mangla dam, a study tour through the Irrigation Research Institute, attending the exhibition at the university, and visits to new industries and Packages Limited gave us a very good cross section of basic educational institutes, research stations, water resource developments, control of salinity and water-logging, farms and industries in Pakistan. We observed great accomplishments in every part of this cross section. Last but not least, the incredible hospitality of our colleagues from Pakistan made us feel perfectly at home.

In the success of this seminar Dr. Bishop has had a great role by serving as a vital bridge between the NESA countries and USAID. His technical advice during the meetings, panel discussions and executive committee meetings was excellent. USAID too did much for the success of this seminar. And all of the delegates should be highly credited for their contribution to the seminar through their reports, suggestions and comments. I hope these seminars will continue to help with our problems in the way this seminar did.

Thank you!

Observations of USAID

by

CURRY C. BROOKSHIER
USAID/Pakistan

This is the closing session of the Seventh NESA Regional Irrigation Practices Seminar. This seminar has not had the largest attendance: we have had only 10 nations represented this year as against 15 at a previous seminar. But if I have been properly informed this has been the best—the best in quality of papers, the best in technical knowledge of the delegates, and, above all, the best for focusing on the real problem of relating irrigation to agricultural land and ultimately to increased agricultural production.

I hope that your field trips to SCARP-I and Mangla dam last Saturday and Sunday were worth-while. My work in SCARP-I in Pakistan has taught me a lesson. I hope the same lesson has been properly demonstrated to you, that is, if the coordinated forces of government departments can be brought to bear on a problem such as SCARP-I, then success will come about much more rapidly than when each operates as a separate entity.

I have been able to attend very few of the sessions but fortunately I have been able to keep in touch with the progress. I have been impressed with a number of things, of which I will mention only four.

First, the ability of the delegates to focus on the problem of correctly using water for agricultural production. Irrigation means many things to many people—big canal systems, laterals, drops, gates, ditch riders and weirs. All these things are great engineering feats. But how the farmer utilizes the water and the yield he gets from a unit of water are the ultimate objectives in irrigation. I congratulate all of you on the attention you have given this subject and the recommendations you have made to tackle the problem.

Second, the fine quality of the technical papers. It has been interesting to note the participation of the delegates in discussions following the presentation of these papers, and the excellent preparation of each speaker as demonstrated by his answers to questions related to his paper.

Third, the recommendations made by the panels. These recommendations demonstrate the technical knowledge, sincerity and devotion of the delegates toward their chosen specialty and their desire to get things done.

Fourth, the excellent facilities provided by WAPDA for holding this seminar. Although the weather has been exceptionally warm, even for Lahore at this time of the year, the delegates have continuously had a comfortable place to meet and work in.

At the opening session Mr. C.W. Kontos, Director of USAID/Pakistan, extended a welcome on behalf of USAID. At this closing session, may I, on behalf of the USAID Mission in Pakistan, express our appreciation for the excellent participation of the delegates that has made this seminar a success. May I also express my sincere gratitude to the Government of Pakistan for its part as host to the seminar. This is the second time it has played host, and I am sure the experience gained previously accounts for the excellent treatment we have all received. We are also indebted to the wise guidance in seminar affairs given to us by Dr. Bishop; his previous experience has certainly contributed to making this a better seminar.

I hope we are able to go back to our jobs with new knowledge, new friends, new hopes and new professional contacts. I challenge you to go back to your homes and put some of this new knowledge to work. If you do that you have made your stay here in Pakistan worth-while. May all of you have added success in your dedicated work to improve the livelihood of your agricultural people in your respective countries.

Thank you.

Closing Address

by

SARWAR JAN KHAN
Pakistan

This is the concluding session of the Seventh Near East-South Asia Regional Irrigation Practices Seminar, which has been in session for the last 13 days. I learn that during your deliberations as many as 25 papers were presented on various subjects covering the field of irrigation practices. I want to thank the authors who labored to prepare valuable papers and have thereby generously shared their experience and knowledge with all the participating countries.

I would also like to thank Dr. Bishop, who took special pains in organizing this seminar in cooperation with USAID and the officers of the Pakistan Government, and has made it an outstanding success. I am sure you will all join me in congratulating the managing committee for the excellent arrangements and management.

As already indicated in various addresses and deliberations during the course of the seminar, we are all confronted with different problems, some of which pose a serious threat to our agricultural economy. By a planned and concentrated effort we in this country have been able to deal effectively with water-logging and salinity, and have not only been able to maintain our agricultural produce level, but have, by the grace of Allah, improved on it substantially. Our main efforts have been to make water available for irrigation at the proper time during the growth period of crops. Efforts have also been made to help the cultivator in the procurement of other agricultural inputs needed for high crop production. Primitive and unscientific irrigation and agricultural practices are now being replaced by improved and scientific practices.

Seminars like this pave the way for further improvements, and I am quite confident that my country will gain a lot from what has been presented by the distinguished delegates from the participating countries.

I appreciate the recommendation of the executive committee for holding a seminar in the future every two years. This will be of great advantage to all those concerned with irrigated agriculture. Now, gentlemen, I once again thank you all at the successful conclusion of the seminar.

Chapter IV
COUNTRY PROGRESS REPORTS

AFGHANISTAN

Irrigated agriculture has been the backbone of Afghanistan's economy. The Government of Afghanistan, realizing the need for the-full utilization of the natural resources of the country, has concentrated its efforts toward land development and irrigation improvement works in the past decade. The following presentation gives a summary of major undertakings and accomplishments over the past two years, which coincide with the first and second years of Afghanistan's Third Five Year Plan.

Poor harvests in 1965 and 1966 resulted in soaring food prices in the country, which induced farmers to divert their attention from commercial and other crops to the production of food grains. This fact, coupled with favorable climatic conditions in 1967, gave rise to an overall increase in farm production.

Generally, we can say that run-off for the whole country was below normal in 1966 and normal for the year 1967.

Surface water investigation has continued on existing hydrological stations, and considerable advancement has been made in this field.

The number of gauging stations has increased and high water measurements have been made in all stations on the important rivers. Eighty-one new gauging stations have been built in the last two years on the major rivers of the country. This increase will bring to 175 the total number of stations equipped with automatic recorders, cableways and measuring facilities.

During the period from 1966 to 1968, project investigation for irrigation and land development has continued for various parts of the country.

Soil Surveys

Reconnaissance soil surveys and land classification of some projects have been made. The following table gives the areas surveyed to date.

Drainage, engineering and feasibility studies have been carried out in connection with individual projects.

Semi-detailed soil surveys have been completed in the Kabul and Harirud river basins. Topographic surveys have been completed for the upper Kabul basin (60,000 ha.), Harirud river basin (250,000 ha.), and the Kunduz and Khanabad river basins.

Dam site surveys for small dams have been

carried out in the past two years for the following :

Khishtpul	..	Shirin Tagao river.
Qarashiekhi	..	Shirin Tagao river
Deala	..	Ghazni river
Park	..	Naharah river.
Tamaky	..	Tamaky Wash
Khwajagan	..	Ghazni river
Ab-Band	..	Ghazni river
Sia Gil	..	Ghazni river tributary

TABLE I

Areas of Soil Surveys in Afghanistan

	PROJECTS	AREA (ha. approx.)	
	AGENCY : WATER AND SOIL SURVEY AUTHORITY ASSISTED BY FAO/UNSF		
1.	Farah Valley Area	59,000	
2.	Jiwain Area	6,290	
3.	Kala-i-Kah Area	8,850	
4.	Shindand Area (Adraskan)	155,000	
5.	Upper and Lower Harirud Valley Area	410,700	
6.	Jilga River Valley Area	139,990	
7.	Upper and Middle Nahar Valley	123,400	
8.	Ab-i-Istada Area	310,000	
9.	Ghazni Valley	250,000	
10.	Waza Khwa Area	54,000	
11.	Kabul and Upper Kabul Valleys	173,000	
12.	Logar Area	36,000	
	TOTAL		1,726,230
	AGENCY : WATER AND SOIL SURVEY AUTHORITY ASSISTED BY THE INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT		
13.	Kunduz-Khanabad Area	19,740	
14.	Taluqan Area	21,010	
15.	Baghlan-Pul-i-Khumri Area	42,610	
16.	Kunduz-Aliabad	41,970	
17.	Iskames	38,050	
18.	Kalagai	7,600	
	TOTAL		170,980
	AGENCY : WATER AND SOIL SURVEY AUTHORITY*		
19.	Northern Regions of Afghanistan		3,603,100
	AGENCY : WATER AND SOIL SURVEY AUTHORITY		
20.	Dasht-i-Darwazagai	80,700	
21.	Dasht-i-Nawabad and Dasht-i-Noguman	2,488	
22.	Dasht-i-Gambiri	6,000	
	TOTAL		89,188

	AGENCY : MINISTRY OF PUBLIC WORKS*		
23.	Nangarhar Development Project Area		31,520
	AGENCY : HELMAND & ARGHANDAB VALLEY AUTHORITY		
24.	North Arghandab Area	27,400	
25.	Central Arghandab Area	53,530	
26.	Tarnak Area	44,720	
27.	Seraj Area	43,580	
28.	Boghra Area	10,120	
29.	East Marja Area	20,200	
30.	Shamalan Area	26,700	
31.	Darweshan Area	29,900	
32.	Garmsel Area	63,500	
33.	Bakwa Area	106,000	
34.	West Kajakai	5,200	
35.	Chakhansur	234,400	
	TOTAL		665,250
	GRAND TOTAL		6,286,268

*Land classification maps not available.

Ground Water Investigations

Comprehensive ground water geophysical investigations covering the following items have been performed :

(1) Inventory of ground water (springs, wells and karezes) quantity and quality. So far 1,300 samples have been analyzed.

(2) Geophysical resistivity mapping and profiles: 55 vertical, 807 km. of horizontal profiles and 1137 vertical electrical soundings have been taken in Katawaz, Charikar, Kabul and Andkhui areas.

(3) Drilling : nine large-diameter (8"-16") boreholes to a total depth of 1,279 meters and ten small-diameter (3"-5") boreholes to a total depth of 398 meters have been tested. Drawdown and recovery tests have also been made in the boreholes in the Katawaz and Charikar areas.

Irrigation and Land Development Projects

(A) HELMAND AND ARGHANDAB VALLEY

In the past two years detailed soil and drainage investigations of 12,500 ha. of the Shamalan project have been completed. Feasibility studies and reports, topographic surveys, and mapping and cadastral land ownership surveys are also complete for this area. Preliminary plans of land development and irrigation layout have been developed. It is hoped that final design and specifications will start by 1969 and the first phases of construction by 1970.

The development of block 2E2 of Darweshan will be completed by the end of 1968. The design and excavation of the Marja and Nadi Ali drains have been continuing for the past two years. It is hoped that the excavation of these drains will be completed in 1970. Soils and drainage investigation of the Central Arghandab project has been started, and feasibility studies and reports will be prepared for this area.

Drainage investigation and designs of the Karz and Zakird emergency outlet drainage in Central Arghandab have been developed, and the excavation of these drains will be completed by 1969. A new division of engineering has been organized by HAVA, which is responsible for all designs, specifications, construction contracts and inspection for the Helmand and Arghandab valleys. The HAVA engineering division has slowly gained momentum during the past two years, and is attempting to handle all project engineering works through intensive training of a sufficient number of young Afghan engineers

(B) NANGARHAR VALLEY PROJECT

The leveling of 8,931.4 ha. of land has been completed, and the structures and irrigation system of Farm No. 1 have been finished.

Distribution of water from the Nangarhar canal to 14,000 ha. of new and already cultivated land, and the structures and irrigation system for 3,436 ha. of Farm No. 3 have been completed. Out of 12,300 ha. of land outside the government farms needing improvement, 4,574 ha. have been leveled and structured. It is planned that 3,000 ha. per year will be improved from the coming year.

(C) PARWAN IRRIGATION PROJECT

The reconnaissance survey of this project started in 1964 and the detailed general survey of 40,600 ha. was completed in 1966. The survey included the following :

(1) Hydrology
(2) Geology
(3) Soils and land classification
(4) Topography and engineering

The construction of project workshops, laboratories and offices is complete.

The main construction features of the present plan are :

(1) Diversion dam on Punjsher river.
(2) Main canal of 29 m^3/sec capacity with a length of 25 kilometers.
(3) (a) 180 m. long Salang siphon.
    (b) 680 m. long Ghorband siphon.
(4) East branch, 19 km. long, 16 m^3/sec capacity and a 2,000 kva power plant.
(5) South branch, 21 km. long and 9 m^3/sec capacity. Pumping canal, 3 m^3/sec capacity with a head of 24 m. Gravity canal, 6 m^3/sec capacity.

The first phase of development of this project will be : 16,000 ha. served by a gravity system, and 9,000 ha. served by pumping.

(D) SARDEH PROJECT

Construction of the Sardeh dam on the Jilga river, which is 38 km. southeast of Ghazni, was originally finished to a height of 29 m. and a reservoir storage of 220 mcm. Further investigations showed that if the height was raised to 31 m., the capacity would be increased to 250 mcm. and the reservoir would be capable of serving 19,000 ha. of land, now partially irrigated from karezes (4,000 ha.), and providing additional reservoir storage for flood control purposes. The construction of the first km. of a masonry-lined canal of 15 m^3/sec is complete. A spillway of 35 m^3/sec capacity has been provided at a distance of 200 m. from the intake.

The right branch canal of 7.2 m^3/sec capacity has been dug for about 2 km., and work on the siphon crossing the Jilga river is 40 per cent complete. The left branch of 7.8 m^3/sec capacity has been dug for 9 km. The construction of the outlet works, spillway and dam was completed in May 1968.

(E) SHARWAN CANAL

This canal has a capacity of 55 m^3/sec and will irrigate a gross area of over 34,000 ha. The intake reach is 470 m. long, 220 m. of which is made of gabion dikes. A sluiceway, a 650 m. sluice canal, the intake structure and 4 km. of the head reach of the main canal have been completed. It is anticipated that the project and the rehabilitation of the existing canal will be completed in 1969.

(F) KALAGAI IRRIGATION PROJECT

This project will serve a gross area of 2,500 ha. A diversion weir with a maximum capacity of 1,650 m^3/sec, a head regulator, distribution system and desilting canal, and three km. of a canal of 16 km. length and 5.7 m^3/sec capacity have been built. It is anticipated that the distribution system will be completed in 1969.

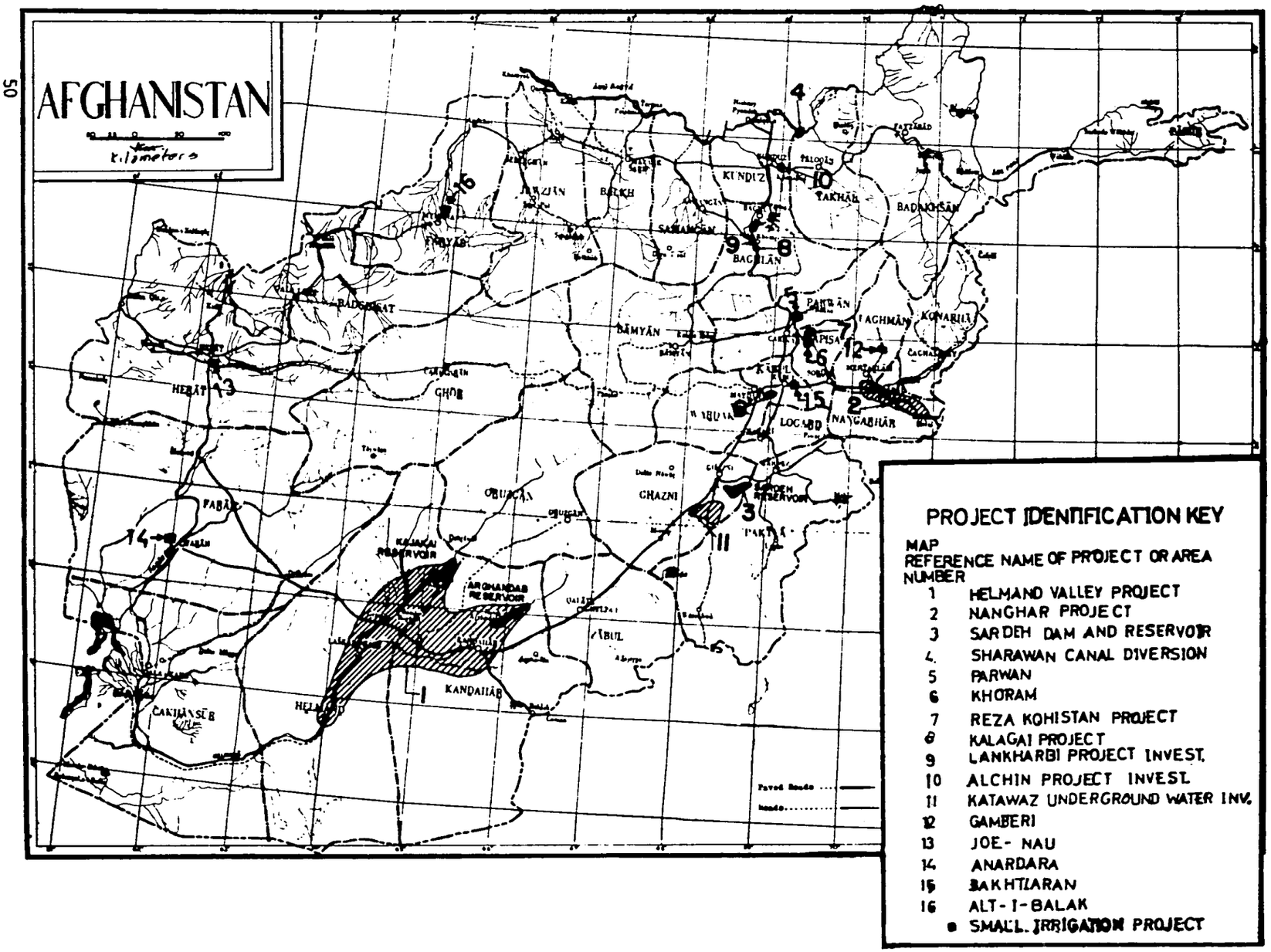
(G) SMALL IRRIGATION PROJECTS

Small scheme improvement of existing irrigation systems has been considered a very important and necessary work. Old canals, intakes and systems, even with an abundant water supply, have the least conveyance and irrigation efficiency. Canal intakes from the rivers are built from loose material, such as stones, gravel, wood, brush, etc., and are thus subject to wash outs.

The Ministry of Agriculture and Irrigation has made special plans to help the farmers by constructing new intakes, diversion weirs, diversion structures and turnouts. Reconnaissance surveys, engineering and feasibility studies were made of some of the critical areas. A summary of the work done in the past two years is shown in Table 2.

TABLE 2
Small Irrigation Projects

Job Description	Location	Area Benefited in Hectares	Survey	Design	Construction
Flume and Canal	Joie-Nau Herat	12,000	Completed	Completed	Flume and 1 km. of canal lining completed
Weir	Anardara Farah	800	Completed	Completed	Completed
Intake and Canal Extension	Bakhtiaran Kabul	800	Completed	Completed	11 km. canal completed; intake work will start soon
Intake and Canal Extension	Gamberi Laghman	1,000	Completed	Completed	Both works will start very soon
Weir	Alt-i-Bolak Fariab	8,000	Completed	Completed	Completed
New Intake and Canal Extension	Khoja Canal Kapisa	4,000	Completed	Completed	Project almost completed; only 4 km. canal excavation left
New Intake	Khoram Canal Kapisa	5,000	Completed	Completed	Completed


AFGHANISTAN
Kilometers
KUNDUZ
TAKHAR
BADAKHSHAN
BALKH
SAMANGAN
BAGHLAN
PARWAN
BADGHAIS
BAMYAN
LAGHMAN
KONARHA
KABUL
HERAT
GHOR
LOGAR
NANGARHAR
OBUZGAN
GHAZNI
PAKTIA
FARAH
KANDAHAR
HELMAND
ZABUL
Paved Roads
Roads
PROJECT IDENTIFICATION KEY
MAP REFERENCE NUMBER
NAME OF PROJECT OR AREA
1 HELMAND VALLEY PROJECT
2 NANGHAR PROJECT
3 SARDEH DAM AND RESERVOIR
4. SHARAWAN CANAL DIVERSION
5 PARWAN
6 KHORAM
7 REZA KOHISTAN PROJECT
8 KALAGAI PROJECT
9 LANKHARBI PROJECT INVEST.
10 ALCHIN PROJECT INVEST.
11 KATAWAZ UNDERGROUND WATER INV.
12 GAMBERI
13 JOE- NAU
14 ANARDARA
15 BAKHTIARAN
16 ALT-I-BALAK
• SMALL IRRIGATION PROJECT

CEYLON

Introduction

Ceylon is an island situated southeast of the southern extremity of India. It covers an area of 16.25 million acres. The country is divided into two zones by the 75-inch isohyet. The wet zone, which forms the southwestern quadrant, has an area of 3.75 million acres and an average annual rainfall of 75 to 200 inches. The northeastern portion, having an area of 12.5 million acres, is the dry zone with an annual rainfall of 40 to 75 inches, 80 per cent of which falls during about 100 days of the northeast monsoon from October to March. The mean annual yield from 103 river basins, having catchment areas from 4,000 to 4 square miles, is estimated at 27 million acre-feet. The percentage of this yield that can be economically utilized for agricultural development has yet to be assessed.

Ceylon is an agricultural country and its economy depends almost entirely on agriculture. In 1966 the estimated cultivated land under the following crops was about 4,114 million acres :

Rice	1,324,000	acres
Tea	595,000	acres
Rubber	671,000	acres
Coconut	1,152,000	acres
Highland cultivation	372,000	acres
Total	4 114,000	acres

The main crop under irrigation is rice. The developed paddy lands classified in terms of water supply are :

Under Major Irrigation Schemes	374,810	acres
Under Minor Irrigation Schemes	427,129	acres
Under Rainfed Conditions	522,061	acres
Total	1,324,000	acres

Land Resources

The uncultivated area of 12.1 million acres may be roughly grouped as follows :

(a)	Roads, streams, tanks, towns, villages, etc.	1,300,000	acres
(b)	Forests (including natural reserves and sanctuaries)	3,500,000	acres
(c)	Rocky, steep lands, etc.	4,700,000	acres
(d)	Balance available for future development	2,600,000	acres
	Total	12,100,000	acres

About 50 per cent of the 2.6 million acres available for future development is in the dry zone, under irrigation schemes for the cultivation of paddy and other subsidiary food crops, as under:

Irrigable land under major schemes (over 500 acres) under construction	275,000	acres
Irrigable land under proposed major schemes, excluding Mahaweli Diversion scheme	215,000	acres
Irrigable land under proposed Mahaweli Diversion scheme	620,000	acres
Total	1,110,000	acres

Population

The estimated population of Ceylon in 1966 was 11.49 million and the annual rate of increase is 2.5 per cent. Rice is the staple diet, and it requires 1.3 million tons to feed the population annually. Only about 60 per cent of this requirement is produced locally. In 1966 food items constituted 47 per cent of total imports. Imported rice, flour, sugar, milk products, meat, fish, potatoes, chillies, onions, etc. cost Rs. 956 million ($159 million).

Progress Since Sixth Seminar

A five year plan of development for the period 1966-1970 has been drawn up, as reported in the country report at the Sixth Seminar. The targets set out and the achievements in providing irrigation facilities for new land for the first two years are as follows :

Acreage provided with irrigation facilities under	1966 Target	1966 Achievement (acres)	1967 Target	1967 Achievement (acres)
1. Major works	21,202	21,045	20,622	16,107
2. Village works	5,476	9,737	9,501	8,145
3. Lift irrigation	1,400	648	1,905	1,170
Total	28,078	31,430	32.028	25,422

Some of the major projects in the five year program are listed below:

Kaudulla Reservoir Scheme

Stage I of the scheme, to provide irrigation facilities to 4,090 acres at a cost of Rs. 8 million ($1.33 million), has been completed. Irrigation facilities to 3,000 acres had been provided before 1966, as reported in the last country report, and have since been extended to the remaining area of 1,090 acres. Construction work on stage II is in progress. This will benefit 6,000 acres at an estimated cost of Rs. 9.5 million ($ 1.58 million). The work consists of providing a 650-ft. clear overfall spill, with 12 radial gates each 20 ft. by 12½ ft. The embankment has to be raised by 7 ft. and the final capacity of the reservoir will be 104,000 acre-feet. This involves 30,000 cubes of earthwork and 200 cubes of concrete for the embankment and spill respectively. The work is scheduled to be completed by 1970.

Rajangana Reservoir Scheme

The spillway dam, which involved 18,000 cubes of concrete and the installation of 32 radial gates, 20 ft. by 10 ft., has been completed. The channel system involves about 200,000 cubes of earthwork and about 1,500 concrete channel structures. Forty per cent of this work is complete. Of the estimated cost of Rs. 31 million ($ 5.1 million) about Rs. 27 million ($ 4.5 million) has already been spent, and of the total acreage of 15,000 acres to be benefited, 8,000 acres have been provided with irrigation facilities.

Nagadeepa Maha Wewa Reservoir Scheme

The scheme is to construct a reservoir of 13,600 acre-feet capacity across the Heppola Oya, a tributary of the Mahaweli Ganga. The areas to be developed are 4,000 acres of new land under paddy cultivation by gravity irrigation, and 1,200 acres under subsidiary food crops by lift irrigation. The total cost of the scheme is estimated at Rs. 12 million ($ 2 million) and is programmed to be completed by 197'. The headworks consist of an earthen dam of 310,000 cubes of earthwork, a spill of 300 cubes of concrete with 4 radial gates, 20 ft. long by 10 ft. high, and a tower sluice. The channel system and the necessary roads in the area to be developed require about 120,000 cubes of earthwork. The headworks are expected to be completed by the end of this year.

Padaviya Extension Scheme

The Padaviya reservoir was restored six years ago to impound 72,000 acre-feet of water. The capacity was subsequently increased to 85,000 acre-feet by raising the spill by 2 ft. The headworks are complete and 2,560 acres of the 5,000 acres of the scheme have been provided with irrigation facilities.

Muruthawela Reservoir Scheme

The reservoir, being constructed across the Urubokka Oya in the southern region of Ceylon,

will have a capacity of 38,000 acre-feet to irrigate 3,000 acres of new land directly and provide irrigation facilities to 4,000 acres of existing fields. The cost of the scheme is estimated at Rs. 16 million ($ 2.65 million). The headworks consist of an earthen dam of 340,000 cubes of earth, a spill of 1,100 cubes of concrete with 5 radial gates, 20 ft. long by 12 ft. high, and a tower sluice. The headworks are in progress and programmed to be completed by 1971.

Elahera Scheme Rehabilitation Project

An FAO mission visited Ceylon in 1966 to review the irrigation five year plan. The mission focused its attention on the urgent need to increase productivity per acre in major schemes in the island, so that there would be an optimum return on the very heavy capital investments made in irrigation facilities and development of land under these projects. The mission considered that irrigation rehabilitation was of primary importance to all present and future irrigation development in Ceylon. It recommended a program of work to include: (*a*) improvements to irrigation construction and designs; (*b*) installation of water measurement structures; (*c*) installation of effective methods of control over timing and quantity of irrigation water distributed at the field level; (*d*) extension to bring about effective water use and management without undue wastage on the basis of well-devised farm plans; and (*e*) facilities to provide other inputs.

These recommendations of the mission were tested on the Elahera scheme as a pilot project. This scheme consists of an anicut across the Amban Ganga, a tributary of the Mahaweli Ganga, and a channel taking off from the anicut to feed Minneriya tank. Direct irrigation is provided to the scheme from this inlet channel to Minneriya. The project area consists of 4,686 acres of paddy land blocked out in five-acre units. The entire area is cultivated for *maha* and 50 per cent of it for *yala*.

A project office was set up under a project officer, under the direct supervision of the government agent of the district. The immediate attention of the project officer was concentrated exclusively on *maha* paddy cultivation of the 4,686 acres to obtain the maximum yield per acre.

Repairs and maintenance work of the irrigation system were completed by August 1967, in time for *maha* cultivation, thus ensuring a sufficient supply of water for the entire project area. However, no attempts were made to measure the quantity of water supplied. Liberal credit facilities were made available by the government to the farmer through the cooperative machinery, and the farmer was able to finance the purchase of recommended inputs—seed paddy, fertilizer, etc—in sufficient quantity at the required time.

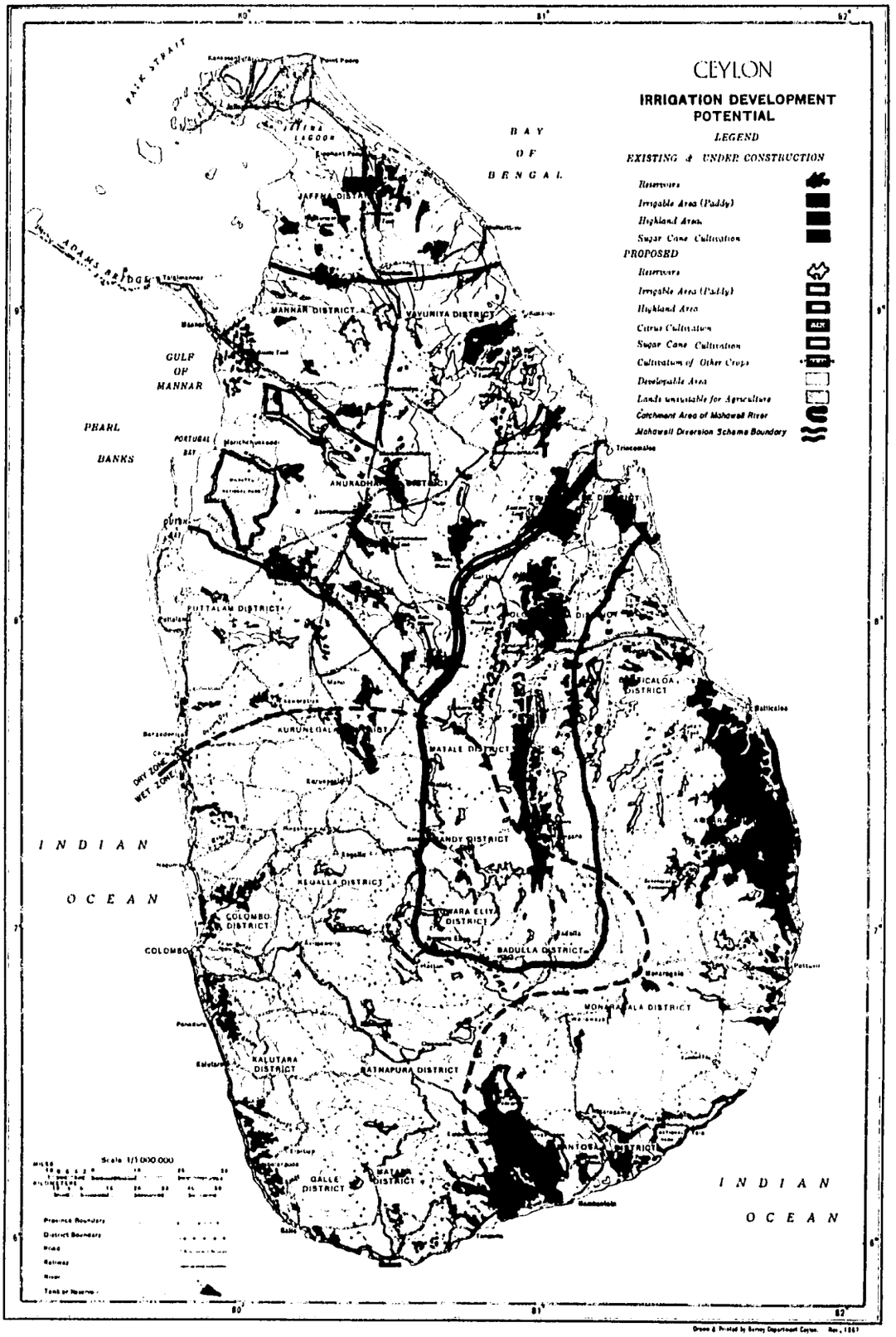
The 1967-68 *maha* harvest in the project area showed an average yield of 86.5 bushels per acre, an increase of 36.5 bushels, or 73 per cent, over the average for the previous years. The rehabilitation program was extended to cover about 40,000 acres in eight other schemes in the island for *maha* 1968-69. These schemes are Padaviya, Hakwatuna Oya, Allai, Minipe Stage I, Minneriya Stage I, Rajangana, Iranamadu and Gal Oya tracts 22-28.

Multipurpose Project

MAHAWELI GANGA DIVERSION SCHEME

The project area covers 39 per cent of the island of Ceylon. The master plan prepared for the development and utilization of the resources of the Mahaweli Ganga indicates that it would be possible to provide some 6,000,000 acre-feet of water for the irrigation of 900,000 acres. Of this, 280,000 acres are already irrigated and the balance of 620,000 acres are at present mostly uncultivated lands in the dry zone of Ceylon. In addition, the combined use of reservoirs and canal drops in the entire project will permit the development of 492mw. of installed generating capacity and an average annual output of around 2,400 million kwh. The plan provides for the construction of a system of 13 multipurpose reservoirs having a total regulated yield of 4,500,00 acre-feet, and 12 hydro-power stations. The larger reservoirs envisaged are Moragahakanda reservoir, with a regulated yield of 1,318,000 acre-feet, and Randenigala and Victoria reservoirs, having a combined regulated yield of 1,517,000 acre-feet.

The overall cost of irrigation, drainage, flood protection and land development, including land clearing and power stations, is estimated at around Rs. 5,300 million ($ 883 million). The economic appraisal has been carried out by a comparison of


CEYLON
IRRIGATION DEVELOPMENT POTENTIAL
LEGEND
EXISTING & UNDER CONSTRUCTION
Reservoirs
Irrigable Area (Paddy)
Highland Area
Sugar Cane Cultivation
PROPOSED
Reservoirs
Irrigable Area (Paddy)
Highland Area
Citrus Cultivation
Sugar Cane Cultivation
Cultivation of Other Crops
Developable Area
Lands unsuitable for Agriculture
Catchment Area of Mahaweli River
Mahaweli Diversion Scheme Boundary
BAY OF BENGAL
INDIAN OCEAN
INDIAN OCEAN
GULF OF MANNAR
PEARL BANKS
ADAMS BRIDGE
PALK STRAIT
JAFFNA DISTRICT
MANNAR DISTRICT
VAVUNIYA DISTRICT
PUTTALAM DISTRICT
KURUNEGALA DISTRICT
MATALE DISTRICT
KANDY DISTRICT
KEGALLA DISTRICT
COLOMBO DISTRICT
NUWARA ELIYA DISTRICT
BADULLA DISTRICT
MONARAGALA DISTRICT
RATNAPURA DISTRICT
KALUTARA DISTRICT
GALLE DISTRICT
MATARA DISTRICT
HAMBANTOTA DISTRICT
BATTICALOA DISTRICT
AMPARA
DRY ZONE
WET ZONE
COLOMBO
Trincomalee
Batticaloa
Scale 1/1,000,000
Province Boundary
District Boundary
Road
Railway
River
Tank or Reservoir

capital expenditure with net income over a project life of 50 years. Judging from the value added by production and benefits from major improvements in present agricultural methods, the capital-net benefit ratio is 4.4 at market prices and the internal rate of return is around 15.5 per cent for the entire project.

In view of the vast dimensions of the project, it has been decided to undertake step-wise development spanning a period of 22 years from 1969 to 1990. The construction of the entire project has been planned in three phases.

Irrigation Policy

With the implementation of the Mahaweli project, a radical change in irrigation policy is likely to take place. At present, paddy is the traditional crop in Ceylon, and the irrigation works so far have been undertaken to provide water mainly for paddy cultivation. The methods of irrigation practiced are:

(1) A diversion structure across a stream or river, known as an anicut, with an irrigation channel leading from it to the paddy lands below it.

(2) A dam constructed across a stream or river, with an irrigation canal leading from it to the paddy lands below it.

(3) Lift irrigation for the cultivation of subsidiary food crops and cash crops in the highlands, on a small scale at present.

The proposed Mahaweli project envisages the diversification of cropping. Paddy is a crop with a high consumption of water. With the cultivation of other crops it would be possible to reduce water consumption and increase the irrigated area. Moreover, these cash crops will bring better financial returns to the farmer, and also relieve the foreign exchange burden on the economy caused by the present need to import them. The cropping pattern will be determined by the type of soil available in each area.

It has also been proposed to increase the unit of alienation for irrigated lands to units varying from 5 acres to large-scale farms of 200 acres and above. The existing unit of alienation is 2-3 acres of paddy land and 1-2 acres of highland.

The issue of water from the reservoirs to the distribution system will be strictly controlled. Water measuring devices, which hitherto have not been in use in Ceylon, will be installed at all regulating points to control the consumption of water. To minimize losses in the distributary system, the canals will be lined wherever necessary. At present, since farmers in the existing schemes pay only Rs. 5 ($ 0.82) per acre for irrigation maintenance, they tend to waste a lot of water. The new proposals have suggested a charge of Rs. 7 ($ 1.16) per acre-foot of irrigation water as measured by these measuring devices, so that no water will be wasted.

Irrigation Methods

Irrigation water is to be conveyed through a number of conduits and distributaries to the field canals, where one of three methods will be used to irrigate the fields :

(1) *Flood Irrigation.* Flood irrigation will be applied to flatter areas, where each field is divided into strips by means of low levees or borders. The water will be issued from the field canals to each field at the highest strips, and will flow slowly to the lower end before entering the drainage canal.

(2) *Furrow Irrigation.* Furrow irrigation is to be used on slopes less than 4 per cent, for the irrigation of dry food crops. Water is issued from a field canal to a furrow, which runs over a distance of 300 feet to 600 feet at a slight gradient towards a drainage canal.

(3) *Sprinkler Irrigation.* Sprinkler irrigation is proposed for land with slopes greater than 4 per cent. It may also be used for areas beyond the command of gravity water or of irregular topography.

Adequate facilities have been provided in the existing schemes for the drainage of irrigation water, and for the discharge of excess water from frequently occurring storms of high rainfall intensity. It is proposed to protect the higher sloping areas under cultivation against erosion, and the lower flatter areas against flood hazard by means of flood embankments.

Conclusion

With these improved methods for the utilization of the water resources of the Mahaweli Ganga, the country's economy will materially improve and the problem of attaining self-sufficiency in food will also be solved.

INDIA

India is a vast country extending 1,800 miles from east to west and 2,000 miles from north to south, with a geographical area of about 1.26 million square miles. Such a vast territory presents a peculiar diversity of topography, climate and vegetation. Agriculture has always been the major industry and has played a leading role in the economic life of the country. About 75 per cent of the population depends on agriculture, which accounts for about 50 per cent of the national income.

The cultivable area in India is about 480 million acres, of which more than 390 million acres (gross) are cultivated at present. The monsoon in India is very erratic, with uncertain variations in duration and in the quantity and incidence of rainfall. These seasonal variations and periodic failures make the artificial supply of water essential to sustain crops in their various stages of growth. Development of irrigation is thus vital to the economy of the country.

The ultimate gross area that can be irrigated by major and medium schemes (schemes costing more than Rs. 50 million are termed major, those between Rs. 1.5 million and Rs. 50 million medium) has been assessed at 112 million acres. This figure of the ultimate potential is likely to undergo a change, however, after further detailed studies. The irrigation possibilities from minor irrigation works (costing less than Rs. 1.5 million), that is, from small surface water schemes and ground water resources, is likely to be about 90 million acres (gross). Thus the ultimate potential from major, medium and minor schemes is of the order of over 200 million acres (gross).

Accomplishments Since the Sixth Seminar

Irrigation potential developed in the pre-plan period (prior to 1951) by major and medium schemes was nearly 24 million acres. About 465 such schemes were taken up during the country's three five year plans (1951-66) and nearly 200 of these have since been completed, raising irrigation potential from 24 million acres to 41 million acres. The corresponding utilization at the end of the Third Five Year Plan was 37 5 million acres. Further progress on these schemes and on those taken up during the years 1966-69 is expected to raise the irrigation potential to 46 million acres, with a corresponding utilization of nearly 42 million acres, by the end of this year. The total financial outlay on major and medium projects during the three years 1966-69 has been about Rs. 3,870 million.

The pre-plan irrigation potential under minor schemes was 32 million acres, which was increased to 42 million acres by the end of the Third Plan. Schemes taken up during the last three years should raise this potential to 47 million acres by the end of the current year. Of this total, 20 million acres will come from utilizing surface water and 27 million acres from utilizing ground water resources. The financial outlay on these schemes in the last three years has been Rs. 5,500 million. The outlay during the first three five year plans on major and medium schemes and minor works was of the order of Rs. 13,360 million and Rs. 6,780 million respectively.

The total estimated cost of continuing major schemes amounts to Rs. 18,900 million, against which an expenditure of Rs. 11,220 million is likely to be incurred by the end of 1968-69. Similarly, the total estimated cost of continuing medium schemes is about Rs. 2,610 million, against which an expenditure of Rs. 1,860 million is expected to be incurred by the end of 1968-69. Early completion of these major and medium schemes is envisaged under the Fourth Five Year Plan, now being formulated. The potential of

schemes accepted in the first three five year plans and the years 1966-69 is anticipated to be 43 million acres, which would raise the irrigation potential to 67 million acres. Irrigation schemes under the Fourth and subsequent five year plans will thus cover a potential of 45 million acres.

Physical progress, in terms of units of important minor irrigation works during the years 1966-69 and the total at the end of 1968-69, is shown below.

Schemes	Anticipated during 1966-69	Anticipated by end of 1968-69
Wells	595,667	5,706,552
Boring of wells	262,436	507,233
Deepening of wells	115,575	216,448
Diesel pumps	185,126	650,350
Electric pump sets	506,690	1,020,921
Private tubewells (including filter points)	157,329	270,545
State tubewells	3,468	15,754

Progress of Water Supply Development Mainly as Related to Farm Irrigation

Most of the irrigation works in the pre-independence period consisted of a network of canals drawing supplies from the main rivers, such as the Upper and Lower Ganga canal systems from the Ganga, the Eastern and Western Yamuna canals and the Agra canal from the Yamuna, the Godavari and Krishna Delta canal systems from the Godavari and Krishna rivers, the Cauveri Delta canal system from the Cauvery, etc. The headworks for these canals comprise only diversion works, not storage reservoirs. Consequently, the required supplies can be drawn by the canals only when adequate flows for diversion are available in the main rivers. Quite frequently, therefore, due to a delay in the outbreak of the monsoon or the failure of the monsoon in subsequent months, particularly in the catchment of the southern rivers, which are non-perennial, the supply position in the rivers during the early part or towards the end of the *kharif* season proves inadequate for the irrigation of the first crop of paddy.

In these circumstances it becomes necessary to stagger the transplantation operation by adopting the "turn system" in regulating the supply of water. As a result, the transplantation of crops, which should normally be over early in July, drags on till the middle and in some cases even the end of August. This delayed transplantation generally has two adverse effects: (1) per acre yield of paddy is reduced and (2) the *kharif* crop does not attain sufficient height by the time heavy and widespread rainfall occurs during August and September, and thereby becomes susceptible to damage by submersion.

In the *rabi* season, also, the second crop under these canal systems is raised over a limited area. The available supplies in the rivers during the low water period are unpredictable and generally insufficient to ensure a successful crop. In many reservoir systems, also, it is necessary to retain some water to meet the early requirements of paddy at the seedling stage, *i.e.* in the months of May and June.

To overcome these difficulties, the integrated use of canal water and ground water by shallow and deep tubewells is being resorted to in areas under the command of large projects. Such tubewells are already in operation in the states of Punjab, U.P., Andhra Pradesh, etc. These tubewells supplement the canal flows in lean periods and also help in developing additional second crop irrigation over areas not covered at present. In some irrigation projects, open wells, ponds or small tanks are provided to help grow seedlings in advance of the availability of canal waters.

With a view to intensifying agricultural production, a package project has been formulated in the state of Andhra Pradesh, envisaging construction over a period of five years of 7,500 production tubewells (5,000 in the deltas and 2,500 in the uplands) in the districts of Guntur, Krishna, West Godavari and East Godavari. The construction of these production tubewells will be preceded by rapid ground water surveys and exploratory drilling, so that more precise data regarding the geo-hydrology of the region is made available for the efficient planning and implementation of the tubewell program. This is proposed to be completed in about one year so that the con-

struction program can be launched from the second year onwards.

Under the proposed scheme, the government would procure the drilling machinery and carry out the construction of tubewells which the beneficiaries would then own and operate. According to the existing pattern of assistance for private tubewells by the Government of India, 25 per cent of the capital cost of construction is subsidized, the burden being equally shared by the state and central governments. Now, however, it is proposed that the entire capital cost of each production tubewell should be borne by the farmer for whom it is planned. Long-term loans will be arranged for him through agencies such as the Agricultural Refinance Corporation and the land mortgage banks, these loans to be recovered in easy installments over a period of five to ten years. For unsuccessful wells, 50 per cent of the expenditure will be subsidized by the government, the balance being borne by the farmer concerned.

Rural Electrification Program for Energizing the Pump Sets

Experience has shown that lift irrigation is the backbone of intensive irrigated agriculture, and that rural electrification is a very essential supporting program to provide the necessary power. The number of irrigation pump sets and tubewells energized at the beginning of the First Five Year Plan was only 18,698. By the end of the Third Plan this had increased to more than 583,000, of which more than 100,000 were energized in 1965-66 alone. The progress during 1966-67 was stepped up to 137,276 pump sets and tubewells, and during the year 1967-68 it is anticipated that 183,498 irrigation pump sets will be energized.

Water Management Cell

During the Third Five Year Plan, the question of maximum utilization of the irrigation potential created by the major and medium projects was examined by a joint working group, consisting of representatives of the Ministries of Irrigation and Power, and Food and Agriculture, and the Planning Commission. The group highlighted the need to ensure optimal agricultural development of commanded areas through measures such as completion of water distribution systems, the leveling of land and the provision of agricultural inputs. This gave rise in 1966-67 to what is called the Ayacut Development Program, or the area approach to the problem.

It was realized that proper utilization of irrigation water involved the study of a multitude of factors, including soil and climatic conditions, water requirements of crops, irrigation practices and drainage requirements, etc. A cell called the water management cell was created in the Ministry of Food and Agriculture in the beginning of 1967 to study the problems of water utilization in some detail. It was decided in consultation with the USAID team to undertake a limited number of pilot projects in depth, with the object of studying the problems of certain specified irrigated areas in blocks of about 10,000 acres. Financial sanction was given in March 1968 for a total of 10 water management pilot projects—3 on a regional basis and 7 on a state basis. A thorough study of the soil, climatic, agronomic and irrigation situations will be made so as to improve the methods of water conveyance, control and measurement of water, cropping pattern, determination of irrigation water requirements, surface and sub-surface drainage methods, methods for alkali and salinity control and reclamation, etc. It is also proposed to take up 10 more such programs during the Fourth Five Year Plan.

Coordination Amongst Various Agencies

It has been well recognized that for maximizing agricultural production under irrigation projects, proper coordination between the Departments of Agriculture and Irrigation and other agencies dealing with credit facilities, etc. in each state is vital. With this in view, special committees have been set up in the Nagarjunasagar project on the Krishna river in Andhra Pradesh, the Kosi project in Bihar, etc., with officers of different departments working together. Teams of junior officers from these various departments move from village to village, contacting every farmer in the command area to ensure the timely delivery of water, suggest a suitable cropping pattern, or arrange for the supply of improved varieties of

seeds, fertilizers, pesticides and the necessary credit facilities. This approach has been found to be very effective, and has revolutionized the development of irrigated projects even in the initial stages. In the Nagarjunasagar project, for example, out of 650,000 acres for which an irrigation potential was created, crops were grown on an area of 530,000 acres during the very first year.

Introduction of High-yielding Varieties

The introduction of high-yielding varieties has revolutionized prevailing agricultural practices in the country. Initiated on a modest scale with a target of 6.25 million acres in 1967-68, the program has tentatively been set a target of 21 million acres for 1968-69. It is anticipated that by 1970-71 the coverage will reach 32.5 million acres. This change in cropping pattern has enabled the raising of two crops, and relay cropping with three to four crops annually is being suggested to the cultivators. This practice, with a supply of the necessary fertilizers and irrigation waters, coupled with sound irrigation practices, has increased the yields of individual crops and the total production per year. In the case of wheat the increase in yield has been threefold and in the case of bajra as much as ninefold.

Development of Institutions and Procedures for Improvement of Farm Irrigation

Some of the steps taken in this direction have already been indicated in the preceding paragraphs.

Financial assistance to farmers for private minor irrigation works comprise loans and subsidies according to policies which vary from state to state and scheme to scheme. Prior to 1967-68, the subsidy, subject to a maximum of 25 per cent of the total cost (upto 50 per cent for diesel engines), was shared equally between the central and state governments on a scheme-wise basis. From 1967-68, however, central assistance comprises 60 per cent in loans and 15 per cent in grants for all minor irrigation schemes, irrespective of the quantum of subsidy that the state governments make available to the farmers on individual schemes. The outlay on minor irrigation and area development works during the last two years has revealed that a significant source of funds has been developed in the institutional sector, *viz.* the land mortgage banks, central cooperative banks, the Agro-Industries Corporation and the Agricultural Refinance Corporation. The Agricultural Refinance Corporation, through the mortgage banks, is providing liberal financial facilities to farmers for land shaping to ensure the proper utilization of irrigation waters in the command areas of projects, *e.g.* in Andhra Pradesh. Similar financial facilities are being provided to farmers in respect of minor irrigation works if they are implemented in an integrated manner, with assured complementary inputs by the state governments. The Agro-Industries Corporation in some states like Bihar, U.P. and Mysore has started the distribution of pump sets on a hire-purchase basis.

In the field of irrigation it often becomes difficult for small farmers with holdings of one or two acres to afford a pump set or well of their own. The benefits of irrigation to such cultivators can best be extended by tubewells and lift irrigation schemes and surface water flow irrigation projects taken up in the state *zila parishad* (district board) sector. Some states like Andhra Pradesh, Maharashtra and Mysore have recently introduced a scheme for constructing community wells for small farmers. Such a cooperative approach extends irrigation benefits to a large community, the benefits under the scheme being limited exclusively to small farms below a certain holding.

JORDAN

Jordan has a total area of about 100,000 square kilometers and supports a population of about 2,100,000 people. About 87 per cent of the total area receives less than 200 millimeters of rainfall per year. The need to improve the water resources of the country in order to increase agricultural production, as well as the standard of living, is the major concern both of private and governmental agencies.

This report deals with the progress of the following agencies: Natural Resources Authority, Agricultural Extension, Agricultural Credit Corporation, and Jordan River and Tributaries Regional Corporation.

1. Natural Resources Authority

In 1966, the East Ghor Canal Authority and the Central Water Authority were amalgamated into the new Natural Resources Authority, which now takes care of water and irrigation development all over the country. The progress between 1966 and 1968 is as follows :

(A) East Ghor Canal

Distribution of the new farm units continued and is now about 90 per cent complete. The project is still operated and maintained by the authority in spite of continued aggression against the project by the Israelis.

(B) East Ghor Canal Extension

Studies and contract documents were completed for the extension of the East Ghor main canal by another eight kilometers, to provide winter irrigation for an additional 20,000 dunums in the second stage of the East Ghor Canal project. The contract for the main canal, which will cost about JD. 500,000, will be awarded very soon. This extension includes about 40 kilometers of lined lateral canals and 16 kilometers of surface drains. Construction of these laterals and drains, which will cost JD. 250,000, was started by the authority and is now about 22 per cent complete. The whole extension scheme was scheduled to be finished by 1968, but was delayed because of the Israeli aggression against Jordan last year.

(C) Wadi Dhuleil Project

Construction is going on in the 500-dunum first stage of the Wadi Dhuleil project. This area, which is about 80 kilometers northeast of Amman, will be irrigated by pumping up the underground water which was discovered there. Operation of this first stage which will start next year will provide information on the available ground water under long-term pumping, and the project might be extended to include 40,000 dunums in the future if the underground supplies are found to be sufficient.

(D) Small Schemes

(1) Lined canals were built in the following small schemes as part of the small schemes development plan:

(a) Ghor El-Safi Canal
(b) Ghor Haditha Canal
(c) Auja Canal

(2) Dikes were built for water spreading on 1,200 dunums at Daba'a.

(3) Two springs were developed for the irrigation of 400 dunums at Shoubak.

(E) Small Earth Dams

(1) *Wadi Ziglab Dam* (Sharhabeel Dam). Construction on this dam was completed in late 1966, and it has been operated since to store 4.5 million cubic meters annually to supplement the East Ghor main canal.

(2) *Al-Ghadir Al-Abiad Dam* was completed to store 850,000 cubic meters annually for the irrigation of 1,500 dunums.

(3) *Shu'eib Dam*. Thirty per cent of this earth-fill dam is now complete. It will store 2.5

million cubic meters annually to supplement the base flow of Wadi Shu'eib for the partial irrigation of 9,000 dunums. This dam will be 20 meters high when completed and the volume of embankment will be 0.5 million cubic meters.

(4) *Kafrain Dam.* This 30-meter-high earth-fill dam was completed this year and will be operated in the coming winter season. It will store 4 million cubic meters to supplement the base flow of Wadi Kafrain. The volume of embankment is about 1 million cubic meters.

(F) GROUND WATER INVESTIGATION AND DEVELOPMENT

(1) *The Sandstone Project*

Drilling of exploration wells continued in this project, which covers about 80,000 square kilometers of east Jordan. A total of 67 wells of an aggregate depth of 24,453 meters have been drilled. Geological mapping, geophysical surveys, isotope investigations, infiltration tests and hydrochemical analysis continued. A geological map in the scale of 1:50,000 has been prepared for the western highlands and the plateau area. The hydrogeological phase of the project is nearing completion and is being phased out, and activities related to development of areas of irrigated agriculture are being started.

(2) *Southern Shuneh Area*

Thirteen exploratory wells were located and five were drilled in the eastern escarpment to develop underground water for irrigation in the south Shuneh area.

(3) *East Ghor Canal Area*

Twelve exploratory wells were located and four wells are being drilled to develop water in the eastern escarpment alongside the south Shuneh area.

(4) A total of 113 permits were issued for the drilling of private wells, all of which were drilled.

(G) SOIL STUDIES FOR IRRIGATION

The soil section of the irrigation department of N.R.A. has started a soil survey and land classification for irrigation over scattered parts of southern Jordan. The results of this work during the last two years are as follows :

AREA	TOTAL AREA (DUNUMS)	ARABLE LANDS (DUNUMS)
Shobak	10,000	2,080
Fujeij (area 2)	20,000	11,000
Fujeij (area 3)	70,000	50,000 (expected)
Jurf El Daraweish-Ma'an	555,000	320,000 (expected)
Uneiza-Ma'an	1,000,000	Under study by German mission
Uweina	15,000	3,500 (expected)
Udruh	3,600	2,000 (expected)
Wuheida	20,000	5,000 (expected)
Qurein	10,000	2,500 (expected)
Querira	20,000	13,500 (expected)
Qa'adisi Sahal Suwan	150,000	7,000 (expected)
Hasa-Karak	40,000	15,000

II. Agricultural Extension

Control of irrigation water for the most efficient use on the farms is one of the major goals of the Extension department.

(A) THE INCENTIVE PAYMENT PROGRAM

This program has been established in the East Ghor Canal project since 1962 to partially support the cost of applying irrigation and drainage practices. Through this program the demand by the farmers for applying these practices has been increasing. The following data shows the achievements from 1966 to 1968 :

TYPE OF WORK	NO. OF UNITS	LENGTH (M)	AREA (DUNUMS)
Topographic Study	235	—	8,500
Lining of Irrigation Ditches	58	15,800	—
Constructing of Unlined Ditches	30	5,500	—
Constructing of Drain Ditches	4	750	—
Scraping and Leveling	70	—	1,700
Complete Irrigation System	13	—	390

Total cost : JD. 23,700
Incentive payment : JD. 10,326
No. of farmers benefited by the program: 70
No. of farmers who applied for the work: 235

(B) THE DEMONSTRATION FARM

The Extension department owns three farms in the three sections of the East Ghor Canal project. The farm in section 1 has an area of 150 dunums and has been divided into three units. These are used to demonstrate sprinkler, border and furrow irrigation systems. Border irrigation system is also used in the other two units of section 2 and 3 of the project. Each unit has an area of 30 dunums. The total cost of applying irrigation and drainage practices on the three farms is JD. 4,930. This cost includes the cost of a sprinkler unit which is used to irrigate part of the unit in section 1.

These farms are used to demonstrate modern irrigation and drainage systems and other agricultural practices and to train the staff. They are very important tools to convince the farmers about the programs planned by the extension service in the Ghor district.

(C) NURSERIES, EXPERIMENT AND RESEARCH STATIONS

The department prepared engineering plans and supervised most of the executed work in connection with the irrigation of the nurseries and plots of the agricultural research stations owned by the Ministry of Agriculture. The following table shows these practices from 1966-68:

TYPE OF WORK	NO. OF STATIONS	AREA (DUNUMS)	LENGTH (M)
Topographic Study	7	750	—
Sprinkler Systems	4	350	—
Lining of Irrigation Ditches	4	—	4,800
Constructing of Field Drains	1	—	300

(D) PRACTICES IN OTHER PARTS OF JORDAN

Five farmers requested technical assistance and supervision for applying irrigation systems by pumping from rivers and streams. The total area was 700 dunums. Plans were made and the systems are under operation.

III. Agricultural Credit Corporation

The Agricultural Credit Corporation (ACC) with sound policies and procedures has accomplished a substantial degree of agricultural development in Jordan. It continues to extend medium and long-term loans to individuals and agricultural groups to enable them to embark on a larger number of irrigation projects and to make efficient use of water resources.

Credit given to farmers is based on feasibility studies of the technical and economic aspects of projects. Loans are strictly supervised and are paid in installments according to the progress of work achieved. The cost of engines, pumps and pipes is paid to the commercial supplier. This procedure is intended to ensure the proper use of credit. The cost of digging cisterns and artesian wells, building concrete channels, powerhouses, reservoirs, etc. is paid in installments to the borrower, according to the work accomplished and under effective supervision. Repayments are scheduled on an annual basis, and a real estate mortgage provides the security.

During the period 1960 to 1967, the corporation issued loans amounting to JD. 6,887,166, ($ 19,284,059) for different agricultural projects, of which about JD. 1,370,544 ($ 3,837,523) was invested in irrigation projects.

YEAR	TOTAL AGRICULTURAL LOANS (JD)	IRRIGATION LOANS (JD)	PERCENTAGE OF IRRIGATION TO TOTAL LOANS
1960-61	457,681	66,124	13.13
1961-62	470,197	82,622	17.78
1962-63	1,036,306	104,251	10.06
1963-64	902,807	275,025	28.47
1964-65	833,472	160,996	19.32
1965-66	1,206,991	235,132	19.48
1966*	1,293,935	231,057	17.80
1967	685,777	214,337	31.10
Total	6,887,166	1,370,544	

*Figures cover 9 months only

The following table shows the activities of this corporation in the development of water resources and in introducing practices for better use of available water for the period 1960-67.

Irrigation Projects

YEAR	ARTESIAN WELLS	CISTERNS	RESERVOIRS	ENGINES	PUMPS	PIPES
1960-61	6	88	16	16	15	4,666
1961-62	1	92	18	26	25	5,754
1962-63	5	234	29	16	17	13,439
1963-64	6	726	59	49	45	23,534
1964-65	7	214	42	48	40	26,665
1965-66	5	64	47	60	48	47,578
1966*	11	401	83	62	39	33,095
1967	3	229	42	23	16	19,510
Total	44	2,052	336	300	245	174,241

YEAR	CONCRETE CHANNELS (METERS)	NON-CONCRETE CHANNELS (METERS)	SPRING IMPROVEMENTS	DAMS	POWER HOUSES
1960-61	23,984	—	—	—	—
1961-62	26,751	3,285	—	—	11
1962-63	28,176	255	2	1	21
1963-64	45,335	2,520	—	—	27
1964-65	17,425	1,580	—	—	34
1965-66	16,596	13,325	—	—	41
1966*	27,305	4,840	—	2	23
1967	17,945	3,450	7	—	17
Total	203,517	29,955	9	3	174

*Figures cover 9 months only

IV. Jordan River and Tributaries Regional Corporation

Since the unfortunate events of June 1967, the program of development being carried out by the Regional Corporation has received a setback. Construction progress to date is as follows: the main canal has been completed; 5 per cent of the Mukheibeh scheme has been completed; and 45 per cent of the Zor project has been completed.

In June 1966 an agreement was executed with Messrs. Nedeco-Dar-Al Handasa to carry out a study covering the technical, economic and social aspects related to the extension of irrigated agriculture in the Jordan valley, and, based on the findings of this study, to design an irrigation and drainage network for 200,000 dunums. The up-to-date progress on various phases of this agreement is:

Stage A. The report, consisting of a review of existing data, previous studies, etc. and the proposals for a detailed program of studies for stage B, has been received and approved.

Stage B. The draft report, consisting of field investigations and analysis, proposals and economic evaluation, has also been prepared and submitted by the consultants.

The design of the irrigation and drainage network for 200,000 dunums is progressing, and approximately 20 per cent of the work has been completed.

NEPAL

Abstract

Nepal encompasses a complete range of topographic and climatic conditions within a very small area. These phenomena have a strong influence on agriculture and its supporting practices. They create conditions which limit or, in some respects, extend the potential of water development. At any rate the factors involved are extensive or restrictive in their influence on agricultural development projects which involve the use of land and water.

About 13 per cent of the total land area of the country is devoted to agriculture, and much of this is limited in potential by its steep topography. This creates a need for promoting heavy production on the limited area that is suitable for intensive farming.

Irrigation has been practiced for many years by farmers using small stream diversions and ingenious canal systems. The application of formal engineering techniques in the design and construction of irrigation structures has been practically nonexistent until very recent years. Government projects using complete survey, design and construction technology are being expanded at the present time.

The introduction of scientific methods in the use and management of irrigation water on the farms is just now being undertaken. Progress in this vital area is at present limited to a recognition of its importance, and the initiation of activities designed to develop technical competence to undertake assistance to farmers in using water effectively in crop production.

Geography and Topography

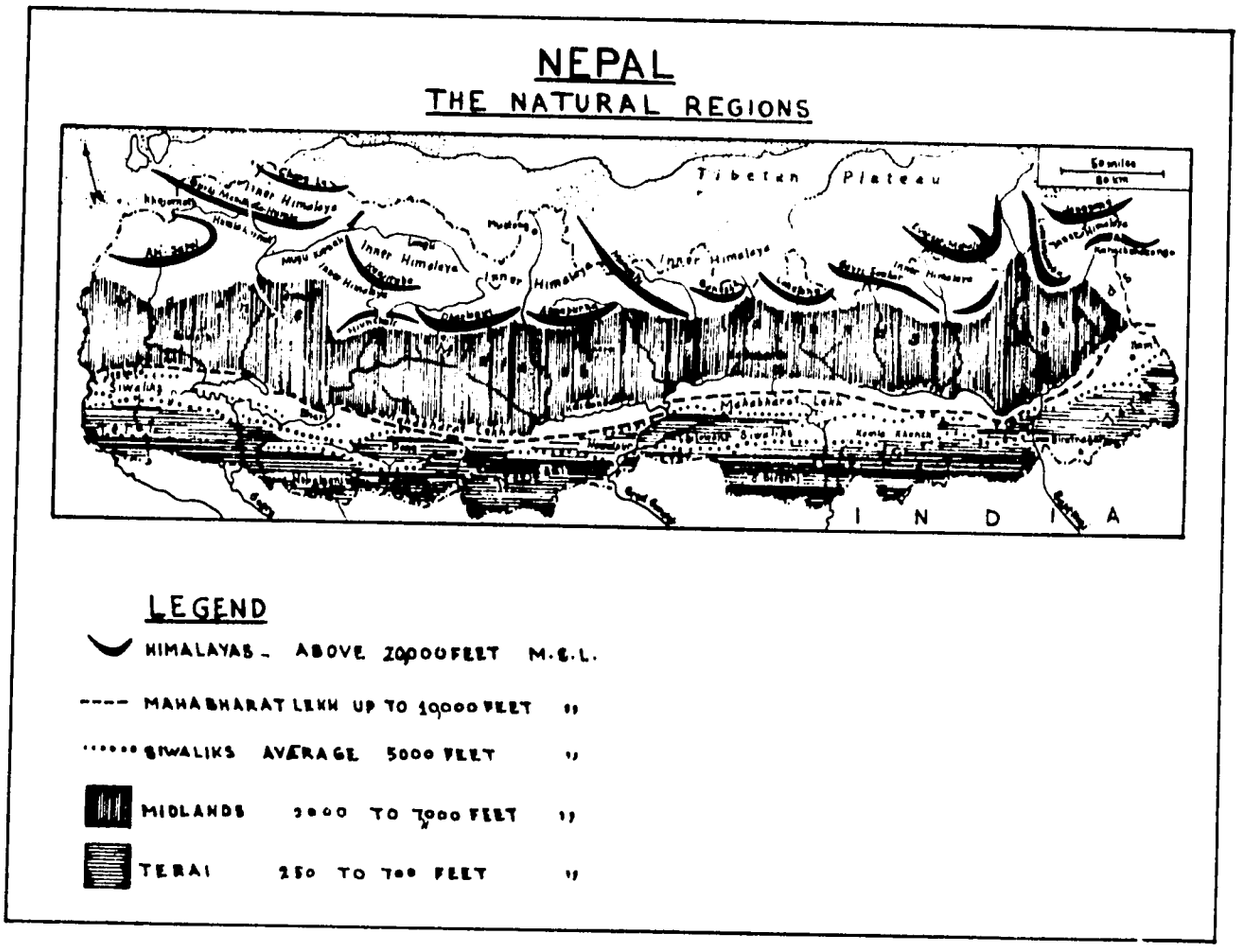
The Kingdom of Nepal lies on the southern slope of the more than 1,300 mile long Himalaya mountain range, the highest chain of mountains in the world, which separates tropical India from the Asiatic plateau. It has the shape of an elongated rectangle with an area of about 54,000 square miles, and is located between longitudes 80° and 88° E and latitudes 27° and 30° N. The length and width are approximately 550 miles and 100 miles respectively.

Nepal can be divided topographically and, to a certain extent, geographically into four main zones: (a) Terai plains and Bhabar belt; (b) Churia hills (Siwaliks); (c) Mahabharat sector (Mahabharat lekh and midland included); and (d) the Himalayan range.

The Terai is a strip of comparatively level alluvial terrain, lying between 200 feet and 750 feet elevation above mean sea level. It is situated between the Indian frontier and the foothills. Nowhere more than 20 miles in width, it is Nepal's modest share of the Ganges plain. The Bhabar belt is an almost continuous heavy tropical jungle strip about 10 miles in width along the northern fringe of the Terai. This area is full of sand and gravel brought down from the Churia hills by severe erosion, and acts as a kind of filter protecting the extremely fertile Terai belt from being covered by the sterile sand and gravel. The total area of the Terai and Bhabar belt is about 6 million acres, with a total arable area estimated at about 2.7 million acres.

To the north of the Bhabar belt, the Churia hills (Siwaliks) rise to an average elevation of about 5,000 feet above sea level. These hills, being formed during recent geological times and consisting of sand, gravel and boulders of conglomerate formations, are subject to severe soil erosion and are unfit for settlement or agriculture.

Between the Himalayan range in the north and the Mahabharat lekh in the south, lie the



midlands of the Mahabharat sector, the average width of which is about 80 miles. This sector is clearly defined, with elevations varying from 2,000 feet to 6,000 feet above sea level. There are innumerable small and large valleys between the mountain ranges. The midland region not only provides an agreeable climate to the inhabitants, but is also favorable for horticulture and agriculture. All cereals and every kind of fruit and vegetable of the subtropical and the temperate zones will thrive here. Cultivation is practiced even on incredibly steep slopes of the mountains by an intricate system of terracing.

The Himalayan range of granite and limestone formations rising to more than 20,000 feet remains in perpetual snow, and forms the northernmost sector of the country.

The ground area of the mountainous part of the country, which is the whole country less the Terai and Bhabar belt, is about 29.63 million acres. Only 1.7 million acres of this is estimated to be arable.

The whole of Nepal lies in the watershed of the Ganges river. The country has an abundance of streams. There are more than 6,000 rivers in Nepal, of which almost 1,000 are more than seven miles long and more than 100 exceed one hundred and fifty miles in length. A large percentage of the streams have intermittent flows and all are subject to wide fluctuation. The annual run-off of the rivers is of the order of 170 million acre-feet.

Climate

Nepal falls within the southeast Asia mon-

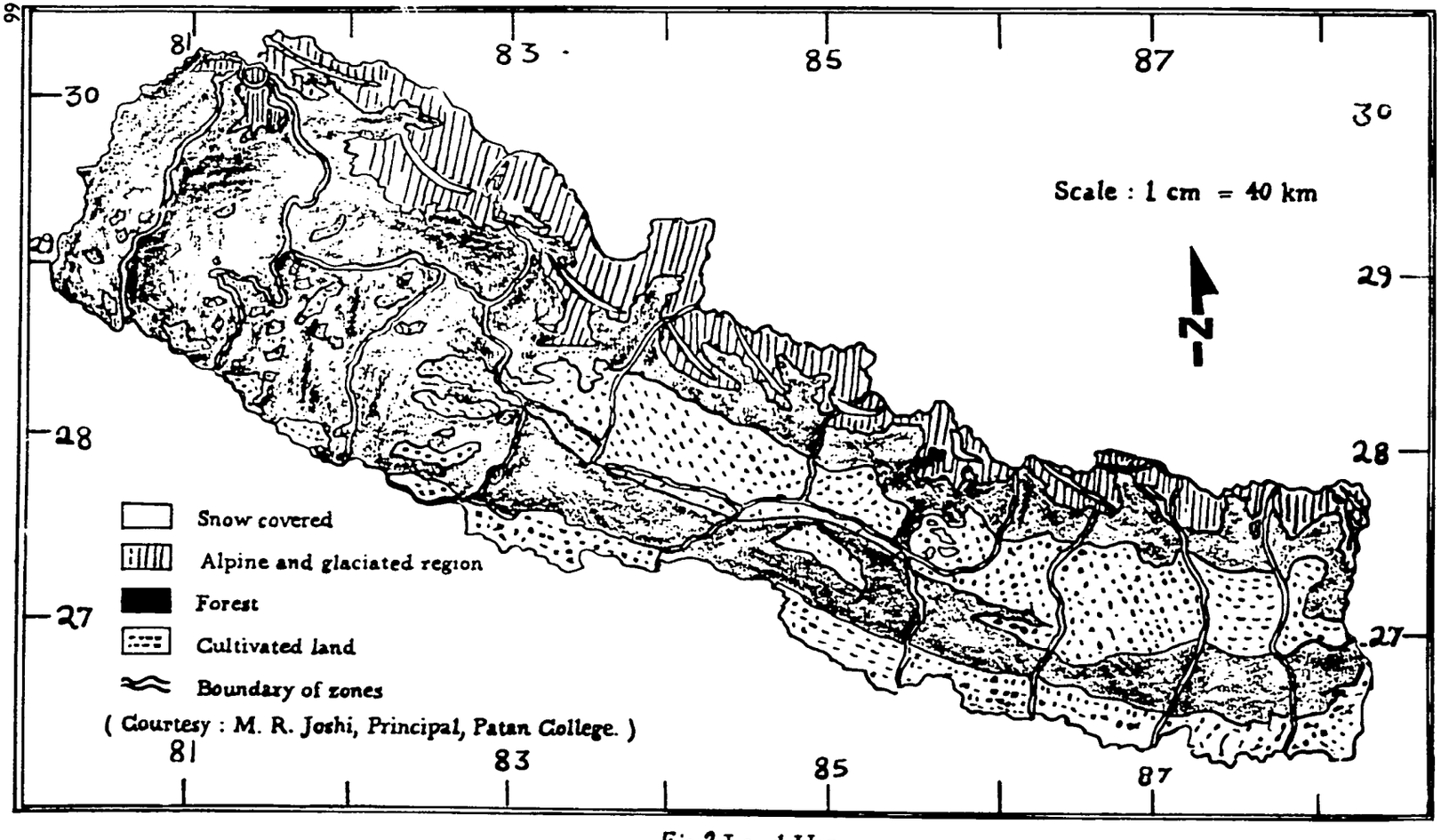


Fig 2. Land Use

soon region. The altitude of the country varies from about 200 feet above sea level to the highest in the world. These tremendous differences in altitude, together with the division of the year into a dry season and a rainy season, have given this small country almost all the climatic variations of the earth, from tropical jungle in the Ganges plain (Terai) to arctic desert waste in the higher regions and the aridity of the Tibetan plateau in the northernmost part.

The southeast monsoon hits the foothills in the beginning of June and in the eastern part of the country rainfall is very heavy, particularly in the hills of the Kosi river watershed. The average annual rainfall in the lower part of the Kosi catchment of about 8,000 square miles is about 70 inches. The rainfall in the Tibetan portion of the watershed is as low as 10 inches in some areas. Considering the whole of the catchment area of 23,000 square miles, the average annual rainfall is approximately 45 inches. The average annual rainfall of the eastern sector of the Terai plain is between 65 and 70 inches, though in the easternmost part annual precipitation of 100 inches is common. In the middle and western part of the country the monsoon arrives progressively later, and in the westernmost areas it begins as late as early July. The average annual rainfall in the western sector is about 40 inches, though very heavy precipitation (as much as 120 inches in Pokhara in 1956) in some localized areas has been observed. The monsoon ends by the last of October and the rest of the year is comparatively dry. Seventy per cent of the annual rainfall occurs during the monsoon months from June to October. Figure 3 shows graphically the rainfall pattern in different parts of the country.

TABLE I

Land Use Data*

LAND USE TYPE	AREA (ACRES)		PERCENT OF TOTAL	
I. Agricultural		4,500,000		12.93
Hilly Region	1,480,000		4.24	
Terai Region	3,020,000		8.69	
II. Forest Land		11,240,000		32.02
Hilly Region	7,160,000		20.36	
Terai Region	4,080,000		11.66	
III. Other Land		19,240,000		55.05
Land Reclaimable	4,680,000		13.41	
Land Unreclaimable	6,700,000		19.11	
Land under Permanent Snow	5,200,000		14.92	
Land under River Beds, Roads, Canals and Others	2,660,000		7.61	
Total of All Land		34,980,000		100.00

*Source of Data : Agricultural Economics Section, HMG, Nepal.

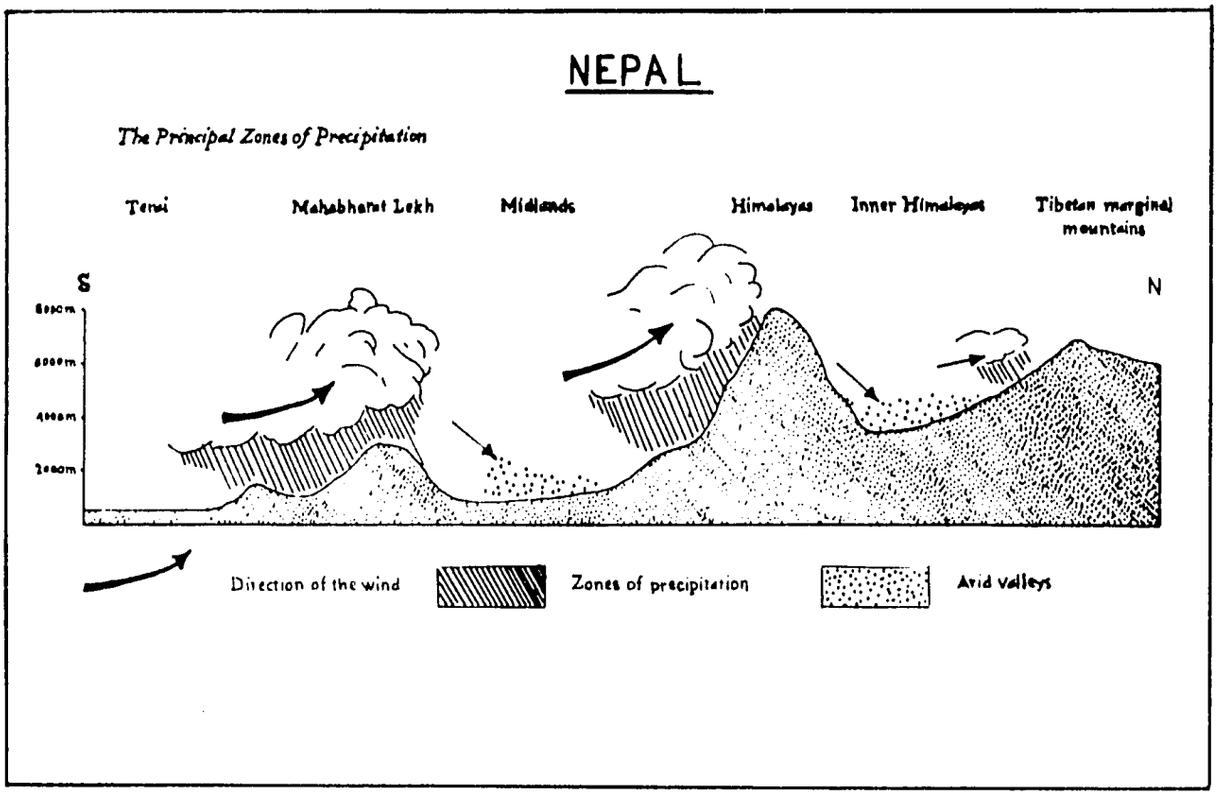
Figure 5 shows the extent of meteorological and stream gauging development in Nepal since the project began in the early 1960's.

Agriculture

Out of the total of 4.5 million acres of arable area of the country, 2.7 million acres are considered wet areas and 1.8 million acres are dry areas. Wet areas get plentiful water and are suit-

able for crops like rice and sugarcane. Dry areas depend purely on rainfall and are suitable for crops which do not require large quantities of water. In general, 95 per cent of the wet area is invariably planted in the basic food crop of the country—rice. A very small percentage of the dry area is also utilized for growing rice of the earlier, lower-water-requiring varieties. About 65 per cent of the dry area is usually cultivated in maize. In 1961 the total rice and maize crop-area of the country was 1.75 million acres and 1.12 million acres respectively.

The Terai is the most intensively cultivated sector of the country. Rice is cultivated on over 80 per cent of the arable land. The rice season coincides with the monsoon period from June to October. Ten to fifteen per cent of the arable area grows the earlier, lower-water-requiring type called "bhadai" between March and September. It is followed by a second crop, predominantly wheat, during the winter period between December and March. The later type of rice, which is of better quality and gives higher yields, is grown between June and November.



The winter crops of the Terai, including wheat, grams, oilseeds and tobacco, are cultivated in only about 20 per cent of the arable area. This is due to the fact that the winter crops are limited to the areas in which the earlier variety of rice or jute is grown. Jute, the crop period of which extends from March to September, is grown in less than 10 per cent of the arable area of the eastern districts of the Terai (Jhapa and Morang). It is a heavy water user. After harvest of the jute crop, a winter crop is raised in the same fields. In the higher lands of the Terai, where sufficient irrigation water is not assured, a maize crop is grown. In the year 1961 maize was cultivated on 0.224 million acres of the arable land in the Terai. Sugarcane is also grown in a very limited area where plenty of

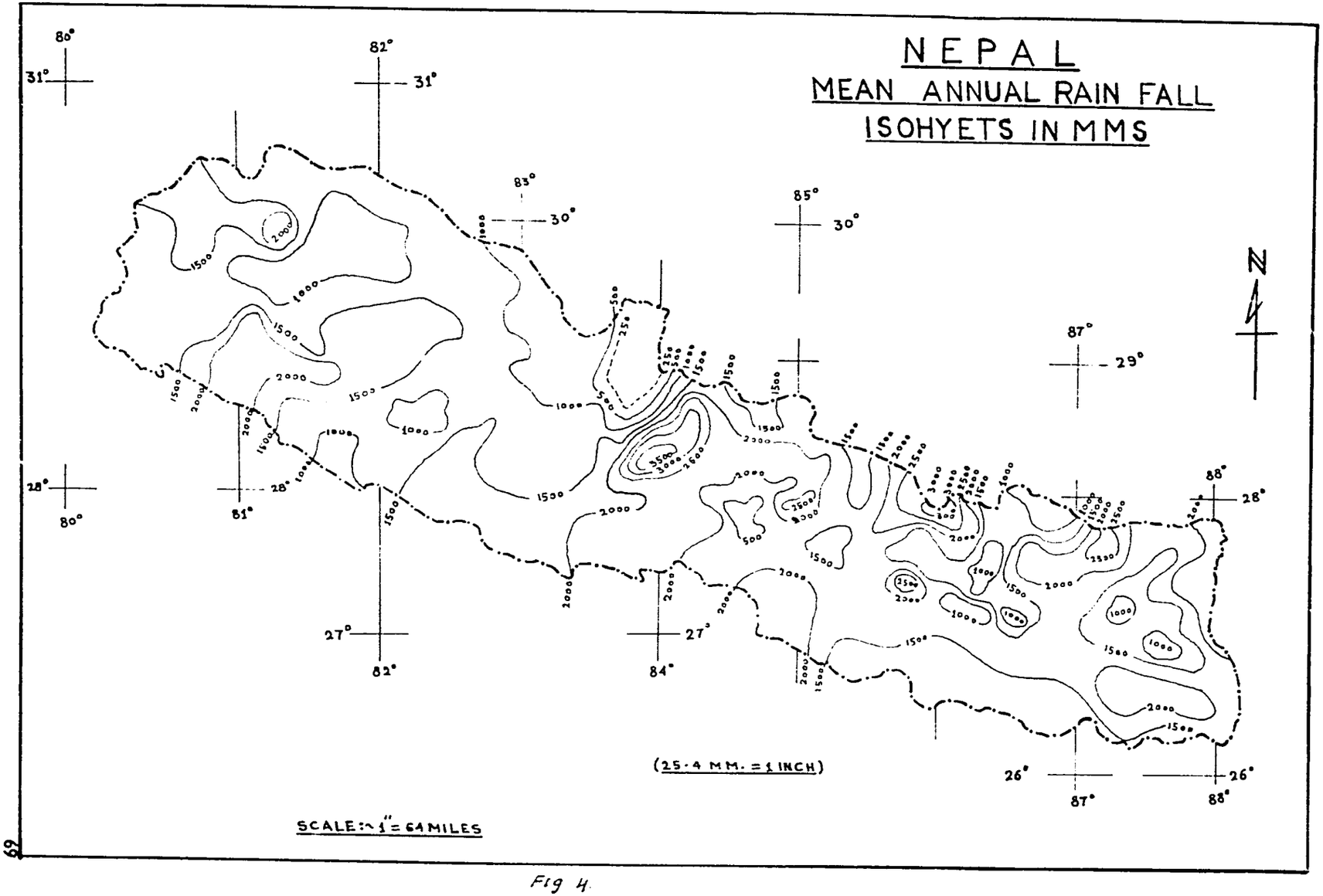

NEPAL
MEAN ANNUAL RAIN FALL
ISOHYETS IN MMS
N
(25·4 MM. = 1 INCH)
SCALE: ~ 1" = 64 MILES

Fig 4.

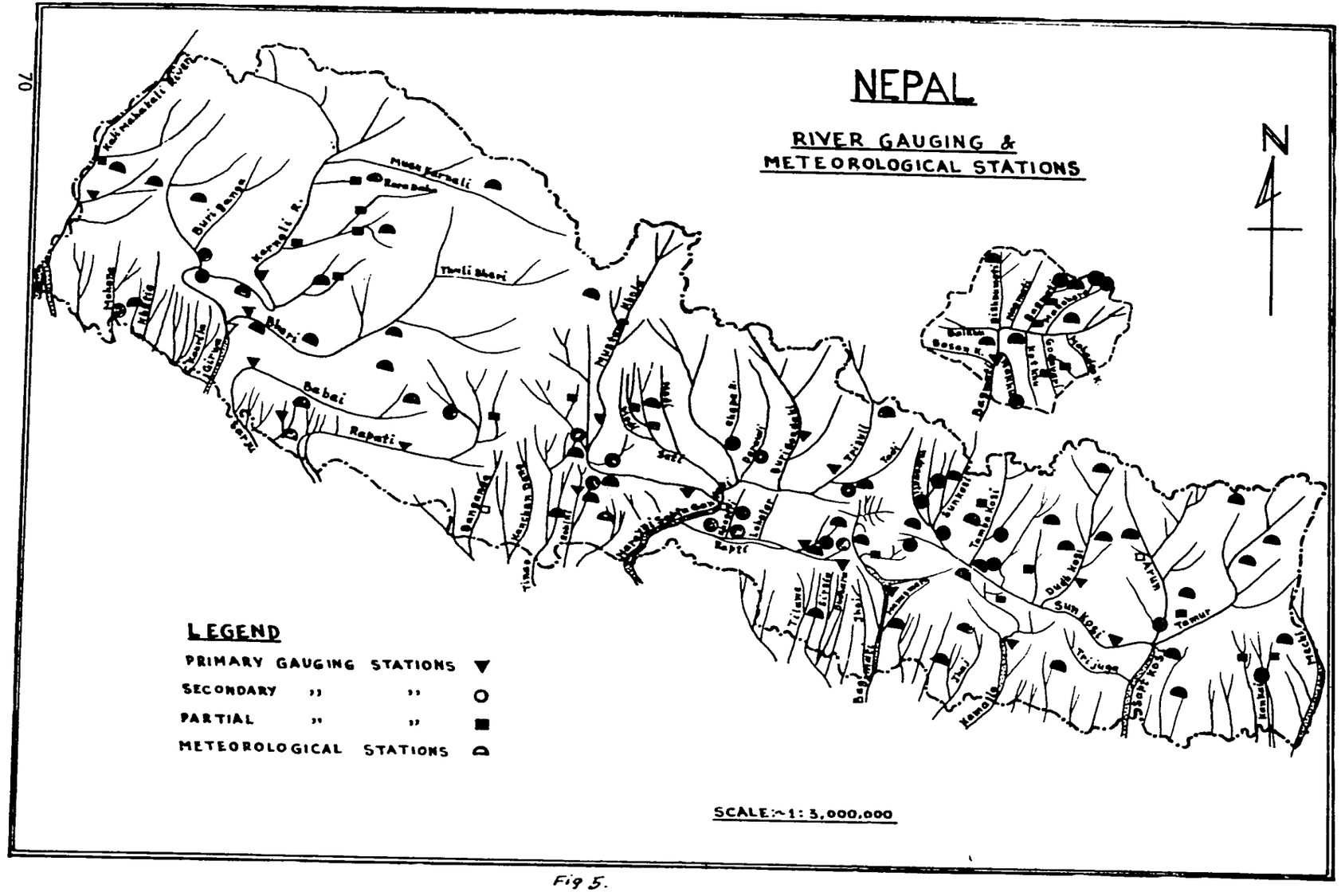

NEPAL
RIVER GAUGING &
METEOROLOGICAL STATIONS
N
LEGEND
PRIMARY GAUGING STATIONS
SECONDARY " "
PARTIAL " "
METEOROLOGICAL STATIONS
SCALE:~1:3,000,000
Kali Mahakali River
Mugu Karnali
Karnali R.
Thuli Bheri
Bheri
Babai
Rapati
Kamla
Kosi
Tamur
Arun
Sun Kosi
Trijuga
Sapt Kosi
Bagmati
Kamala
Tamakoshi
Dudh Kosi
Trisuli
Marsyangdi
Kali Gandaki
Seti
Tinau
Rangung
Jhikhan Khola
Tinau
Kaski
Jhikhan
Jhikhan
Bagmati
Jhikhan
Kamala
Tamakoshi
Dudh Kosi
Arun
Tamur
Mechi
Kosi
Kamla
Bagmati
Kamala
Bishnumati
Balkhu
Bosen R.
Kathmandu
Godavari
Hetaunda
Bishnumati
Kathmandu
Bagmati
Kamala

Fig 5.

water is assured. There is not much cultivation during the spring months from March to June. In the areas of the Terai where good irrigation facilities are available, a crop rotation is possible; in fact, as many as three crops a year are being grown.

In the Mahabharat sector (midlands), farmers have cultivated rice up to an elevation of 6,000 feet. Terraces are developed on hill slopes, and water is brought to the fields from nearby streams by constructing temporary bunds and canals through

TABLE 2

Total Area under Different Crops*

CROPS	AREA (ACRES)		PERCENT OF TOTAL	
I. Cereal Crops		4,380,000		87.57
Paddy	2,720,000		54.20	
Maize	1,110,000		22.18	
Wheat	300,000		6.16	
Millet	250,000		5.03	
II. Pulses		157,000		3.13
III. Vegetable Crops				
Potato		101,000		2.05
IV. Industrial Crops		363,000		7.25
Oil Seeds	241,000		4.80	
Jute	79,000		1.58	
Sugarcane	23,000		0.47	
Tobacco	18,300		0.37	
Others	1,700		0.03	
Total of All Crops		5,001,000**		100.00

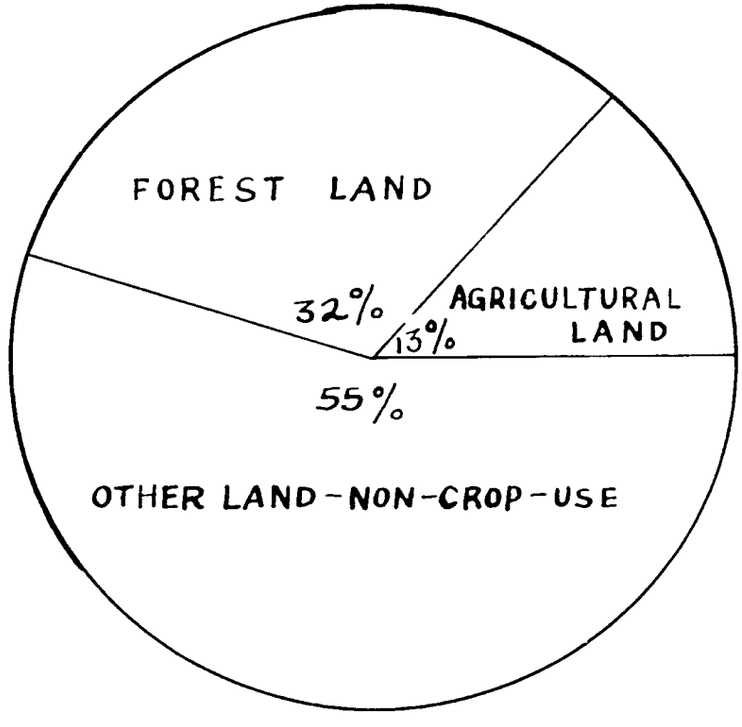
*Courtesy: Agricultural Economics Section, HMG
**This area exceeds the total area (4,520,000) due to double cropping in some areas.

cooperative efforts. Due to the somewhat earlier beginning of the monsoon, particularly in the eastern sector, the rice crop grown from May to October is followed by a winter wheat crop. In the year 1961 rice was cultivated on about 0.585 million acres out of a total arable area of 1.65 million acres of the midlands. Maize is grown in more than 50 per cent of the arable area. In the year 1961 the maize crop, which can be grown up to an altitude of 9,000 feet if some rainfall is available, was grown in an area of 0.896 million acres. Vegetables of all types are grown during the winter and summer months.

At altitudes higher than 10,000 feet and below 15,000 feet, winter wheat sown in November and harvested in September is a popular crop. It lies dormant under snow during winter. Short-term barley is grown between April and June, followed by buck wheat from June to November as an alternative.

Irrigation Development

Farmers all over the country, in the past as at present, working individually and in groups, have developed irrigation systems of their own. No actual record of all the area irrigated in this manner is available, but in the numerous river valleys and mountain slopes in the midlands many such schemes have been successfully developed. In the Terai, most of the small and medium-sized rivers have been harnessed by temporary diversion works constructed through the cooperative efforts of



Land Use

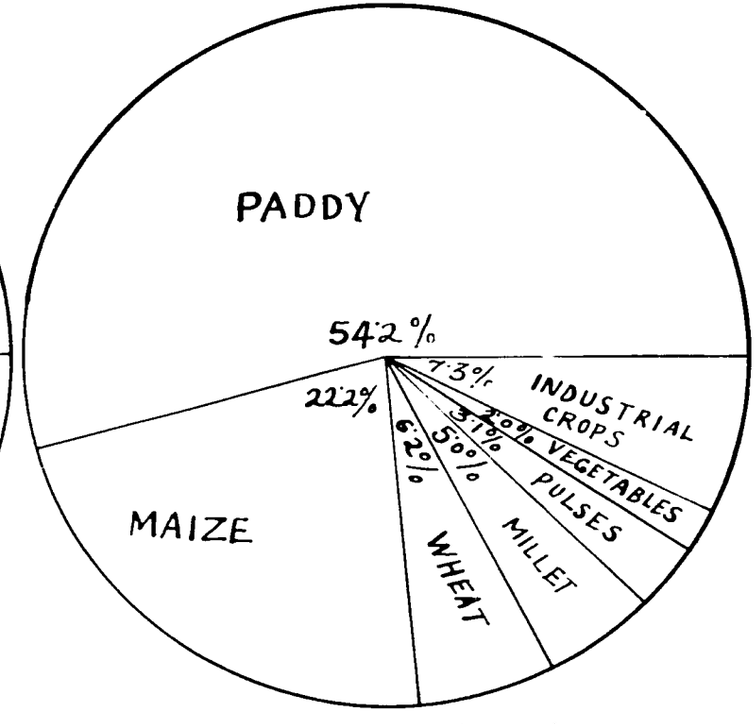


Fig 6. Use of Agricultural land by crops

farmers. But these schemes have overlooked technical considerations, with the result that maintenance is costly and the life of the project is short. In the Terai, irrigable areas are vast and there are many rivers. Therefore, large-scale schemes which can provide irrigation water needed for suitable crop rotation are being taken up by the government.

Before 1950, projects constructed by government agencies after due technical consideration irrigated only 36,200 acres of land in the Terai. The country has come a long way in constructing technically sound irrigation projects since a full-time Irrigation department came into existence in 1951. The following table, indicating the area served by projects constructed by the department in different plan periods, reflects the scope of development.

DESCRIPTION	AREA SERVED (ACRES)
1. Area irrigated before 1950	36,200
2. Total area irrigated at the end of First Five Year Plan (1956-57 to 1961-62)	79,540
3. Total area irrigated at the end of Second Five Year Plan (1961-62 to 1964-65)	145,490
4. Estimated total area irrigated after completion of Third Five Year Plan (1964-65 to 1969-70)	543,490

Besides these, complete technical project reports of a number of tentative irrigation schemes have been prepared.

(A) MAJOR PROJECTS

Good progress has been maintained in the construction of the three major projects in the Terai as listed below:

PROJECT	AREA SERVED (ACRES)
1. Chatra Canal	150,000
2. Gandak	143,000
3. Kamala	66,000

(B) MINOR PROJECTS

Minor irrigation schemes, costing generally less than about $10,000, have been taken up in all 20 districts of the Terai and more than 10 districts in the midlands. In the year 1967 more than 100 such small-scale projects were completed, providing irrigation facilities to more than 100,000 acres of land in different parts of the country. The experience of the last year indicates the highly successful results of this kind of irrigation development. The following factors were considered in launching this new program:

(1) Though there are a number of big rivers which can be harnessed to provide year-round irrigation facilities, the cost involved, the highly technical skill required and the great numbers of engineers necessary, make it impossible for the country to take up many such projects at one time.

(2) Because at the present moment there is great scope for increasing the yield by providing simple diversion works to utilize flood water, these projects not only will be cheap but will also bring quick returns.

(3) Local experience and technical know-how are utilized in the construction of small, temporary projects.

(4) In the organization and implementation of the program, local people are directly involved in the planning, execution and running of these projects. This will ensure the people's participation in the development works throughout the country. This will also provide experience for the local administration in managing the development works of the area.

(5) Because of transport and communication difficulties, the cost of transporting material from one place to another is often prohibitive. These projects scattered throughout the country will considerably relieve the problem of transporting food.

(6) The scattering of development works throughout the country provides more people with an opportunity for participation in the program.

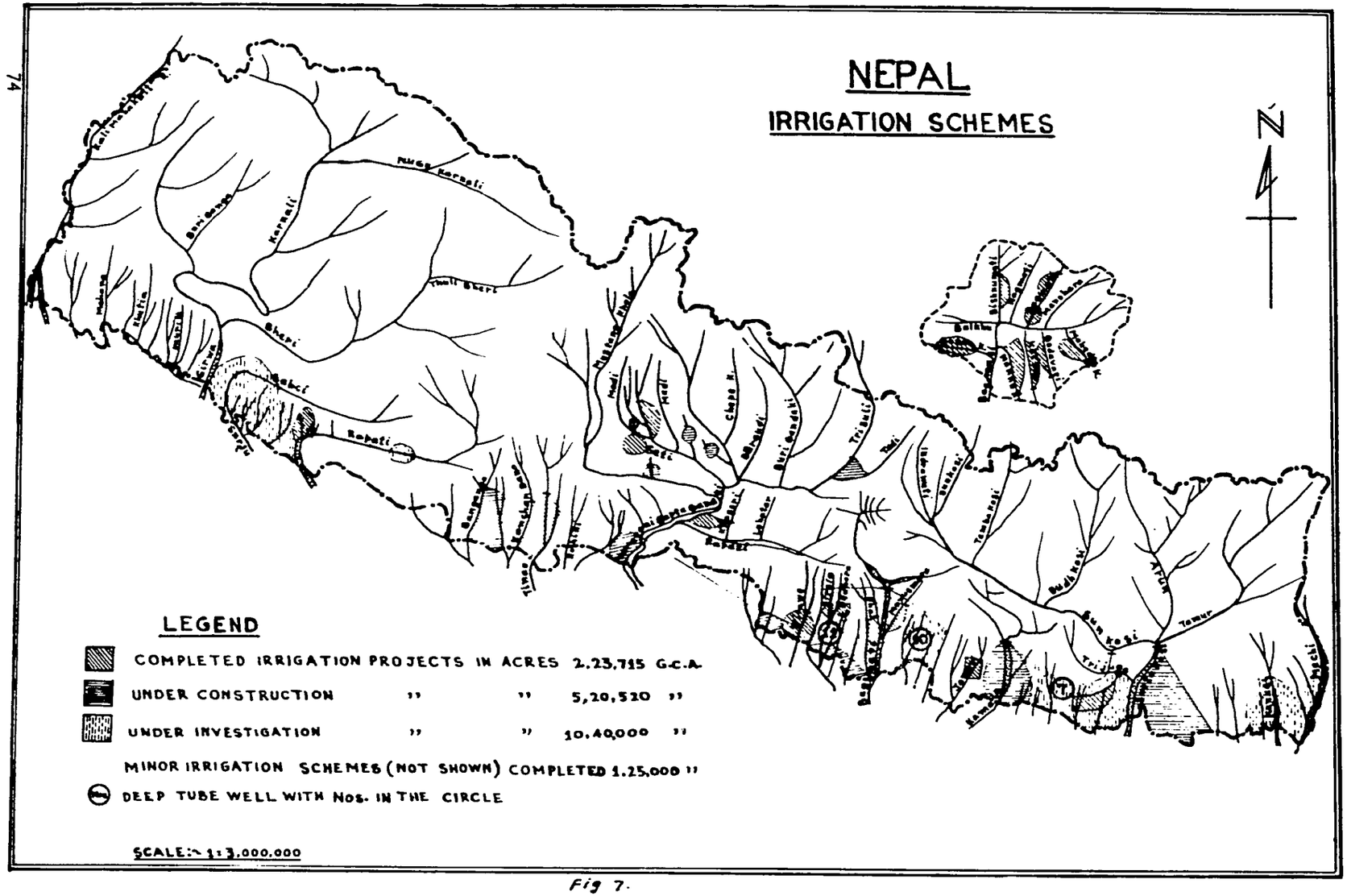

NEPAL
IRRIGATION SCHEMES
N
LEGEND
COMPLETED IRRIGATION PROJECTS IN ACRES 2,23,715 G.C.A.
UNDER CONSTRUCTION " " 5,20,520 "
UNDER INVESTIGATION " " 10,40,000 "
MINOR IRRIGATION SCHEMES (NOT SHOWN) COMPLETED 1,25,000 "
DEEP TUBE WELL WITH Nos. IN THE CIRCLE
SCALE:~ 1:3,000,000

Fig 7.

(7) The voluntary labor offered by the people in construction of these projects has been most encouraging.

(C) GROUND WATER

There are innumerable shallow wells in the Terai, used particularly for vegetable cultivation. Deep tubewell construction by private enterprise has been negligible because of the initial cost and difficulties of transportation. Under the minor irrigation scheme, 28 deep tubewells of varying depths up to 500 feet have been sunk this year in four different districts of the Terai. They are expected to serve about 150 acres each. More will be constructed next year.

(D) PROJECTS UNDER INVESTIGATION

Big projects that require highly-skilled technical personnel, sound technical analysis and great cost have also been considered. A preliminary study of the Sunkosi Terai project has been completed with the UN/FAO Special Fund. A detailed feasibility survey began in April 1966. The details of the project given below indicate the technical skill and cost involved in planning.

Project:	Sunkosi Terai Project
Project Cost:	UNDP (SF) contribution: $ 1.7 million; HMG/N contribution, cash and kind, (equivalent): $ 0.4 million
UN Agency:	Food and Agriculture Organization, Rome
Duration of Study:	3½ years
Government Co-operating Agency:	Ministry of Transport, Communication, Water and Power
Limits of Development:	From western border of Parsa district (Birgunj) to Sapta Kosi river, and from Indian border to foothills of Himalayan mountains
Area:	Gross 1,300,000 acres Net 780,000 acres

Sources of Water for Irrigation

Surface:	Bagmati river, Kamala river, diversion of the Sunkosi river and other streams where available and warranted.
Subsurface:	Tubewells, artesian water, rain.

Scope of Investigations

Phase I:	(1) Suitability of ground for irrigation; (2) feasibility of diverting the Sunkosi river.
Phase II:	(1) General investigation of whole 1.3 million acres; (2) semi-detailed study about 200,000 acres; (3) detailed plans for approximately 5,000 acres of initial stage development.

Included in the study will be: topographic survey, with aerial photography; geological investigations; hydrological and meteorological studies; ground water investigations; irrigation and drainage system; soil survey; land use survey; agronomic studies; pilot demonstration farm; health studies; layout and designs; and economic appraisal, including power analysis.

Result of This Study

(1) A general plan for the progressive and comprehensive development of irrigation in the entire area, including existing schemes and proposed schemes.

(2) A semi-detailed analysis of the optimum use of the Sunkosi river to irrigate the maximum beneficial area, assumed to be of the order of 200,000 acres.

(3) A detailed design of the irrigation and drainage system for a typical plot of about 5,000 acres in the above 200,000-acre area.

(4) A report, covering the complete study,

which will describe the economic feasibility of the entire irrigation project, suitable for use by the government in applying for the necessary funds to implement it.

Water Management and Utilization

It is recognized that efficient water use is of basic importance to crop production under irrigation. Consequently, Nepal has assigned this phase of irrigation development to the agricultural engineering section, Department of Agricultural Education and Research, Ministry of Land Reforms, Food and Agriculture.

Initial work began on this aspect of irrigation in late 1966. Although progress was delayed by many limiting factors, it is expected that it will accelerate as the following activities develop. The irrigation branch has been organized into functional units with objectives and accomplishments summarized as follows :

(A) Training and Extension

The goals of this activity are to train irrigation technicians, agricultural workers and farmers in irrigation practices. Twelve irrigation technicians have completed a five-month training course in water management and utilization in India. Additional staff members are expected to enroll in this course in the future. About 400 agricultural workers have received short-course training in irrigation methods and techniques. More than

1,000 farmers have observed demonstrations of practical aspects of irrigation. One senior technician is enrolled in a ground water development course in the United States.

(B) FARM DEVELOPMENT

The primary function of this unit is to establish good irrigation facilities and programs on government research stations and farms. Such systems are intended to serve the water needs of the farms and to provide demonstration and training sites for teaching good irrigation practices. Work has begun on the survey, planning and design of the systems for five of seven such farms; construction has begun on two. Figure 8 shows the location of these farms and stations and supporting facilities.

(C) WATER RESOURCE DEVELOPMENT

Overall resource development is the responsibility of the Irrigation department. However, there is a need for technical assistance to individual and small groups of farmers to develop their own sources of irrigation water if conditions are favorable. This activity involves simple techniques of surface and ground water development. Work has begun on devising simple, economical techniques of digging wells and lifting water.

(D) USE AND CONTROL OF WATER

Efficient and effective use of water is the ultimate objective of irrigation in producing increased agricultural production. This is the paramount goal in Nepal as elsewhere, and agriculture is attempting to promote this phase of irrigation development. The three activities briefly described in the preceding paragraphs are directed toward this as the final target. They are intended to develop the competence and incentives to facilitate the adoption of economical irrigation practices by the farmers. The implementation of these efforts has not progressed to the stage at which significant influence on irrigation farming is evident at this time.

Work has begun on developing simple land-leveling implements that will enable farmers to improve water application methods. It is planned to establish advisory assistance to farmers in the survey, planning, design and construction of water distribution facilities. They will be provided with information on the proper techniques of irrigating different crops under different soil and climatic conditions.

Summary

The arable land of Nepal suitable for intensive production under irrigation is limited to three to four million acres. Although the total annual rainfall is from 40 to 70 inches, most of it occurs during less than half of the year. The climate in the better agricultural areas is favorable to year-round production. Consequently, irrigation is a vital factor in agricultural development.

During the past 20 years of government-sponsored irrigation development, about 225,000 acres have been brought under partial irrigation. About 520,000 acres are expected to be covered by projects now under construction, and projects under investigation cover about 1,000,000 acres. The exploration and exploitation of ground water resources is just now being initiated. About 30 tubewells have been installed.

Development of improved irrigation practices is now in the introductory phase. Demonstration, training and technical advisory service to farmers on irrigation are planned for incorporation in the agricultural education, extension and research programs.

PAKISTAN

General Situation

Pakistan consists of two provinces, West Pakistan and East Pakistan, separated by 1,000 miles of Indian territory. West Pakistan lies between 24° and 37° north latitude and 61° and 76° east longitude; East Pakistan lies between 21° and 26° north latitude and 88° and 92° east longitude. The two are dissimilar in topography, soils, climate and problems of development.

In West Pakistan there is an abundance of potentially arable land which cannot be supplied with enough water, whereas East Pakistan, with one of the highest population densities in the world, has too much water during the monsoon period and too little in other months.

West Pakistan

West Pakistan is an arid to semi-arid region served mainly by the Indus river and its tributaries. Rainfall ranges between 3 inches and 20 inches, except in the northeast foothills. According to the precipitation data, 66.7 per cent of the province receives rainfall below 10 inches, 24.2 per cent between 10 and 20 inches, 5.4 per cent between 20 and 30 inches, and only 3.7 per cent more than 30 inches annually. If rainfall were the only source of soil moisture, 96 per cent of the total area of West Pakistan would be barren or sparsely vegetated. However, the province has a network of irrigation canals, the largest in the world. Present aggregate operating capacity of the 43 principal systems is 250,000 cusecs and the total length of the canals is 40,000 miles, with major and minor distributaries commanding 37.5 million acres. The total area irrigated during the year 1966-67 was 28.61 million acres, with total river diversions of 95.7 m.a.f. Since the canals are unlined, conveyance losses are about 50 per cent, including those in watercourses. The net field delivery is of the order of 48.0 m.a.f. Farm deliveries are thus estimated at 1.6 acre-feet per cropped acre. The development of irrigation up to the present time has been almost entirely dependent upon the natural flow of the river system without storage. Nearly 66 per cent of the combined annual flow occurs in the months of June, July and August. During the winter months, the river flows are too low to meet the demand of agriculture.

Of the total land area of 199 million acres, 73 million acres are regarded as suitable for agriculture and forestry. The area under the command of irrigation canals is 37.47 million acres, of which 28.61 million acres received surface water supply in 1966-67. The remaining cultivated area includes: 1.6 million acres irrigated by streams, wells and lakes; 2.9 million acres of riverine land; and 8.0 million acres which are rainfed. The area under forest is 7.20 million acres. Thus, potentially arable land still available for agricultural development is about 16 million acres.

East Pakistan

East Pakistan is a tropical monsoon region at the extreme northern end of the Bay of Bengal. It contains the confluence of two great international rivers, the Brahmaputra and the Ganges, along with a third big river, the Meghna. The combined flow of these rivers averages 1,100 million acre-feet annually. Only a limiting action to control yearly floods can be taken by the government since there are no storage sites within the province. The land is criss-crossed by a network of rivers with hundreds of small tributaries and spill channels. Floods, droughts and severe tropical storms result from the climatological and geographical conditions peculiar to the area. Annual rainfall varies between 50 and more than 200 inches. Temperatures in East Pakistan range from a minimum in the high thirties to a maximum of 110° F. Mini-

mum temperatures generally occur in December, January or February, while maximum temperatures are usually in April or May. The mean monthly temperatures vary from about 65° F to 85° F throughout the year. The relative humidity is high throughout East Pakistan, except during the daylight hours of some days from November to May when it may decline to less than 20 per cent. This is an important factor in reducing evaporation losses from soil and water surfaces. Day length in East Pakistan is not a limiting factor for a wide range of crops. Occasional cyclonic storms during the months of May to November produce wind velocities of hurricane force. These winds frequently cause extensive damage to crops, livestock and buildings. Because of flat terrain and heavy rainfall, the surface drainage system of the province is not well defined. Flooding by the overflow of the rivers is widespread during the monsoon, and a major part of the province is under water for some part of each year. About 80 per cent of the rainfall is concentrated between June and mid-October. Because of the shortage of winter moisture, approximately 65 per cent of the cultivated land is idle and yields are low. Excessive rainfall during the critical period of crop growth and harvesting also causes severe damage.

Soils and Water

During the two years since the Sixth Seminar, further progress has been made in soil and ground water investigations in both wings of Pakistan. Special soil surveys have been undertaken, both within and outside the irrigation boundary, through various organizations, *viz.* the Directorate of Land Reclamation; the Water and Soil Investigation Division of WAPDA in the Upper Indus basin; Hunting Technical Services Ltd.; WAPDA in the Lower Indus plain; and U.N. Soil Survey for reconnaissance soil survey in both wings. Prior to these surveys a reconnaissance survey was conducted under the Colombo plan, and results for West Pakistan were reported in the last country report.

The survey work deals with the physico-chemical characteristics of the soils, the quality and quantity of the ground water, and other allied fields. According to the survey of the Lower Indus plain by Hunting Technical Services Ltd., the total area is 14.9 million acres, of which 13.19 million acres are within the command of the Guddu, Sukkur and Ghulam Mohammad barrages, as detailed below:

Barrage Command	Gross Area	Cultivable Command Area
	(1,000 acres)	
Guddu	3,100	2,802
Sukkur	8,501	7,470
Ghulam Mohammad	3,316	2,924
Total	14,917	13,196

These commands can be divided into five major physiographic units, shown hereunder as percentages of the total area:

Barrage Command	Meander Flood Plain	Cover Flood Plain	Piedmont Plain	Desert Fringe	Tidal Zone
Guddu	55	17	22	7	—
Sukkur	54	38	5	4	—
Ghulam Mohammad	50	45	—	1	4
Region	53	34	8	4	1

With respect to salinity, the area can be classified into moderately and severely salt-affected lands:

Barrage Command	Non-saline and moderately salt affected (1000 acres)	Severely salt affected (1000 acres)	Total (1000 acres)
Guddu	1,378	1,424	2,802
Sukkur	5,931	1,539	7,470
Ghulam Mohammad	1,044	1,880	2,924
Total	8,353	4,843	13,196

This shows that moderately salt-affected land forms 63.29 per cent of the total. The reasons for excessive salinity are discussed in a technical paper on "Irrigation-Soils-Salinity and Plant Interactions in West Pakistan" presented in a separate section of the proceedings of this seminar.

In the Ghulam Mohammad barrage more than 86 per cent of the area has a water table within 10 feet of the ground surface. About 8.57 million acres out of 13.19 million acres, or 65 per cent of the Lower Indus plain under the command of canal irrigation, has a water table less than 10 feet below the surface. In the Upper Indus plain about 76 per cent of the total area in Chaj Doab and 50 per cent in Rechna Doab have a water table within 10 feet of the ground surface.

(A) Soil and Water Survey by Water & Soil Investigation Division, WAPDA

The soil survey carried out in the upper region of the Indus plain classified the area into five major soil series. The area falling under each is shown below:

Doab	Total Area Surveyed (million acres)	Percentage Under Each Soil Series					Unclassified	
		Jhang (coarse textured soils)	Farida (moderately coarse textured soils)	Buchiana (medium textured soils)	Chuharkana (moderately fine soils)	Nokhar (fine textured soils)	Area	Dunes
Rechna	6.05	9	41	31	15	2	2	—
Chaj	3.06	14	28	37	17	1	3	
Thal	5.96	25	38	12	4	—	2	19
Bari	7.14	8	15	65	8	—	4	—
Bahawalpur	4.58	9	39	39	11	—	2	—
Total	26.79	13	32	38	10	1	2	4

From this it can be inferred that the soils of the Upper Indus plain are generally light textured. The Hunting technical report on drainage estimates that in the Lower Indus heavy soils are

33 to 55 per cent of the total.

Ground water survey has been conducted in 41.5 million acres of the Upper Indus plain. Classification of the salinity status of ground waters in 30.71 million acres of the area in the northern region is given below:

Doab	Total Area (million acres)	Percentage of Total Area		
		0—1000 ppm	1000—2000 ppm	Above 2000 ppm
Thal	7.89	63	20	17
Chaj	3.23	73	8	19
Rechna	7.04	75	12	12
Bari	8.05	70	16	14
Bahawalpur	4.50	28	11	61
	30.71	64	15	21

Concerning the quality of the ground water strata of the Indus plain, it is estimated that 48 per cent of the area has ground water with a salt concentration less than 1000 ppm

(B) SURVEY BY U.N. SOIL SURVEY OF PAKISTAN

The U.N. Soil Survey of Pakistan, a cooperative scheme of the Government of Pakistan and the U.N. Special Fund, with FAO as the executing agency, started operations on July 1, 1961. The organizational training of the staff and other work took about three years. Actual survey of the soil started in 1964. It was originally intended to survey the whole of Pakistan, *viz.* 354,000 square miles, by December 1969, but since the FAO personnel are to remain only four years, the area now proposed to be surveyed is 240,000 square miles. According to the revised plan of operations an area of 110,000 square miles will be surveyed by 1969, and the remaining area will be surveyed by the Pakistani staff after the departure of FAO technicians. The progress made so far is shown below:

Province	Total Area Surveyed (sq. miles)		
	'A' Level	'B' Level	Total
East Pakistan	23,400	5,000	28,400
West Pakistan	33,053	19,312	52,365
Total	56,453	24,312	80,765

There are hundreds of series of soils in East and West Pakistan. Information on them has been published in various soil survey reports, of which nine have so far been issued for East Pakistan and four for West Pakistan.

(C) VISUAL SALINITY SURVEY BY DIRECTORATE OF LAND RECLAMATION

The Directorate of Land Reclamation is entrusted with the salinity survey annually conducted through the existing revenue staff of the Irrigation department. The survey is made by visual observations under different categories of salinity, each category denoting a specific stage of soil deterioration as confirmed by the results of laboratory tests. In this survey, only severe salinity is accounted for. A field is categorized as saline if the land is affected by salinity to the extent of 20 per cent or more of the area of the field unit. If fields containing salt patches less than 20 per cent and the presence of salts within the root zone of the fields are taken into account towards moderate salinity, the area affected by salinity is of the order of 46 per cent. Details of the estimation have been published in a separate technical paper titled, "The Problem of Waterlogging and Salinity in West Pakistan".

Details of the physiographic divisions of the soils of West Pakistan were given in the country report presented at the Sixth Seminar. The soils of agricultural interest in East Pakistan can be divided into five major divisions:

(1) *Recent Alluvial Piedmont Soils.* These soils cover an area of 3.78 million acres and are located above the flood level. They are medium to heavy textured, are fertile and capable of producing a large variety of crops if properly irrigated. Generally, these soils are moderately acidic in reaction.

(2) *Recent Alluvial Soils.* The area covered by these soils is 6.35 million acres They are subject to annual flooding, vary from silt loam to silty clay loam in texture and are the most fertile of the province.

(3) *Inter-stream Alluvial Soils.* These cover about 9.17 million acres and are older soils. They are quite productive provided irrigation facilities are available.

(4) *Older Alluvial Soils.* This division covers about 0.316 million acres. These red-colored soils are moderately to strongly acidic in reaction, often contain iron concentrations and have poor moisture relationship.

(5) *Saline Coastal Soils.* These soils cover approximately 6 million acres and are subject to flooding with sea water at high tide. They are predominantly grey-colored, silt loams to clays, and frequently contain peat layers. Adsorbed as well as soluble sodium are present in the profile.

Water Resources

The principal water resources of Pakistan, inclusive of rainfall, have been briefly described in the preceding paragraphs and in more detail in the last country report. The discussion is now confined to the progress achieved in water resource development since the last seminar.

Efforts have been made to improve surface water availability for irrigation by constructing major and small dams, improving management of the water supply from the river diversions and exploiting ground water resources to supplement surface irrigation water.

(A) DAMS

Mangla Dam. The Mangla dam was completed in 1967 and is now in operation. The reservoir has a gross storage capacity of 5.88 m.a.f., of which 5.35 is live storage. Provision has been made to raise the height of the dam by another 40 feet at some future date, which will increase the gross storage to a total of 8.9 m.a.f. The construction of the Tarbela dam on the Indus river is in progress and is scheduled for completion in 1975. The Tarbela reservoir has a gross storage capacity of 11.1 m.a.f., of which 9.3 m.a.f. is live storage.

Smaller Reservoirs. The construction by the Water and Power Development Authority of smaller reservoirs with an estimated storage capacity of 4 m.a.f., located in the valleys of the tributaries of the major rivers, is in progress. The Rawal dam and, since the last seminar, the Tanda dam have been completed. The Khanpur dam, Hub dam and Gomal Zam multiple project are in various stages of construction. Particulars of these are given below:

Dam	Storage Capacity	Area to be Irrigated (acres)
Tanda	78,400 acre-feet completed since last seminar.	32,100
	UNDER CONSTRUCTION	
Gomal Zam	2,150,000 acre-feet	133,000
Khanpur	59,000 "	70,000
Hub	773,000 "	131,000

Small Dams Organization. The uplands of West Pakistan, which hitherto have not been given due attention, can no longer be neglected at a time when Pakistan is determined to tap all of its resources. The tract has all the basic resources, *viz.* a fertile soil, ample rainfall synchronizing with the crop seasons, and hard-working farmers. The missing factor has been a scientific approach to the problem of soil erosion now being provided by the soil conservation organization. The farmers of the tract are busy converting gullies into water reservoirs, with the advice and assistance of the organization, on the pattern of two model reservoirs

which the organization has constructed. The Small Dams Organization of the Agriculture Development Corporation is responsible for construction of relatively bigger reservoirs, *viz.* small dams for dry and hilly tracts to check soil erosion and provide irrigation facilities to these rainfed areas. The progress made is shown below:

Name of Project	Constructed		Under Construction	
	No. of Dams	Capacity (acre-feet)	No. of Dams	Capacity (acre-feet)
Small Dams Organization	12	7,501	8	13,000

(B) GROUND WATER

For a suitable cropping pattern and to obtain a reasonable economic return, it is necessary to provide optimum moisture levels which permit the growing of crops during different parts of the season. As already indicated, the surface irrigation applications are short of the consumptive use requirements. During the last ten years serious attention has been given to ground water development for the needed water supply. The government has undertaken a comprehensive program of soil and water investigation, and has formulated many Salinity Control and Reclamation Projects (SCARPs) in West Pakistan. In these SCARPs, an ample supply of water of reasonable quality is obtained by the installation of tubewells to supplement the surface water supply. In this way it has been possible to increase the water allowance from 1 cusec for more than 300 acres to 1 cusec for less than 150 acres. The two SCARPs in operation (SCARP-I and SCARP-II) have given encouraging results in lowering the water table and increasing the intensity of cropping where scientific land and water use has been followed. At places where poor quality water has not been properly managed some adverse effects have been observed. These SCARPs have given impetus to the cultivators, and the rate of tubewell installation in the private sector has attained a surprisingly high rate. The total number of tubewells so far installed in West Pakistan, both in the private and public sectors, is estimated to be of the order of 56,000. Details of the tubewells installed by different government agencies are as follows:

Agency	No. of Tubewells		Total
	In Operation	Under Installation	
1. SCARPs	4,904	2,106	7,010
2. Irrigation	700	2,300	3,000
3. Cooperative	582	—	582
4. Agriculture	13,636	—	13,636
Total	19,822	4,406	24,228

The remaining tubewells have been installed by the cultivators through private agencies. It is estimated that 11.5 m.a.f. of water from ground water sources is now used annually for the purpose of irrigation.

In East Pakistan irrigation cannot be separated from flood protection; hence water development implies concurrent progress with both. Schemes for flood protection and utilization of surface water through gravity flow, as well as lift

irrigation and tapping of ground water resources where necessary, are in hand. The progress so far achieved is indicated below:

Serial No.	Name of Project	C.C.A (acres)	Area Irrigated in 1967-68 (acres)	Canals (miles)	Drains (miles)
1.	(a) G.K. Project Phase I	120,000	75,200	492	271
	(b) G.K. Project Phase II	230,000	—	745	388
2.	Ground Water Development Project				
	(a) Under Low-lift Pumps	76,400	14,983	301	—
	(b) Under Tubewell Project	91,200	52,812		
	(c) Electricity-driven Pumps	19,200	—		
3.	D.N.D. Project	15,000	3,074	29.5	20
	Total	551,800	146,069	1,567.5	679

Note: In addition, 5 blocks in 5 places comprising 100 acres each were irrigated in Chandpur irrigation project with the help of small pumps, for the purpose of demonstrating source of water from existing rivers.

Seepage Control

The existing canals in West Pakistan are unlined. Of the annual conveying capacity of 95.7 m.a.f., only 48 m.a.f. reaches the field for the irrigation of crops, the remaining 48 m.a.f. being lost between headworks and the field due to evaporation and seepage. This seepage loss is the major factor contributing to water-logging, and must be drained out of the soil to keep the water table well below the root zone. This is essential in the interest of successful plant growth. To check the situation, horizontal drainage is being provided in addition to vertical drainage (tubewells) in the project areas. Thus far 4,500 miles of surface drains have been constructed in West Pakistan. In East Pakistan surface drainage is also being provided and the target is 679 miles of drains.

Flood Control

The coastal embankment project in East Pakistan provides for 3,000 miles of embankments and 435 sluices in the first phase. Thus far 1,620 miles of embankments have been completed, providing protection to nearly 1.5 million acres. A 135-mile long embankment along the Brahmaputra river has also been completed. A number of other flood protection works have been commenced.

Land Development

Various organizations are engaged in land development. The progress achieved since the last seminar is as shown below:

Name of Project	Bulldozers Employed	Tractors Employed	Area Leveled ('000 acres)	Area Ploughed ('000 acres)
Ghulam Mohammad Barrage Project (A.D.C)	200	—	285	—
Guddu Barrage Project (A.D.C.)	141	—	77	—
Soan Valley Land Improvement Project (A.D.C.)	178	—	142	—
Agricultural Engineering Circle, Lyallpur	120	99	40	56
Agricultural Engineering Circle, Peshawar	98	47	9	3
Agricultural Engineering Circle, Tando Jam	111	17	29	0.12
Total	848	163	582	59.12

Land Reclamation

About 2,000 to 3,000 cusecs of river flood supplies are utilized every year for suppressing excessive salts by providing 1 cusec for every 45 selected acres. The supply is provided by rotation to deteriorated fields for a period of three years. This supply is curtailed as the areas come under a SCARP. This scheme, executed by the Directorate of Land Reclamation of the Irrigation and Power department, so far has reclaimed 0.65 million acres.

It is still premature to assess the land reclamation work in various SCARPs excepting SCARP-I, as the work is not yet in full swing. In SCARP-I, the water table has gone down from the original 3 to 6 feet below the ground surface to about 19 feet. The area reclaimed is of the order of 0.254 million acres, out of the deteriorated land amounting to 0.425 million acres. WAPDA has prepared seven Salinity Control and Reclamation Projects in the northern zone, and seven ground water development and tubewell and surface drainage projects in the southern zone.

The area that has gone out of cultivation amounts to 2.8 million acres. Assuming 10 acres as the size of holding per family, about 280,000 families are very severely affected. This alarming situation has been brought under control by the implementation of Salinity Control Projects and by the efforts of the cultivators in the private sector.

Up to 1958 the rate of land deterioration due to salinity in West Pakistan was more than 100,000 acres every year. As a result of land reclamation operations, proper application of irrigation water and adequate drainage the spread of salinity has been checked.

Saline inundation in East Pakistan is confined to the coastal areas and covers 6.0 million acres. Of this, 3.4 million acres are protected by the coastal embankment project. At present nearly 0.14 million acres are being reclaimed in East Pakistan.

Extension Services

The extension service is the connecting link between the research worker and the farmer, and is one of the "musts" for the success of a project aiming at land development. Soil scientists and agronomists can successfully accomplish this job. The extension service is available in all the related organizations, and the number of personnel employed by some of them is as follows:

Status	Agriculture Peshawar	Agriculture Lahore	Land Reclamation Irrigation	G.M. Barrage	Guddu Barrage	T.D.A.	S.V.	East Pakistan WAPDA	Total
Class I	4	6	10	1	1	1	2	6	31
Class II	28	51	24	4	2	2	5	13	129
Class III	93	312	56	27	7	—	4	106	605
Class IV	460	1847	870	—	—	—	4	—	3,181
Total	585	2216	960	32	10	3	15	125	3,946

Through the efforts of extension workers, the research findings on the soil-water-plant relationship are conveyed to the cultivators. Modern irrigation practices which lead to increased irriagtion efficiency and increased production are taught by laying out demonstration plots, both on the land of the cultivators and at the experimental farms of various organizations. The utility of other inputs for increased production per unit of water applied, *viz.* fertilizers, pest control, proper seed bed preparation, timely sowing of crops and high-yielding varieties, is made known to the cultivators through lectures, cinema slides, radio talks, pam-

phlets, direct conferences, annual yield competitions amongst the cultivators and demonstrations.

There has been a quick response from the cultivators, who have promptly adopted new high-yielding varieties of rice and wheat. A tremendous increase in the use of chemical fertilizers has occurred. During the year 1967-68 the fertilizers utilized by the farmers were of the order of 1.0 million tons, against 0.07 million tons utilized a few years ago.

The necessity for extension services has been felt more acutely since land development programs on scientific lines have been started. To meet the challenge of producing properly trained extension workers from the public and private sectors, the West Pakistan Agriculture university has started a program called the farm guide movement. It is a voluntary movement in which persons from all walks of life interested in social work are participating. All participants have to undergo a pre-enrollment training varying from one to two months, depending upon the categories taking part in the program. The subjects of training include crop production under irrigated conditions, plant protection, livestock management, community development, adult education, civil defense and first aid. Besides this preliminary training, facilities also exist for training by correspondence in 13 different trades and professions. The movement has its own weekly newspaper, *Shaoor-e-Nau*, which besides other subjects carries lessons in farming.

During the last one and a half years about 200 guides and guide-leaders have been trained and are now operating in the field. The movement is now being extended to rural schools.

Land Reclamation Research

In West Pakistan, research on problems related to irrigation-soils-salinity and plant interactions has been conducted by the Directorate of Land Reclamation of the Irrigation department for the last four decades. Other related organizations are also investigating their specific problems covering a wide range of subjects, details of which have already been presented in the country report for the Sixth Seminar. Technical papers and reports on the subject are issued by various organizations.

In East Pakistan, research on various soil problems is being conducted at a number of stations. An important aspect is the development of improved varieties and strains of all major crops. Research on water requirements, irrigation and cropping practices under irrigation are being conducted at the East Pakistan WAPDA Amla experimental farm, which has had technical guidance from FAO. Similarly, there are institutes where research is being done on jute and tea culture. At present there is a continuous need for more research on the kind, amount, time and method of application of fertilizers on most field crops under various soil conditions; varietal recommendations; pest and disease control recommendations; planting dates; cropping patterns; tillage practices; irrigation recommendations; and recommendations for the use and management of coastal saline soils under irrigation.

Concluding Remarks

With improved irrigation and agronomic practices, specific planning and proper implementation of various schemes and projects, it has been possible to check the salinity menace which a decade ago posed a serious threat to West Pakistan's agricultural economy. Today the situation stands vastly improved. It is intended to return to normal production the entire area which has gone out of cultivation, and to restore its fertility so as to permit a cropping intensity of 150 per cent. East Pakistan, on the completion of proposed flood control and irrigation schemes, will also be self-sufficient in food requirements.

TURKEY

I. Introduction

Turkey is located in a land which has seen the birth of such world-renowned cultures as the Hittites, the Romans, the Byzantines, the Seljuks and the Ottoman Turks. It lies in the intercontinental area of the Middle East and forms a bridge stretching from East to West. The country is bounded by the sea on three sides; the section in Asia is known as Anatolia and that in Europe as Thrace. Anatolia includes high mountains enclosing extensive plateaus and narrow plains lying along the shores, while Thrace is mainly composed of wide plains.

Agriculture has a very important place in Turkey's economy. In 1967, agriculture's share in the gross national income was 76.7 per cent, and 72.3 per cent of the working age population was engaged in agriculture.

The annual average rate of population increase in Turkey is 2.5 per cent. The State Planning Organization has estimated that it will be necessary to increase the value of agricultural production at a rate shown in Table 1. This is in order to provide the food and fiber needs of an expanding population and to increase the export of agricultural goods during the Second Five Year Plan period (1968-1972). Higher rates of increase are required for legumes, industrial crops, oil crops, fruit and vegetables, which can be grown only with irrigation in most parts of the country.

Due to its geographical location and topography, Turkey has several different climates. Along the southern, western and northern coasts the climate is mild, with rain in the winter and spring, and warm summers. Summers are dry and hot, winters cold and snowy, in the central and eastern parts of Turkey. The climate is more severe toward the east as the ground elevation rises. Average annual precipitation is about 630 mm. (24.8 inches). It varies between the extreme values of 220 mm. (8.7 inches) and 2,400 mm. (94.5 inches). Distribution of average annual precipitation over the country is shown on Map No. 1. Monthly distribution of precipitation is not uniform. During the growing season, the evapotranspiration is generally much greater than the precipitation. Shallow ground water conditions, which may supply (through capillary movement) some of the consumptive use requirement of crops, are not generally available in the highlands and plateaus. In the lowlands the water table is high. However, the quality of water is not suitable for crops and the precipitation during the season must be augmented by irrigation in order to realize the most beneficial use of land. Average water requirement estimates for crops are presented in Map No. 2.

TABLE I

Necessary Increase in Value of Agricultural Production during the Plan Period 1968-72

CROPS	REQUIRED INCREASE IN VALUE PER CENT
Cereals	4.0
Legumes	5.2
Industrial Crops	5.0
Oil Crops	6.0
Other Field Crops	3.6
Fruit	5.5
Vegetables	5.6

Due to differences in climate, the country is naturally divided into a variety of agricultural regions. Fruit, vegetables, olives, cotton and tobacco are the main crops grown on the coastal plains. The plateaus are the main source of

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KIRKLARELI
TEKIRDAĞ
İSTANBUL
SEA OF MARMARA
KOCAELİ
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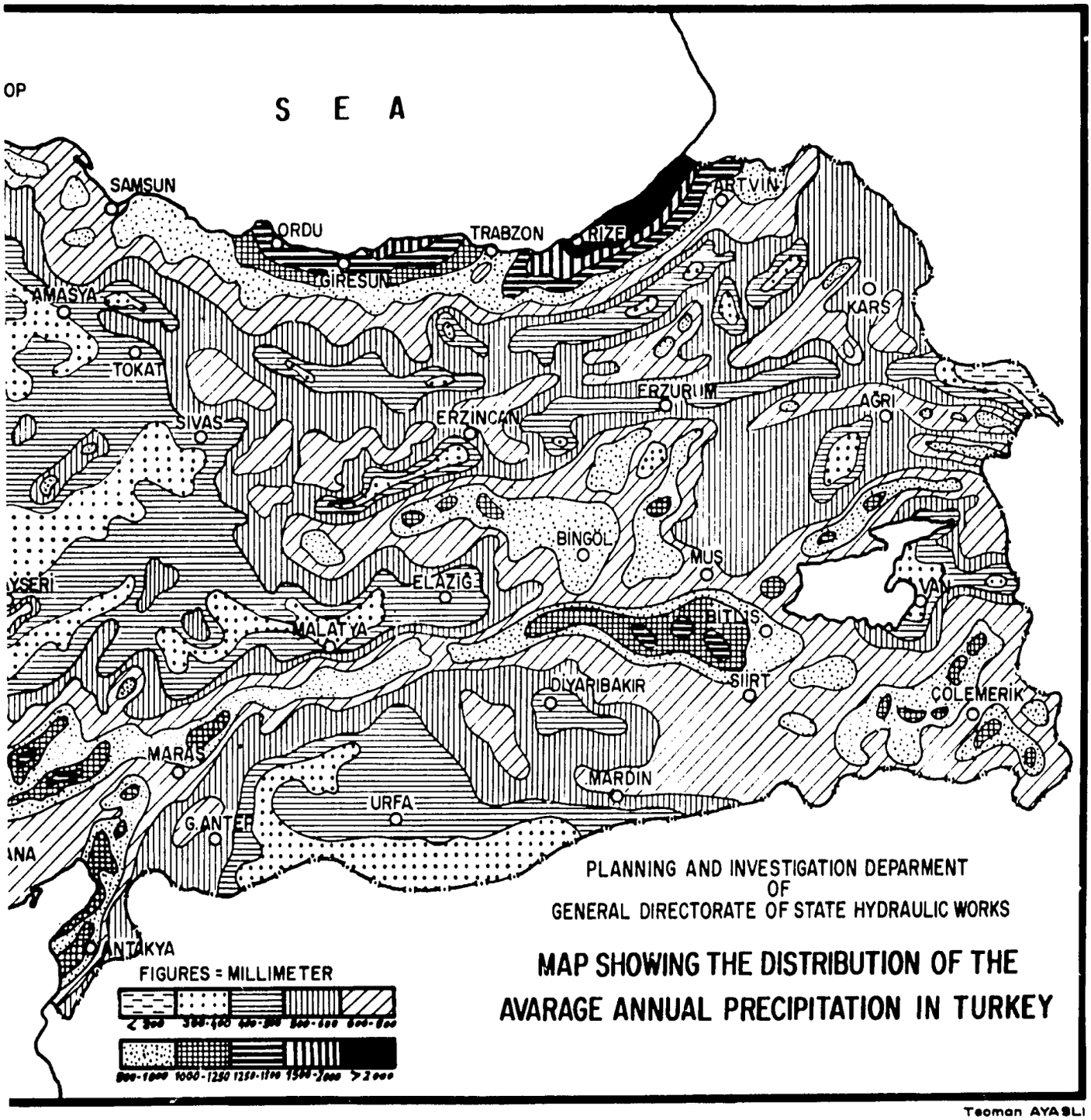
ÇANKIRI
ÇORUM
ÇANAKKALE
BURSA
BİLECİK
ESKİŞEHİR
ANKARA
YOZGAT
BALIKESİR
KÜTAHYA
KIRŞEHİR
MANİSA
UŞAK
AFYON
İZMİR
NEVŞEHİR
AYDIN
DENİZLİ
KONYA
NİĞDE
ISPARTA
BURDUR
MUĞLA
ANTALYA
MERSİN
MEDITERRANEAN SEA

MAP No. 1



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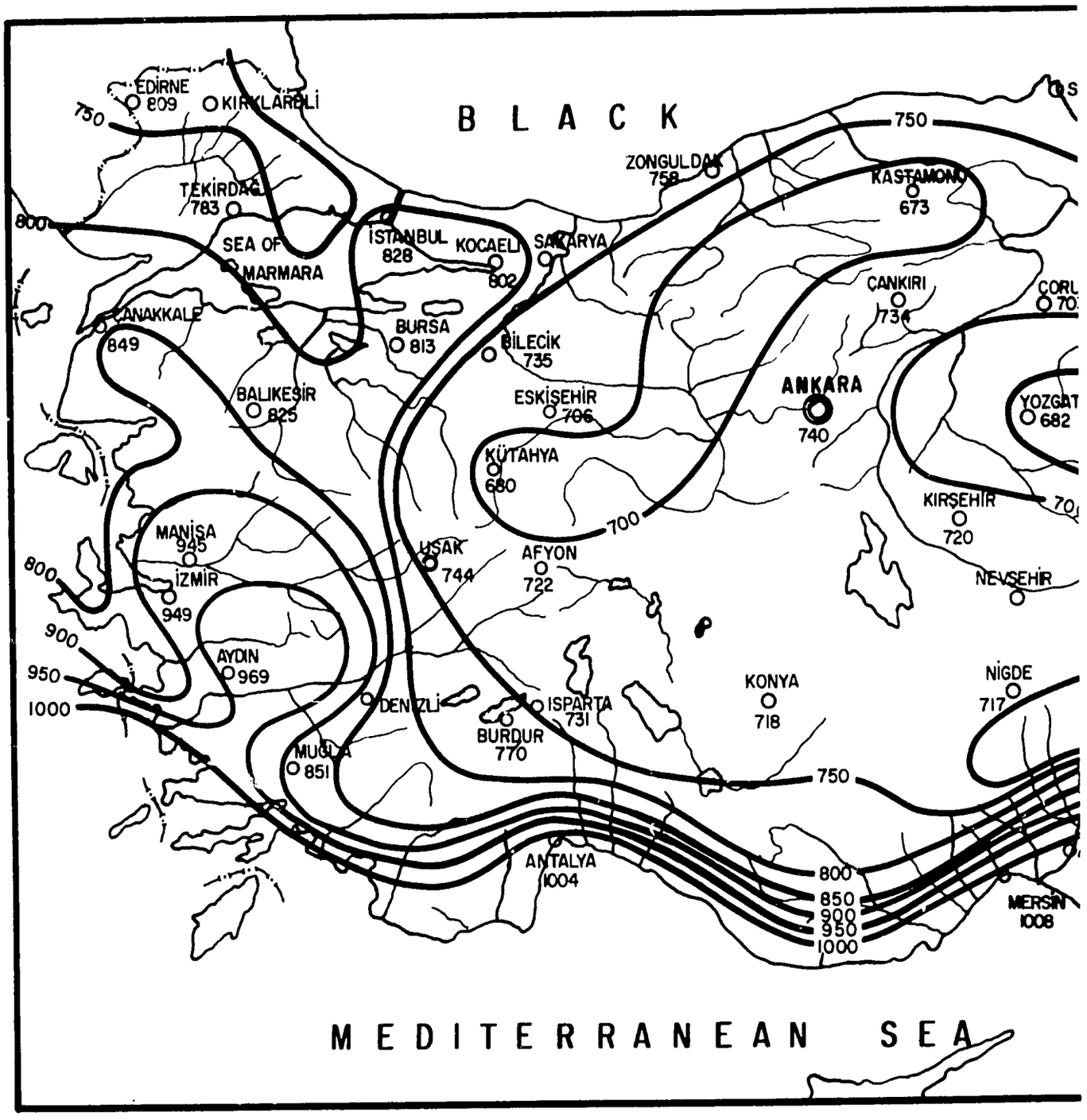
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SEA OF MARMARA
İSTANBUL 828
KOCAELI 802
SAKARYA
ZONGULDAK 758
KASTAMONU 673
ÇANKIRI 734
ÇANAKKALE 849
BURSA 813
BİLECİK 735
BALIKESİR 825
ESKİŞEHİR 706
ANKARA 740
YOZGAT 682
KÜTAHYA 680
KIRŞEHİR 720
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İZMİR 949
UŞAK 744
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NEVŞEHİR
AYDIN 969
DENİZLİ
ISPARTA 731
BURDUR 770
KONYA 718
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MERSİN 1008
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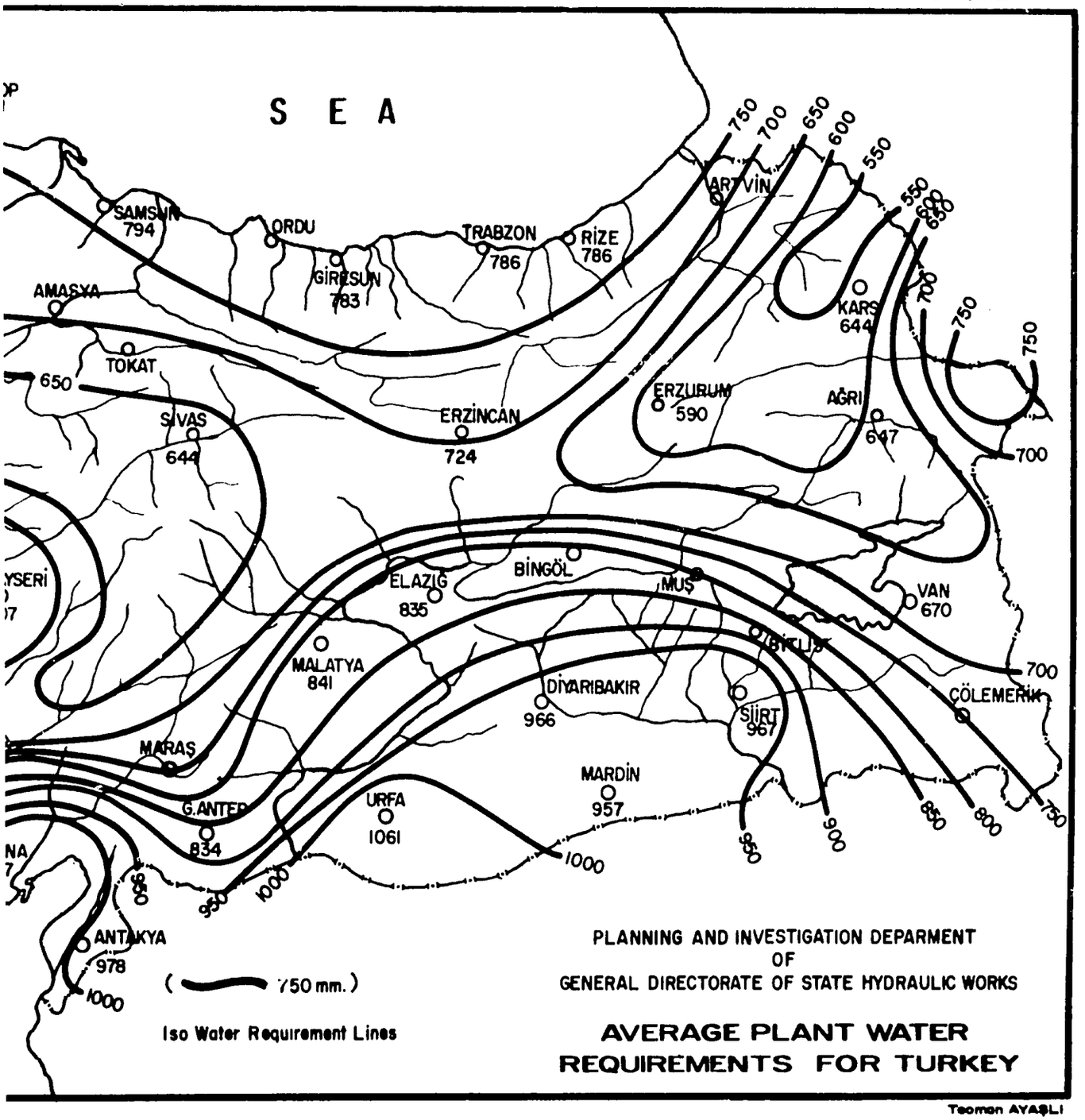
MAP No.2



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cereals. Table 2 shows the present land use. Due to the lack of sufficient moisture during the summer months, early-maturing crops such as cereals are grown in areas where fruit, vegetables, industrial crops and forage crops could be grown if they were irrigated. Each year one-third of the cultivated land is left fallow in order to store needed moisture for the following year.

TABLE 2
Present Land Use

KIND OF USE	AREA (1000 HECTARES)			AREA (1000 ACRES)		
Agricultural Land			23,539			58,141
Cultivated Fields		21,200			52,364	
Cropland	14,170			35,000		
Fallow Land	7,030			17,364		
Gardens and Vineyards		2,339			5,777	
Pastures and Meadows			30,839			76,172
Forest Land			10,584			26,809
Unproductive Land			13,096			32,347
TOTAL			78,058			193,469

II. Status of Irrigation in Turkey

Irrigation is necessary for growing cash crops such as vegetables, citrus and rice, and to increase the yields of other crops. Table 3 lists the yields of different crops with and without irrigation. These results indicate a significant increase of crop yields due to irrigation.

Economic analysis of 30 irrigation projects constructed in 1965 shows that the average value of agricultural production increased from TL. 100 to TL. 363 per decare (from $ 45 to $ 163.4 per acre) as the result of irrigation.

Investigations of the country's water resources indicate that the total annual surface flow of rivers is about $167 \times 10^9 m.^3$ (135×10^6 acre-feet) of which $155 \times 10^9 m.^3$ (126×10^6 acre-feet) can be controlled. The reserve of underground water which can be withdrawn annually for irrigation is about $4 \times 10^9 m.^3$ (3.25×10^6 acre-feet).

The total area of irrigable land if water were available is 12.6 million hectares (31.2 million acres). Reconnaissance soil surveys conducted in the watersheds of Turkey indicate that approximately 6 million hectares (14.8 million acres) of this area could be economically provided with irrigation water.

At the beginning of 1968, a total of 1,724,334 hectares (4,259,105 acres) was provided with irrigation systems. Approximately one million hectares (2.47 million acres) of this area obtained water by means of irrigation systems constructed by individual farmers, local organizations and private enterprise. The remaining 724,334 hectares (1,789,105 acres) of land are provided with water by means of irrigation systems constructed by the state. Of the land served by state-built irrigation systems, 48 per cent gets its water from reservoirs or regulated lakes, 46.6 per cent from diversion dams and the remaining 5,4 per cent by means of pumping stations, which obtain water from surface or underground water resources. The area served by reservoirs and pumping stations has increased yearly.

Topographical conditions in the irrigated areas are generally favorable for irrigation. These lands are usually flat-to-gently sloping, and need light-to-medium leveling for efficient irrigation.

Soils in the irrigated lands may be broadly characterized as deep alluvial, colluvial terrace and alluvial fan. Textures of the soils are extremely variable, ranging from loamy sands to heavy clays. Profiles are sometimes uniform for one or two meters (3 to 7 feet) or may be stratified with discernible horizons. Lime content of most soils is medium, resulting in neutral to slightly alkaline soil reactions. In general, they have high base exchange and medium water holding capacity. Permeability of the soils is not uniform and ranges from low to extremely high.

TABLE 3
Yields of Different Crops under Dry and Irrigated Conditions

CROP	FERTILIZER APPLICATION	YIELD (lbs/acre)		LOCATION OF RESEARCH STATION
		DRY	IRRIGATED	
Sugar Beet	No	7,430	16,750	Eskisehir
Sugar Beet	Yes	17,550	36,700	"
Wheat	No	1,154	1,925	"
Flax	"	188	1,290	"
Chick-pea	"	654	1,700	"
Sunflower	"	537	2,420	"
Cotton (lint)	"	895	1,390	Tarsus
Cotton (lint)	Yes	985	1,880	"
Peanuts	No	1,700	2,685	"
Cotton (lint)	"	625	2,015	Menemen
Sesame	"	671	1,120	"
Corn	"	1,210	2,240	"
Wheat	"	1,210	1,880	Cumra
Sugar Beet	Yes	8,600	23,800	"
Corn	"	4,840	7,030	Samsun
Soybean	"	1,433	3,140	"

The kinds of crops grown in the irrigated areas vary greatly from one region to another. Table 4 shows percentages of the total irrigated area and of the total area under cultivation, for each of these crops.

There are 185,136 irrigated farms in Turkey and 186,024 farm families were engaged in irrigation farming in 1967.

There is a strong desire by farmers to increase mechanization both on irrigated and dry farms. Table 5 presents recent trends in mechanization.

Irrigation is recognized by the country as one of the most important factors contributing to increasing agricultural production. The State Planning Organization estimates that of the total required increase in crop production during the Second Five Year Plan period (1968-1972), 20 per cent will result from irrigation; 52 per cent from the use of fertilizers; 10 per cent from the use of good quality seeds; 8 per cent from decreasing fallow land ; and the remaining 10 per cent from plant protection and other technical measures. A total investment of one billion dollars has been programmed for the development of water and soil resources, approximately 50 per cent of this for

TABLE 4

Percentage of Areas of Irrigated Crops, 1967

IRRIGATED CROP	PERCENTAGE OF TOTAL IRRIGATED AREA	PERCENTAGE OF TOTAL AREA UNDER CROP*
Wheat	12.9	2.9
Barley	2.6	1.6
Corn	4.8	12.5
Rice	3.9	100.0
Legumes	3.5	14.8
Sugar Beet	7.1	61.0
Potatoes	5.1	50.0
Oil Seeds	4.5	16.6
Cotton	25.8	57.2
Vegetables	15.5	100.0
Forage Crops	2.9	14.8
Citrus	2.4	100.0
Other Fruit	9.0	23.0
Total	100.0	Average 11.8

*For example, only 2.9 per cent of the total area under wheat is irrigated.

large irrigation projects. During the plan period 1,335,694 additional acres of land will be provided with irrigation water. Of this, 968,240 acres will actually be irrigated. In the development of small water resources, emphasis will be given to the development of underground water resources and the construction of storage reservoirs.

III. Accomplishments since Last Seminar

(A) A total of 663,901 acres of additional land has been provided with irrigation systems built by the state.

(B) A government decree in 1966 gave authority to TOPRAKSU to conduct land leveling, farm drainage and land consolidation by utilizing state funds to accelerate the development of irrigation projects. The cost of these works will be repaid by the water users by means of water charges. As a result of this arrangement 61,750 acres of land were leveled, 50,000 acres of land were drained and 12,350 acres of land were consolidated.

(C) The manufacture of farm development equipment, such as scrapers, landplanes, ditchers, listers, subsoilers, is encouraged by TOPRAKSU. Six companies are manufacturing these items in Turkey.

(D) Sprinkler irrigation is encouraged by TOPRAKSU in areas where it is more economical than gravity distribution. This will shorten the development period for irrigation projects, save water, and eliminate erosion and drainage problems in irrigation projects. Several companies are manufacturing sprinkler systems in Turkey.

(E) In 1966 a protocol was signed by the General Directorate of State Hydraulic Works (DSI), the General Directorate of Soil Conservation and Farm Irrigation (TOPRAKSU), and the Agricultural Bank of Turkey to accelerate the development of underground water resources for irrigation. According to this protocol, farmers who want to develop underground water resources for irrigation in a certain area must form a TOPRAKSU cooperative for this purpose. DSI will drill the wells and supply the pumps, TOPRAKSU will construct the pump houses, stilling pools and water distribution systems, and provide technical assistance to farmers for on-farm development activities. Loans for land development and operation of pumps are obtained from the Agricultural Bank upon request by the farmers. These loans will be based upon farm plans prepared by TOPRAKSU. Cost of the wells and pumps will be repaid to the state by the farmers in 30 years, without interest. A five-year grace period is permitted before repayment starts. The cost of pump houses, stilling pools and water distribution systems is wholly subsidized. Cooperatives must operate and maintain the wells, pump stations and water distribution systems according to the rules set up by DSI and TOPRAKSU. During 1967-68, 188 cooperatives were established for developing ground water resources and 13 of them are already irrigating 8,035 acres belonging to 1,492 members.

(F) A bylaw for land consolidation was approved by the Board of Ministers in 1966.

(G) A proposed law for the establishment of associations for the development of soil and water resources has been prepared by TOPRAKSU and presented to the National Assembly. According to this, if at least seven farmers in a certain area make a written application for establishing an association, TOPRAKSU will prepare a development project for them. This project and agreement are submitted for approval to all of the farmers in the project area. If it is approved by two-thirds of those who together own more than half of the project area, the proposal is submitted to the Ministry of Village Affairs, then to the Council of Ministers, for approval. An association is established with at least 25 farmers. All of the farmers in the project area must go along with the agreement and the project after the establishment of an association. Loans will be provided to associations from a special fund in the Agricultural Bank. A government subsidy up to 50 per cent of the project cost can be provided to the association. The association can operate and maintain irrigation systems, and collect water charges and other fees.

This law will eliminate the opposition of a minority to the development of soil and water resources; will accelerate on-farm development activities such as land leveling, drainage, etc., by cost sharing programs; will provide enough loans to associations; will give the responsibility for operating irrigation systems to the associations; and will motivate farmers to use their own resources for development. What is to be seen, however, is whether the state's financial resources will be able to conduct such programs at the desired rate.

(H) A proposed law for the use of water resources has been prepared by DSI and presented to the National Assembly. This law, if enacted, will regulate water rights, provide more efficient use of water and give authority to water users' associations for construction, operation and maintenance of irrigation projects.

Since 1966, DSI has made contracts with beneficiaries before construction, giving priority to those projects whose beneficiaries are willing to sign an agreement which specifies the terms of repayment, operation and maintenance.

TABLE 5
Trends in Mechanization

KIND OF EQUIPMENT	1948	1960	1964	1967
Tractors	1,756	42,160	51,784	65,103
Tractor Plows	1,119	31,528	37,100	50,100
Disk Tractor Plows	353	15,552	18,000	22,800
Tractor Cultivators	401	6,134	6,500	15,300
Grain Drill (tractor-pulled)	162	8,343	9,800	12,700
Cotton Planters	2,570	11,147	16,600	20,100
Binders	335	3,037	3,780	6,300
Combines	268	5,554	6,790	7,200
Motor Pumps	253	22,557	45,700	66,300

(I) In 1966, the operation and maintenance of 14 irrigation projects were transferred to irrigation associations. Additional transfers have been made since then.

(J) In 1966, it was decided to start reimbursement of four irrigation projects which were built by DSI. Each year the number of such projects has increased.

(K) In 1966, 23 out of 63 irrigation projects built by DSI were rehabilitated at a cost of TL. 31.2 million.

(L) To accelerate the early utilization of irrigation systems, the following percentages of actual irrigations were accepted during the preparation of the Second Five Year Plan, and the programs were prepared accordingly:

Year Following Completed Construction	Percentage of Service Area That Will Actually Be Irrigated
LARGE IRRIGATION PROJECTS	
1st	15
2nd	30
3rd	45
4th	55
5th	65
6th	70
7th	75
8th	80
9th	85
10th	90
SMALL IRRIGATION PROJECTS	
1st	30
2nd	55
3rd	70
4th	80
5th	90

(M) It was decided by the State Planning Organization and the Agricultural Bank to provide supervised credits to the farmers in large irrigation projects for seeds, fertilizer, insecticides, machinery and tools, livestock, etc.

(N) Coordination among the extension service, the plant protection service, the Agricultural Bank, the agricultural research service and TOPRAKSU was provided in Seyhan irrigation project for on-farm development and agricultural activities. As a result of this coordination, average cotton yield in the project was raised from 1,730 kg. per hectare to 2,200 kg. per hectare in one year. The average yield on leveled fields was raised to 2,428 kg. per hectare. Similar coordination has been organized for Gediz irrigation project and planned for other irrigation projects.

(O) Technical standards for small earth-fill dams and land leveling were prepared by TOPRAKSU. Standards for drainage are being prepared.

Chapter V
EDUCATION AND TRAINING

IMPACT OF HIGH YIELDING VARIETIES ON CROPPING PATTERNS AND IRRIGATION PRACTICES

by
R. T. Gandhi*

Abstract

High-yielding varieties are assuming an important role in making up our deficit of food grains. The target of 6.25 million acres during 1966-67 is likely to increase to 21 million acres during the current year and 32.5 million acres during 1970-71.

The existing yardsticks for calculating additional production from high-yielding varieties are 0.67 tons per acre for paddy and wheat; 0.5 tons per acre for maize and jowar; and 0.25 tons per acre for bajra.

Besides increasing food production, this program is playing an important role in changing cropping patterns and irrigation practices with important cereals like paddy, wheat, maize, jowar and bajra.

* Irrigation Specialist, Directorate of Extension, Ministry of Food, Agriculture, Community Development & Cooperation, New Delhi.

The high-yielding varieties in national demonstrations have indicated yield increases of more than threefold in wheat and nearly ninefold in bajra.

The changes in cropping patterns have been noteworthy. Hybrid crops like maize, jowar or bajra are being followed by wheat. Wheat is also being grown after paddy. Cultivators are harvesting an average yield of 60-70 quintals per hectare from the two cereal crops. Production of 90-100 q/ha. per year from two cereal crops is not uncommon.

Early maturity of high-yielding varieties of crops has helped to grow two, three or even four crops per year. Relay cropping is gaining ground. In this, two catch crops of early *moong* and *toria* are grown during the hot weather and autumn respectively, after growing maize in *kharif* and wheat in *rabi*. This cropping pattern has pushed up the gross income by about Rs. 3,500 per ha. per annum over that from maize and wheat.

Paddy-growing areas are replacing late-maturing varieties with high-yielding and early-maturing varieties. It has become possible to grow two or even three crops on the same piece of land in one year. In some areas, cash crops are being gradually replaced by high-yielding and early-maturing paddy varieties. In some delta areas of Andhra Pradesh cultivators are thinking in terms of growing three crops in place of one, *e.g.* paddy-hybrid jowar-ratoon of hybrid jowar, or hybrid maize or hybrid bajra. These three crops are grown depending upon the availability of irrigation water during *rabi* and summer seasons. Specific cropping patterns are coming up in different agro-climatic regions.

With the changes in cropping patterns and the introduction of early maturing varieties, there has been a development of the sources of irrigation, especially through the minor irrigation projects. Due to need for more water, storage structures and tanks are being built. Ground water sources are being tapped. There has been rapid progress in digging of more wells, installation of diesel engine and electric motor pumps, deepening of dug wells, boring of wells, etc. More and more private and state-owned tubewells are also being bored.

The development in irrigation supplies has helped to effect changes in cropping patterns and irrigation practices. With the availability of water, it is now possible to raise early paddy nurseries for early transplanting. In some of these areas, paddy-wheat rotation is gaining ground due to availability of water throughout the year.

With these developments, the irrigation practices are changing with the inflow of experimental data. High-yielding varieties of paddy need only about 25-30 mm. of standing water, compared with indigenous varieties requiring 100-150 mm. More depth of water in I.R. 8 and T. No. 1 varieties of paddy reduces tiller formation and development. The depth of water has to be increased to 50 mm. from flowering till grains become hard. Irrigation for dwarf wheats at crown root development stage is very important. Delay in irrigation by 20 days at this stage reduced the wheat yield by 9 q/ha. Hybrid crops like maize, jowar and bajra need adequate supplies of moisture at flowering and seed development stages.

The ridge furrow and border methods of irrigation are becoming common for economy in water use.

Report

The introduction of high-yielding varieties is assuming an important role in making up our deficit of food grains. The program was initiated on a modest scale in the year 1966-67 and is now picking up as indicated below :

AREA IN MILLION ACRES

Year	Kharif		Rabi/Summer	
	Target	Actual	Target	Actual
1966-67	—	1.818	4.428	2.842
1967-68	7.857	4.856	10.16 (Rev.)	10.06 (Est.)
1968-69	11.550	—	9.45	—

The target of 6.25 million acres during 1966-67 increased to 21 million acres in the current year. These figures are tentative and are likely to increase further. The five-year target for the high-yielding varieties program has been fixed at 32.5 million acres, to be covered by 1970-71. It comprises 12.5 million acres under paddy, 8 million acres under wheat and 4 million acres each under hybrids of maize, jowar and bajra. This is likely to give an additional production of 18.80 million tons of food grains. The crop-wise and year-wise targets for the years 1969-70 and 1970-71 as proposed are shown below :

AREA IN MILLION ACRES

Crop	1969-70	1970-71
Paddy	11.00	12.50
Wheat	7.00	8.00
Maize	3.00	4.00
Jowar	3.00	4.00
Bajra	3.00	4.00
	27.00	32.50

The proposals for the Fourth Five Year Plan are still under consideration, and it is expected that the plan target for the high-yielding varieties program may be fixed at a much higher level, in view of the considerable enthusiasm shown by farmers to cover large areas under high-yielding varieties of crops. This is very obvious from the trend of the high-yielding varieties program and the rate at which these varieties are being readily adopted by the farmers.

The existing yardsticks for calculating additional production from high-yielding varieties are: 0.67 tons per acre for paddy and wheat, 0.5 tons per acre for maize and jowar, and 0.25 tons per acre for bajra. The additional production of 4.8, 4.5 and 1.0 million tons is by irrigation, multiple cropping and other programs respectively.

Besides an increase in food production to the extent of 18.80 million tons, this program is playing an important role in changing cropping patterns and irrigation practices, especially in important cereal crops like paddy, wheat, maize, jowar and bajra.

The change in cropping patterns is leading to multiple cropping. Where one crop was growing, two crops are being raised. Relay cropping with three to four crops per year is being advocated and is becoming popular with the cultivators. Introduction of hybrids of maize, jowar and bajra, and high-yielding varieties of paddy and wheat have made it possible to grow two, three or even four crops per year. This, with adequate fertilizer application and availability of irrigation water and other practices, has increased the yields of individual crops and the total yield per year. The yield data of national demonstrations conducted during 1965-66 and 1966-67 indicates the extent of increase in yields.

National Demonstrations, 1965-66 and 1966-67

	Rice	Wheat	Hybrid Jowar	Hybrid Bajra	Hybrid Maize
Average Yield (kg/ha)	5,017	3,778	2,524	3,120	4,169
Highest Yield (kg/ha)	10,769	9,029	6,561	6,700	7,400
All-India Average Yield (kg/ha)	874	838	436	315	989
Percentage Increase over All-India Average	463	351	479	890	322

The national demonstrations have indicated the extent of possible increase in production due to introduction of high-yielding varieties. The increase in yield has been more than threefold in wheat and nearly ninefold in bajra. For the year 1967-68, the national demonstration program included multi-crop demonstration with a minimum production target of 9 tons for two crops and 11 tons per hectare for a three-crop demonstration.

The changes in cropping patterns have been noteworthy. There was a time when only one crop of cereals like maize, jowar or paddy was grown in one year. It was believed that wheat following the *kharif* cereals would deplete soil fertility. This resulted in poor yields. The concept is rapidly changing, and cereal rotations like

hybrid maize — wheat
hybrid jowar — wheat
hybrid bajra — wheat
paddy — wheat
paddy — paddy

have been adopted by the cultivators, with an average yield of 60-70 quintals per hectare per year. Production of 90-100 quintals per hectare per year is not uncommon from the two cereal crops. In many areas where irrigation water is available during the summer months, a third crop of early *moong*, early vegetables or short duration fodder is grown. In this way yields are increasing three to fourfold.

The introduction of high-yielding varieties which also mature 30-40 days earlier has helped

to grow more than one crop a year, and relay cropping is becoming the slogan of the day. In relay cropping the cropping pattern is arranged in such a way that, even during the off-season periods of from 60-75 days in summer and autumn, farmers should be able to fully utilize the solar energy, a free gift of nature available in abundance, and convert it into edible products by growing crop plants. With the recent researches carried out in the division of agronomy, I.A.R.I., it has become possible to grow three food crops and one cash crop in quick succession on the same piece of land in one year without over-taxing the farmers' production and investment resources. The multiple cropping sequence followed includes: one legume, *i.e. moong* (*phaseolus aureus*), which is a restorative crop and recoups soil fertility; two exhausting cereal crops, *i.e.* maize and wheat, which are adequately fertilized; and an oil seed, *toria* (*brassica campestris*), which is neither exhausting nor restorative and receives nitrogen. *Moong* is grown on residual fertility after wheat. Maize gets the advantage of the preceding legume. The total quantity of fertilizer used is the same as recommended for two-crop sequence of maize and wheat.

The *moong* variety "baisakhi" matures with two irrigations, *i.e.* one pre-sowing and the other 3-4 weeks after sowing. This is a high-yielding variety and matures within 70 days after sowing. The maize hybrid Gaga-3 matures within 85 days after sowing. *Toria* needs one irrigation before sowing and another a month afterwards.

The 400 per cent cropping intensity followed during 1966-67 yielded a balanced production of 90 q. of cereals, 10 q. of pulse grains, in addition to 150 q. per ha. of nutritious legume green fodder and 8 q. of oil seed containing 33 per cent edible oil.

Introduction of *toria* and *moong* as catch crops during autumn and summer respectively, pushed up the gross income by about Rs. 3,500 per ha. per annum over that from maize and wheat. As an alternative to *toria*, the potato variety Craig's Defiance has been successfully grown after maize and harvested in December.

In some paddy growing areas where one crop of late-maturing paddy was grown with supplementary irrigation, it is becoming possible to grow two or even three crops of paddy on the same piece of land during the course of one year. This has been possible due to the introduction of high-yielding and early-maturing varieties of paddy like T.N.1, I.R.8, etc. At Vyara in Surat district, two crops of paddy grown in succession during monsoon and summer seasons yielded as high as 2,900 kg. and 3,750 kg. per acre respectively. Growing three crops of paddy per year is yet to be adopted on the cultivators' fields on a large scale. The handicaps concern the continuous supply of irrigation water, maintenance of soil fertility and the labor for preparatory tillage and transplanting which synchronize with cutting and threshing operations of the paddy crop.

It may be mentioned that in Surat district (Gujarat state), where cash crops were cultivated, the area under these cash crops is gradually going down, and the area under early-maturing varieties of paddy like Formosa-3 and Mashuri is rapidly increasing.

In some other paddy growing areas of U.P., Madhya Pradesh and some other states where one crop of late paddy was grown, it has become practicable to adopt a paddy-wheat rotation with the introduction of early-maturing varieties of paddy. Paddy is harvested by mid-November and the wheat is sown by the end of November or beginning of December. This has become possible by introducing dwarf Mexican varieties of wheat like Sonora-64 and Lerma-Rojo, and other varieties like Kalyan 227, S-308, S-307, etc., which have shown better performance when sown late. The cultivators in these areas are harvesting 80-90 q/ha. of grain from both the crops. In some areas of Gujarat state where Mexican wheats have failed to give higher yield, paddy is followed by improved indigenous varieties of wheat (N.P. 824). This rotation is getting popular with the cultivators in areas which are suitable for growing both paddy and wheat crops.

In the command area of Hirakud, in Orissa, 2-3 crops of paddy are being harvested by progressive cultivators. Some of the cultivators are growing two crops of paddy followed by wheat. Similarly in Thanjavar district, two crops of paddy

are followed either by short duration cotton, or hybrids of jowar or maize, or vegetables.

Similarly, hybrid maize or hybrid jowar and wheat rotation has gained popularity in areas where hybrid jowar is grown in *kharif* and wheat in *rabi*. In light soil where hybrid maize or hybrid jowar cannot be grown, hybrid bajra and wheat are being grown in rotation.

Growing of two crops per year under assured water supply is being adopted on a large scale. Growing of three or four crops is also gaining in favor.

In some areas where the cultivators have developed their own source of irrigation like deep wells or tubewells, intensive rotations like potatoes-potatoes-chillies are being adopted. The first and second crops of potatoes are grown from mid-September to mid-December and mid-December to the end of March respectively, and the chillies are transplanted as the harvesting of potatoes is in progress. Such intensive rotations have given high profits to cultivators.

In the delta areas of Andhra Pradesh, where rice was grown as an irrigated crop, no other following crop was possible due to the non-availability of irrigation after the harvest. Some changes are also taking place in those areas. The cultivators are now thinking in terms of growing three crops in place of one, *e.g.* paddy-hybrid jowar-ratoon of hybrid jowar, hybrid maize or hybrid bajra. These three crops are grown depending upon the availability of irrigation water during *rabi* and summer seasons. This indicates the most efficient use of available irrigation water and changes in cropping patterns, resulting in very high output per unit area per year. High yields of hybrid jowar and its ratoon have been reported from Coimbatore, as the data below shows:

Yield of Jowar in Kg/ha.

Varieties	Ist Crop	Ratoon	Total
CHS 1	5,772	3,064	8,836
CHS 2	5,661	2,620	8,281
Local (improved)	4,196	1,114	5,310

The crop when sown in the first week of February was ready for harvest in about 90 days, while the ratoon crop was harvested in another 80 days. Both crops yielded as high as 8.8 q/ha. in about 170 days. Ratoon crop is followed by cotton. This is indicative of high grain yield per hectare followed by a cash crop of cotton.

Another important change that is coming up with the introduction of these new varieties and multiple-cropping, is that the green manuring which was being so far recommended as a seasonal feature is being slowly replaced by a short duration pulse crop during summer months. In case of paddy, green manuring is being practiced before transplanting paddy. This has helped to maintain soil fertility by incorporation of root and dry leaf matter in the soil.

The specific cropping patterns being adopted in different regions under irrigated conditions are described in the following paragraphs.

(A) NORTHERN REGION

(Punjab, Haryana, Uttar Pradesh, Rajasthan, Himachal Pradesh, and Jammu and Kashmir).

The most efficient and potential food grain crops around which the crop rotations and cropping patterns are being based are hybrids of bajra, maize, paddy in *kharif*, and wheat and gram in *rabi*. Bajra is the most efficient crop in Rajasthan, Haryana, South-East Punjab and Agra division in Uttar Pradesh. Maize is best in well-drained upland soil, and paddy in valleys of hilly areas and low-lying areas of Punjab, Haryana and Rajasthan.

The most efficient *rabi* crop in the whole northern region is wheat, and its yields depend on supplemental irrigation and fertilizer. In many cropping patterns wheat is occupying prominent place and is being fitted into rotations with all the crops, including cash crops like cotton and groundnut.

Efforts are being made to raise cropping intensity in all the irrigated areas of this region to two crops per year, and under more favorable conditions of water supply, even higher intensity of cropping is being considered.

In case of all the above-mentioned crops, a shift from the local varieties to the newly introduced high-yielding varieties has started, and it is hoped that in the next few years local varieties will be replaced by the hybrids or other high-yielding varieties. This change is likely to be more rapid in case of wheat and paddy. The process can be hastened if adequate supplies of certified seed, fertilizers and pesticides, along with assured supply of water, are made available.

The experience with groundnut on the lighter soils and under assured rainfall and light irrigation on low rainfall areas is very encouraging. This crop is being given greater importance in new cropping patterns. It can also rotate with wheat, of which the dwarf varieties are particularly suitable.

For irrigated areas, particularly where controlled irrigation is available all the year round, more intensive cropping is being contemplated. One short duration crop, such as a *zaid rabi* (mid-April to mid-June) or *zaid kharif* (beginning October to mid-December), or both are being fitted between the two most efficient grain crops. The experience in states in this region shows that for *zaid rabi*, *moong*, cowpeas, *cheena*, *sathi* maize, maize + cowpeas fodder, bajra + cowpeas fodder are suitable. Likewise for *zaid kharif*, after the main season grain crop the suitable crop seems to be potato in the maize tract, *toria* in the bajra tract and dwarf *rai* in the central plains. The cultivation of more than two crops is being recommended only when the additional crop is grown without any detriment to the main crop and without creating any competition for irrigation water and fertilizers.

In the Kashmir valley paddy is the most efficient grain crop, and cultivation of a high-yielding variety, China 1039, is being advocated. Berseem, sorghum, turnips, gram or wheat are being fitted in double cropping. Hybrid maize is quite successful in most areas of Jammu and Kashmir. It fits well in rotation with wheat, *toria* or potato.

(B) SOUTHERN REGION

(Andhra Pradesh, Madras, Mysore, Kerala.)

Paddy is the main crop of the region. According to the rainfall pattern in particular areas, the rotation includes rice and crops like hybrid maize, hybrid sorghum, wheat, cotton, groundnut, potato, sugarcane, grain and fodder legume, etc. These crops either precede or follow paddy, according to the local conditions. In general, the following patterns are in vogue:

1. *Delta Areas.* In the deltas of the Cauvery, Krishna and Godavari, efforts are being made to grow two crops of paddy where conditions do not suit growing of upland crops during the monsoon season. Where crops with supplemental irrigation can be grown, rice is being followed by cotton and groundnut. The possibilities of growing hybrids like maize, jowar, bajra and early castor bean are being explored.

2. *Interior Areas Irrigated by Canals from Rivers or Tanks.* Where the water for irrigation is perennial, efforts are being made to grow two crops of rice and one crop of millets, groundnut or wheat. In some areas the rotation includes one crop of rice-early sorghum, or maize-rice.

Where irrigation is available for only 5-6 months (from late August to December), as in tank fed areas in the northeast, a third crop of short duration grain legume or fodder legume is being grown. The third crop is dropped due to shortage of water. Where irrigation beyond December is available from wells, a third crop such as *ragi*, chillies, hybrid sorghum is being grown. In lower Bhavani Sagar area and several areas of Tungabhadra in Mysore and Andhra Pradesh, and of Nizamasagar (Telegan) area of Andhra Pradesh, where irrigation is found to be sufficient only for one crop of rice, rice is being substituted to a large extent by the high-yielding varieties of millets and maize. This is helping to increase the cropping intensity.

3. *Lift Irrigation Areas or Garden Land.* Rotations comprising two crops of sorghum (planted crop followed by ratoon CSH) followed by wheat, or planted crop of sorghum followed by *ragi* and wheat have already been successfully tried and are being adopted. These rotations are successful in areas of cool winter. Sometimes

potatoes take the place of wheat. Where the winter is not cool enough for wheat or potatoes, the third crop is usually hybrids like maize, jowar, bajra or groundnut.

(C) WESTERN REGION

(Madhya Pradesh, Maharashtra, Gujarat).

Only 5.7 per cent of the area is irrigated in the region. The present intensity of cropping varies from 100-150 per cent, which is proposed to be raised to 200 per cent with the introduction of high-yielding early-maturing varieties.

The most efficient crops of the region are paddy, hybrid jowar, bajra, maize, cotton and groundnut. Sugarcane is an efficient crop in irrigated areas of Maharashtra, and paddy in Chhatisgarh area of Madhya Pradesh. Minor millets, which occupy a considerable acreage in the hilly and backward areas of Madhya Pradesh and Maharashtra, are being slowly replaced by hybrid jowar and hybrid bajra which are of short duration and high-yielding. These are being followed by pulse crops. In Havelli tract of Madhya Pradesh, the percentage area under *kharif* crop is lower than *rabi* crop though most of the rainfall is received during the *kharif* season. The soils of this tract are black, with heavy texture. Efforts are being made by the cultivators to grow paddy in *kharif*, followed by *rabi* crops.

Wheat is also an important crop of this region, but the yields are low due to late-maturing varieties of *kharif* crops and early recession of monsoon. Barley is being tried in such areas successfully. In paddy tracts of Chhatisgarh (M.P.) where the winters are mild, either two crops of paddy or paddy-wheat or paddy-gram (*rabi*) are being planted. Winter and summer paddy in this tract are giving higher yields than the main crop due to controlled irrigation practices. Where the irrigation supplies are assured all the year round, summer crop of vegetables or hybrid maize or maize for fodder is being taken in between the two main crops of *kharif* and *rabi*.

(D) EASTERN REGION

(Bihar, West Bengal, Orissa and Assam).

Paddy, jute, maize, wheat, gram, *khesari* are the most efficient crops of the region. The area of upland paddy in Bihar and West Bengal is going down due to low yield and is being replaced by hybrid maize. Bajra is being slowly replaced by hybrid maize. There is a tendency to fit in pulse crops, like *urd* and *moong*, vegetable crops and potatoes in the rotation to build up soil fertility.

In this region, existing varieties of jute, paddy and wheat are being replaced by the newly-evolved early-maturing varieties. Two crops of paddy followed by wheat are gaining ground. Jute-paddy (*aman*)-*khesari*, or hybrid maize-paddy (*aman*)-*khesari* are some of the rotations being taken up in West Bengal. Under assured supply of irrigation water, *khesari* is being replaced by vegetable crops or potato or mustard. Wheat varieties like Sonara-64 and PV-18 are finding their place in rotation with paddy, jute or hybrid maize.

Intercropping of sugarcane with groundnut, *phaseolus*, *ragi* and some quick growing vegetable is also being taken up. In addition, green manuring is being practiced as a short-duration summer crop under irrigated conditions along with *kalai*, *moong*, etc.

With the changing cropping patterns and the introduction of these new early-maturing varieties in crop rotations, there has been a development in the sources of irrigation through the minor irrigation projects. The canal and tank supplies do not appear to be sufficient in several areas for the last few irrigations for the second and third crops. Therefore, due to need for more water, storage structures and tanks are being constructed. Besides this, ground water sources are being tapped. In coastal areas and river basins having ground water bearing sandy strata, filter points and tubewells have proved successful in Madras, Andhra Pradesh, Orissa, Kerala. The main objective is to utilize land to its maximum capacity and intensity of cropping on a scientific basis. The farmers are ready and are looking forward to new ideas. The experience in some of the new irrigation project areas, *viz.* Nagarjunasagar area, has shown that the farmers recognize the value of water, and from them the suggestion came that instead of

the entire water supply being made available during *kharif*, it may be spread throughout the year and more water supplied during the *rabi* season. This is an example where the farmers have identified themselves with the scientists very closely and found a solution which could have been considered difficult.

With these changes, there has been rapid progress in development of irrigation resources through minor irrigation projects like digging of more wells, installation of diesel engine and electric motor pumps, deepening of dug wells, boring of dug wells and more state and private-owned tube wells. The progress is indicated in the table below:

Scheme	Pre-Plan	1st. Plan	2nd. Plan	3rd. Plan	Anticipated 1966-68	Anticipated end 1968-69
Wells	N.A.	3,641,770*	832,423	636,692	595,667	5,706,552
Boring of wells	N.A.	N.A.	108,657	136,140	262,436	507,233
Deepening of wells	N.A.	N.A.	13,678*	87,195	115,575	216,448
Diesel pump sets	65,794	56,717	107,461	235,252	185,126	650,350
Electric pump sets	18,698	31,399	141,669	322,465	506,690	1,020,921
Private tubewells (including filter-points)	20,520	9,196	19,381	64,119	157,329	270,545
State tubewells	2,507	4,146	3,133	2,500	3,468	15,754

*End of Plan period.

Note: The figures of diesel and electrical pump sets include those pump sets which are installed on dug wells, tubewells and rivers/streams/lakes.

It is obvious that the progress of irrigation facilities through the development of minor irrigation projects has been rapid and satisfactory. More stress is being laid on the development of irrigation resources through minor irrigation, due to scarcity of rainfall all over the country for the past two years (1965-66 & 1966-67).

This development in irrigation supplies has also effected changes in cropping patterns and the methods of irrigation. In the Cauvery delta and many other areas where one crop of paddy was grown, two to three crops of paddy are now being grown in one year. This has become possible by raising early paddy nurseries on the supplies of water from wells or tubewells. In some of the areas paddy and wheat rotation is gaining ground due to the availability of water throughout the year.

In many of the command areas of major irrigation projects, irrigation water is being demanded early in the season for raising paddy nurseries. This demand is encouraging more and more minor irrigation projects to meet the demand of the farmers. With the development of these water resources and the introduction of early-maturing crops, irrigation practices have also changed.

The indigenous or indigenous improved varieties of rice were kept continuously flooded with 100-150 mm. of water, and it was considered harmful to reduce the depth of irrigation water in such rice fields. It is experimentally proved that these high-yielding varieties of rice like TN-1, IR-8, etc., do not need that much water. These varieties need only about 25-30 mm. of water from the time of transplanting to the tiller development. If the depth of water is more, it reduces the tiller formation and development of effective tillers. When the crop has produced the maximum number of tillers, the water has to be drained out completely, especially in case of heavy clay soils. The water has to be again let in to maintain a depth of about 5 cm. from flowering time till the grains become hard. After this, all the water is

drained out. The old method of irrigating rice from plot to plot is slowly going out of practice, and the cultivators are realizing the advantage of irrigating individual plots. In some of the IADP districts, irrigation channels have been constructed in paddy fields to irrigate individual plots. This has enabled the cultivators to grow subsequent crops like wheat, peas or winter and summer vegetables as irrigated crops, depending upon the availability of water. This was not possible before due to the want of irrigation channels and field-to-field irrigation.

Similarly, the irrigation practices of high-yielding dwarf varieties of wheat like Sonora-64, Lerma-Rojo, PV-18, Kalyan 227, S. 308 are changing as the experimental data becomes available. The improved indigenous varieties required three to four irrigations at tillering, booting, flowering and grain development stages, while the irrigation practices recommended for dwarf wheat are slightly different. The first irrigation at crown root development stage has been found to be critical for dwarf wheats. A delay of two weeks in irrigation at this stage resulted in yield reduction of about 9 quintals per ha.

Irrespective of the depth of sowing, the crown in dwarf wheats is located within one centimeter of the soil surface, and if the soil in this region is dry, the crown roots, which are the main functioning roots in wheat, fail to develop or develop sparsely. This results in a fresh crop of tillers. Thus the tillering phase, even in a synchronous tillering variety like Sonora-64, is unduly extended, resulting in subnormal heads and poor grain yield. However, to get the best results from dwarf wheats it is beneficial to irrigate at different growth stages, like crown root initiation, late tillering, flowering, and dough stage of grain. As against about 300-350 mm. of irrigation requirements of improved indigenous varieties, high-yielding dwarf wheats need about 350-400 mm of irrigation waters in good loamy soils. In sandy soils of Rajasthan and in some parts of Gujarat, the irrigation requirements are nearly double and the crop has to be irrigated every 12 to 15 days, irrespective of the stage of growth. Care has to be taken not to stress the wheat plants for want of adequate moisture at any stage of growth.

Sowing of wheat on ridged seed beds eliminates the wastage of farm land under irrigation channels, which amounts to 10 to 15 per cent of the total area. The cropped area is itself increased by about 30 per cent by sowing crops on the crest and the slopes of the ridges as well as in the furrows. Moreover, economy in water use to the extent of 40 per cent is effected by adopting this system of sowing. With the wheat crop sown in flat beds, there is normally enough space between lines, small corrugations being made with a country plow. This helps to earth up the crop and prevent lodging, and cuts down on the use of irrigation water to the extent of 30 per cent.

Other important hybrid crops like maize, jowar and bajra do not entail much change in the irrigation practices, except in areas where the monsoon starts late, in early or mid-July. One irrigation is given for sowing in mid-June. As these crops are shallow rooted, they extract more than three-fourths of their water needs from the first two feet of the soil. Light irrigations, each of 6-7 cm., are adequate for irrigating these crops. Care is usually taken not to stress these crops for moisture at flowering and seed development stages. Under conditions of heavy rainfall and in areas where water-logging is a common feature, these crops are grown on ridges. This reduces the damage due to water-logging and effects economy in use of irrigation water.

Apart from this, the methods of irrigation are also changing for efficient use of irrigation water. The ridge furrow method is becoming common for many field crops, saving irrigation water to the extent of 30 to 33 per cent. Border method of irrigation is being largely used for row crops like cereals, under canal system of irrigation or tubewell irrigation where the discharge is about 0.5 cusecs or more. All these changes are leading to changes of cropping patterns, efficient use of irrigation water, increased intensity of cropping and irrigation, and ultimately to greater production.

THE ROLE OF IRRIGATION FOREMEN IN IRRIGATION PROJECTS

by
Huseyin Yegin*

Abstract

Only a part of the anticipated benefits are realized from irrigation projects by providing irrigation water to the farms and preparing the land for irrigation. The remaining benefits can be obtained through extension services. Due to the shortage of technical personnel in the developing countries, the number of families served by each extension agent may be many times what it should be. There may be several agencies dealing with extension. There may be a gap between technicians of extension and the farmers. All these problems were overcome in Seyhan irrigation project in Turkey by coordinating extension activities. In this coordination, irrigation foremen had an important role. As a result of this coordination, an increase of $946,719 in net benefits was obtained by spending only $57,969.

A discussion of the need for irrigation foremen in irrigation projects, training of irrigation foremen, extension programs carried out by them, and the results of their work in Seyhan irrigation project, are presented in this paper.

*Assistant General Director of Soil Conservation and Farm Irrigation (TOPRAKSU), Ankara, Turkey.

I. Need for Intensified Extension Service in Irrigation Projects

Large investments are being made for construction of dams and canals to bring irrigation water to the farms. Similar investments are being made for land leveling and farm drainage to prepare the land for irrigation. In order to reduce the cost of irrigation projects, engineers all over the world are trying to find more economic means of constructing dams, canals and other irrigation structures. The possibility of maximizing the benefits of irrigation projects on the farm is generally overlooked.

Only a part of the anticipated benefits is realized by providing irrigation water to the farm and preparing the land for irrigation. Uniform application of irrigation water over the farm in an amount and at a time needed by the crops, proper seed bed preparation, use of good quality seeds and seedlings, proper use of fertilizers, proper cultivation, plant protection, harvesting, processing and marketing are some of the practices necessary to achieve maximum benefits. Some farmers may need loans or subsidies in order to apply proper irrigation and agricultural practices. Largely due to an insufficient capital market in developing

countries, farmers generally do not have enough operating cash. They usually cannot get enough loans and subsidies. Concentration of loans and subsidies in irrigation projects could relieve this situation. Many farmers are irrigating their lands and utilizing fertilizers, insecticides and pesticides. Improvements in yields and benefits can be achieved by providing proper know-how to the farmers through extension services.

Good irrigation can be defined as the controlled application of water to land in an amount, at a time, and with a uniformity needed by the crops to produce optimum yields, without excessive waste of water and soil and at a minimum cost. Several efficiencies related to irrigation are defined by Israelsen and Hansen (1). Among these are water application efficiency, water distribution efficiency, water storage efficiency and consumptive use efficiency. These are directly related to saving of water, expense on the farm and yields Method of irrigation, length of run, direction of irrigation, size of stream, duration of irrigation and timing should be properly determined in order to achieve higher irrigation efficiencies. G.L. Steed (2) reports that two inches of water was saved at each irrigation as a result of proper scheduling of irrigation over one million acres in Alberta, Canada.

In Turkey, irrigation efficiencies in operating irrigation projects are not accurately known, due to the lack of complete surveys or research on this subject. It is estimated that they are low. Surveys conducted in 1965 on 18 irrigation systems constructed by the state indicate the following: 73 per cent of the total irrigated land in these projects is irrigated by the wild flooding method, which results in very low irrigation efficiencies; 17 per cent is irrigated by the basin method; and 10 per cent is irrigated by the furrow method. Irrigation efficiencies in areas irrigated by the basin or furrow method are also quite low because the timing of irrigation, length of run, size of stream and duration of irrigation are generally not determined according to the needs of plants, soil and topographic conditions.

Approximately half of the total irrigable area in irrigation systems built by the state is actually irrigated, due to poor distribution systems, lack of land preparation, low irrigation efficiencies and untrained farmers. Methods of water delivery, water charges and other built-in factors also limit the maximum possible irrigation efficiencies. Improving these factors is not the subject of this paper. But irrigation efficiencies are far below the maximum possible under the existing built-in constraints. Large improvements can be accomplished by training the farmers.

In addition to these low irrigation efficiencies, improper ways of using fertilizers, insecticides and pesticides, and improper agricultural techniques have retarded the increase of yields in irrigation projects. An extension service is necessary to assist the improvement of irrigation and other agricultural practices. Extension related to irrigation is conducted by TOPRAKSU (General Directorate of Farm Irrigation and Soil Conservation). Extension concerned with plant protection is conducted by the General Directorate of Plant Protection. Research stations have conducted their extension through demonstrations and field days. The General Directorate of Extension Service of the Ministry of Agriculture provides extension assistance for all agricultural aspects. Due to the lack of coordination among these agencies, the farmers trained by each organization are often not the same. This one-sided know-how has not provided the expected benefits to the farmers. There is also the danger of different remedies being offered by different agencies for the same problem. An institutional change to consolidate the extension services may require a long time, and is likely to bring its own additional problems. It would be more appropriate to devise a system which would provide coordination among the related agencies to meet the immediate needs. Furthermore, such a system to be successful would have to be staffed with qualified personnel in sufficient numbers.

Extension services to the villages have largely been conducted by agricultural high school graduates and some university graduates, who visit the villages irregularly. Farmers are generally expected to come to the offices of related agencies in the towns or cities in order to get advice on their problems. This is because the number of extension technicians is not sufficient. There is only

one extension technician for every 2,000 farm families.

There are no extension workers living in villages and giving on-site suggestions. Under this condition, it is very difficult to motivate the farmers and train them in improved agricultural practices. There is also a large gap at the technical level between the extension specialists in the towns and the farmers in the villages. Extension workers of the foreman type, living in villages, are necessary in order to close this gap.

An intensified extension service was developed in the Seyhan irrigation project. It was to be the means of close cooperation among the agencies concerned with extension activities according to well-defined programs. It was also designed to close the technical gap between extension specialists and farmers. This system is briefly described in the section which follows.

II. Coordinated Extension Service in Seyhan Project

The Seyhan irrigation project lies on the Adana plain. It is part of a multi-purpose development scheme on the Seyhan river. This scheme includes the protection of 210,000 acres of land from floods, power generation of 60,000 kw. and irrigation of 420.000 acres. Construction of flood control works, a storage dam and a power plant with two 18,000 kw. units was completed in 1956. A third unit was added in 1964. The irrigation system was begun even before the construction of Seyhan reservoir. A concrete diversion dam was constructed on the Seyhan river in 1942. Some irrigation canals conducting water from this diversion dam were constructed before 1946. Only a small portion of Adana plain was irrigated prior to the construction of Seyhan reservoir. After the construction of Seyhan reservoir, this situation remained almost unchanged until 1963. Construction of additional canals and rehabilitation of old canals for irrigating one-third of the project area were completed between 1963-1968. Due to the lack of on-farm development work and proper extension services, yields were very low even in the irrigated portions of the project. For example, cotton yields in the irrigated areas were only 1,073 lb. per acre in 1962. Due to the use of improved varieties of seed and a gradual improvement of plant protection practices and agricultural techniques, this yield increased to an average of 1,547 lb. per acre in 1966. It was very difficult to increase this yield further with the uncoordinated and non-intensive extension activities of the different organizations. Extension service, plant protection service, research stations and TOPRAKSU were conducting their own programs. The local extension service was responsible for the Adana province, in which only a very small part of the Seyhan project lies. The local plant protection service and research stations were responsible for neighboring provinces as well as Adana. Their limited personnel could offer only a very limited and irregular service to the Seyhan project because their duties also covered areas outside the Seyhan project. They did not have extension workers at the village level to fill the gap between the technicians and the farmers.

TOPRAKSU established a local office for the Seyhan project. Irrigation foremen were employed to live and work in the villages, in an attempt to fill the gap between the technicians and the farmers. But their activities were inadequately programmed and were not coordinated with plant protection and other agricultural activities. Having a good irrigation extension service but inadequate plant protection and agricultural extension services resulted in only a slight increase in yields.

Because of this inadequacy a new system of extension was devised and implemented in 1967, with the hope that it would yield more satisfactory results. This new system consisted of a board of directors composed of the regional directors of TOPRAKSU, the extension service, the plant protection service, the research stations, the Agricultural Bank, the State Hydraulic Works, and farmers' organizations. This board provides guidance and supervision in the preparation and implementation of annual and long-term extension programs of the coordinated extension service. As shown in the organization chart (Figure 1), the regional offices of TOPRAKSU, the extension service, the plant protection service, and the agricultural research stations serving the project area assign

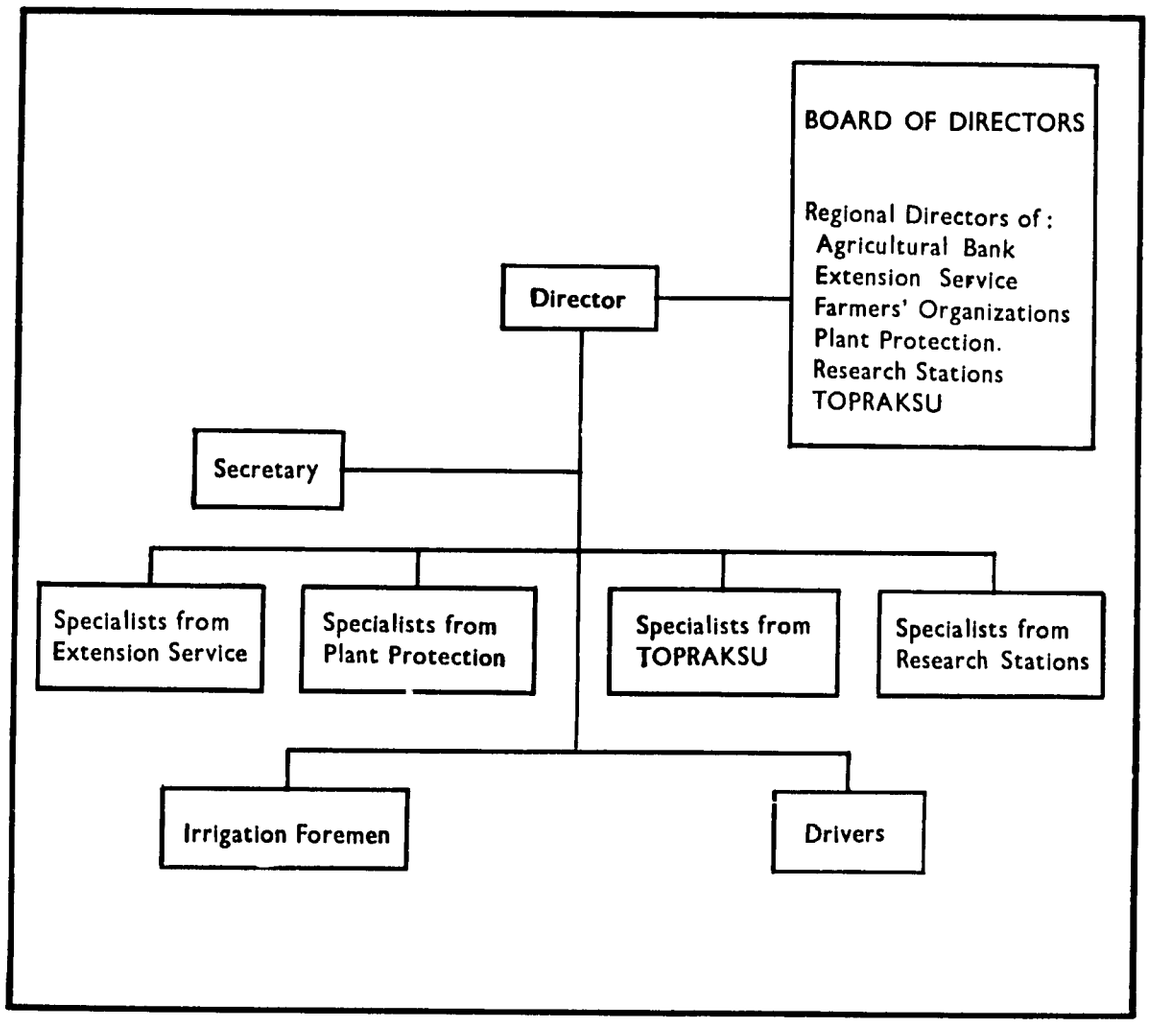

FIGURE 1. Organization of Coordinated Extension Service, Seyhan Irrigation Project

a number of their specialists to the joint body. One of these specialists is chosen as the director of this coordinated extension service. These specialists continue to be responsible to their parent organizations, from which they receive their salaries and with which they maintain close contact on all matters of a technical or professional nature. However, they work full time for the coordinated extension service and are responsible for training and supervising irrigation foremen located in the villages. Each village is provided with one irrigation foreman. Cars and drivers are provided to the specialists to assist their field work.

In the Seyhan project 99,000 acres of land were irrigated in 1966. The irrigated area will be increased to 247,000 hectares by 1972. It was very difficult to provide an immediate extension service with sufficient intensity to serve all of the irrigated area and all of the crops. It was decided to confine these activities during the first year to a portion of the irrigated area and to a major crop with the largest acreage. Cotton was the crop selected. As shown in Table 1, cotton was grown

TABLE I

Acreages of Irrigated Crops in Seyhan Project, 1966

CROP	IRRIGATED AREA	
	ACRES	PERCENTAGE
Cotton	95,117	96.20
Rice	2,984	3.02
Citrus	464	0.47
Melons and Watermelons	82	0.08
Grass	49	0.05
Vegetables	45	0.05
Fruit	37	0.04
Sesame	20	0.02
Forage Crops	17	0.02
Linseed (Flax Seed)	15	0.02
Gardens and Vineyards	17	0.02
Strawberry	3	0.01
Corn	3	0.01
Onion	3	0.01
Total Irrigated Area	98,856	100.00

on 96 per cent of the irrigated area in 1966. The extension activities in 1967 were concentrated on this crop. Concentration was achieved by limiting the number of villages and the number of farms in each village to be served. Only 23 out of 53 villages and only 20 farmers from each village were included in the 1967 extension program. The 1968 extension was expanded to include 43 villages and a total area of 50,000 hectares. Cereals, vegetables and livestock were added to cotton in 1968. Additional crops and other aspects of agriculture will be progressively included in this program, and the service area will be increased with time. The number of specialists, irrigation foremen and other personnel working for the coordinated extension service will also be increased progressively, as shown in Table 2.

It will not be necessary to increase the number of irrigation foremen after 1969. Continuous in-service training of foremen and the experience gained will enable them to include additional extension subjects, areas and farmers.

In this system of coordinated extension, each irrigation foreman lives and works in one village, preferably his own. Individual instruction, group instruction and mass instruction are provided to the farmers in this project area.

(A) INDIVIDUAL INSTRUCTION

Each irrigation foreman directly instructed a predetermined number of farmers (20 farmers in 1967) in his village. These 20 farmers were selected jointly by the irrigation foreman, extension specialist and village elder, with the agreement of the villagers. The irrigation foreman divided these 20 farmers into five groups of four each, and specified the days he would visit them, each in his own field. A weekly and monthly plan of operation for an irrigation foreman is presented in Fig 2.

The order of visits was set in advance for each week throughout the season, and every farmer could expect the irrigation foreman on the specified date. Notices were published in the villages indicating the names of the farmers and the date of the irrigation foreman's visit to their fields. The farmers were permitted to invite their neighbors to the individual instruction, an arrangement which gave every farmer an opportunity to obtain instruction in the field, even if at times it was only in his neighbor's field.

The irrigation foreman indicated the places and times where he could be found each day, so that interested farmers could readily find him and request special visits and/or information.

(B) GROUP INSTRUCTION

In every village, four evening lectures on cotton growing were given each month by the cotton specialist, the plant protection specialist or the irrigation specialist. The lectures were accompanied by the projection of slides showing the present growth of the cotton and the desired growth. In two of the villages model courses were conducted for farmers. These consisted of evening lectures presented each week by the specialists in accordance with a prepared program.

TABLE 2

Personnel Requirements for Coordinated Extension Programs in Seyhan Irrigation Project (1968-72)

Position of Personnel	Agency Supplying Personnel	Number of Personnel according to Year and Estimate of Irrigated Area				
		1968	1969	1970	1971	1972
		123,500 acres	158,000 acres	168,000 acres	227,000 acres	247,000 acres
Director						
Assistant Director	Chosen*	1	1	1	1	1
	Chosen**	—	—	1	1	1
Cotton and Cereal Specialists	Extension Service	2	3	3	3	3
Plant Protection Specialists	Plant Protection	2	3	3	3	3
Irrigation Specialists	TOPRAKSU	2	3	3	3	3
Information Specialist	Extension Service	1	1	1	1	1
Cotton Research Specialists	Research Station	1	1	1	1	1
Livestock Specialists	Extension Service	1	1	1	2	2
Fruit (citrus) Specialists	" "	—	1	1	1	1
Vegetable Specialists	" "	1	1	2	2	3
Forage Crop Specialists	" "	—	1	1	1	1
Farm Econom Specialists	Ext. Serv. or Ag. Bank	1	1	1	2	2
Farm Machinery Specialists	Extension Service	1	1	2	2	2
Irrigation Foremen	TOPRAKSU	43	50	50	50	50
Secretary	Direct Hire	1	1	1	1	1
Drivers	Extension Service	6	7	8	10	10

*Chosen by the board of directors from among the specialists.
**Chosen by the director and approved by the board of directors.

(C) MASS INSTRUCTION

The director of the coordinated extension service was responsible for publishing seasonal instructions for cotton growing and other subjects. This was done by means of posters exhibited in several places in each village and replaced by new ones every two or three weeks. These posters explained in words and pictures what was to be done in the fields during the forthcoming period. During the peak period of pest attacks, different varieties of pests were photographed in color and the methods of control were described. A five to ten-minute broadcast giving advice to the farmers in the project area was provided periodically by the local radio station.

III. Training of Irrigation Foremen

Irrigation foremen are the means of bridging the gap between the technicians and the farmers in the field. They should be accustomed to the farmer's living and working conditions. They should be old enough to influence the farmers and young enough to serve actively in the field. They should

WEEKLY PLAN

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Visit Group 1	Visit Group 2 (Visit by specialists while work with farmers in progress)	Course for foremen by specialists in Adana	Visit Group 3	Visit Group 4 (Visit by specialists while work with farmers in progress)	Visit Group 5

MONTHLY PLAN

July 1968	1	2	3	4	5	6	Sn.	8	9	10	11	12	13	Sn.	15	16	17	18	19	20	Sn.	22	23	24	25	26	27	Sn.	29	30	31
Individual instruction	X	X		X	X	X	—	X	X		X	X	X	—	X	X		X	X	X	—	X	X		X	X	X	—	X	X	
Course in Adana			X				—			X				—			X				—			X				—			X
Visit by specialists		X			X		—		X			X		—		X			X		—		X			X		—		X	
Group Instruction*	XX						—	XX						—	XX						—.	XX						—	XX		

* Weekly evening courses in two of the villages

FIGURE 2. Weekly and Monthly Operation Plan of One Irrigation Foreman

have a certain educational background and a level of intelligence to grasp the subjects they will be taught. They should be able to talk and communicate freely.

Irrigation foremen receive pre-service and in-service training. Pre-service training is given in TOPRAKSU's training center. Candidates from among the young farmers living in the project area are selected according to the foregoing criteria and the following qualifications :

(1) They must have been concerned with growing irrigated crops in the region for at least five years. Villagers are preferred.

(2) They must be graduates of primary schools. Graduates of high schools and vocational agricultural schools are preferred.

(3) They must have completed their military service.

(4) They must be between the ages of 25-40.

(5) They must be in good health.

(6) They must have passed a qualifying test. The pre-service course lasts one and a half months, during which lodging expenses are met by TOPRAKSU. The following subjects are taught:

Subject	Duration in Days
Orientation and general information about TOPRAKSU ..	1
Surveying with simple tools ..	4.5
Soils (horizons, texture, structure, land classes, plant nutrients in soil, methods of obtaining soil and water samples)	4
High water table, drainage, reclamation of saline and alkali soils ..	3.5
Agricultural techniques (crop varieties, selection of good seeds and seedlings, seed-bed preparation, planting, fertilizing, cultivation, crop rotation) ..	3.5
Plant-soil-water relationship and determination of time of irrigation	5.5
Obtaining, conveyance and distribution of irrigation water ..	2
Preparation of land for irrigation (land leveling, surface drainage for irrigation water, measuring and control structures) ..	2
Irrigation methods ..	2.5
Maintenance of irrigation tools and equipment ..	1
Organization (TOPRAKSU loans, TOPRAKSU cooperatives, relations of irrigation foremen with farmers and with TOPRAKSU, reporting) ..	2
Final examination ..	2
Holidays ..	7.5
Total ..	41.0

After employment, irrigation foremen are given in-service training in Adana for five hours each Wednesday during the growing season. In these weekly courses special topics about irrigation, plant protection or general agricultural techniques are discussed. The foremen are given definite duties for the coming week, and the weekly program schedules of the specialists and the schedule of night activities are explained. Pamphlets or brochures to be given to farmers are distributed. Questions from the foremen are answered by the specialists. Selected foremen provide the groups with information about current activities (such as field demonstrations, agricultural practices, farmers' opinions, etc.) in their particular village.

During the winter months when there were no field activities, foremen were given another in-service training course for one and a half months. Programs for this course were altered periodically, offering more and more advanced topics. The course content for the first year is presented below.

SUBJECT	DURATION IN HOURS
Farm economics ..	10
Methods of extension ...	15
Summary of previous season's activities ..	20
Plant physiology ..	20
Soils ..	50
Mathematics ..	10
Agricultural machinery and equipment ..	50
Plant protection ..	50
Instructions for the coming season ..	25
TOTAL ..	250

This type of continuous in-service training is required for the following reasons :

(1) The educational background of irrigation foremen does not equip them to attend an academic course of one or two years, and to preserve the knowledge they gain for use when it is needed later.

(2) Since most of the irrigation foremen are married and have families, their economic status does not permit them to attend a course of one or more years without a salary.

(3) There are no field activities during the winter months. This period was utilized beneficially to increase the knowledge of the irrigation foremen.

(4) The principle of "learn it just before using it" is more productive than the principle of "learn it, save it, and use it when and if you need it".

IV. Results

The total area in cotton in the 23 villages served by the coordinated extension program of Seyhan project amounts to 150,000 decares. The 424 cotton growers under the direct supervision of the coordinated extension service (maximum: 20 farmers per village) cultivated a total of 22,869 acres in 1966. and 23,423 acres in 1967. Average yields in the 23 villages are shown in Table 3. The overall average per acre was 1,547.5 lbs. in 1966 and increased to 1,967.9 lbs. in 1967—the result of the coordinated extension service and the irrigation foremen's work. No increase in yield from 1966 to 1967 was observed in villages outside the coordinated extension program.

In 1968, the coordinated extension program served 123,500 acres in the Seyhan project. Cotton harvesting is not complete. But it is estimated from the initial results and the growth stage of cotton that the average yield in this area will be approximately 2,450 lbs. per acre.

In addition to these direct benefits, the new system of extension has resulted in several side benefits :

(1) Improved irrigation practices are saving water, soil and labor.

(2) Improved plant protection is saving pesticides, insecticides and labor.

(3) The quality of the crop has improved.

TABLE 3

Average Cotton Yields in Villages Served by the Coordinated Extension Service in Seyhan Irrigation Project

VILLAGE	COTTON GROWERS	1966 AREA (ACRES)	1966 YIELD (LBS/ACRE)	1967 AREA (ACRES)	1967 YIELD (LBS/ACRE)
Alifakl	20	1177.7	921.3	995.2	1449.1
Badras	20	1747.0	1619.1	1573.0	2468.8
Ballica	20	780.8	1672.7	779.8	1771.1
Baltali	19	999.9	1377.5	1160.4	1815.8
Cicekli	20	1740.1	2030.5	2161.3	2012.6
Gerdan	20	453.2	1878.5	966.3	2459.9
Hacibozen	20	627.9	2120.0	627.9	2298.9
Karacercili	14	1267.4	1994.7	704.0	1502.8
Kargili	20	707.4	1976.9	785.7	2137.9
Karsavuran	20	977.6	1601.2	1027.0	1869.5
Mahmutaga	20	878.3	2182.6	931.7	2030.5
Nemiroglu	20	1247.4	1762.2	1247.4	1923.2
Resadiye	18	949.7	1100.2	857.1	1511.7
Simithacili	18	628.4	1744.3	685.2	1878.5
Tiznik	20	993.7	1225.5	912.2	1538.5
Yuksek	20	649.9	1153.9	706.9	1252.3
Zubeyir	19	789.7	1225.5	657.8	1744.3
Gokceli	15	1294.8	1449.1	1241.7	1887.4
Kayarli	11	1672.2	1118.1	2005.6	1726.4
Dogankent	20	687.2	1645.9	930.7	2075.2
Sazak	20	988.0	1520.7	1021.3	2057.4
Yuzbasi	14	261.8	1368.6	259.6	1699.6
Zagarli	16	1350.3	1279.1	1185.1	2862.4
TOTAL	424	22869.4		23422.9	
AVERAGE			1547.5		1967.9

(4) Problems related to irrigation, plant protection, fertilizing, cultivation, harvesting and marketing are recognized immediately. This is a result of constant observation of agricultural activities in the field, and necessary corrective measures being taken without delay.

(5) The irrigation foreman helps to motivate the farmer to improve his farm, provides accurate statistics for villages, informs the farmers about the procedures for obtaining loans from the Agricultural Bank, helps the farmers to maintain land leveling and drainage, and serves as a bridge between government agencies and the farmers on all other aspects of agriculture.

These direct and side benefits have cost money. Expenses of the coordinated extension service in the Seyhan project for 1967 are presented in Table 4.

TABLE 4

Seyhan Irrigation Project—Expenses of Coordinated Extension Service in 1967

ITEM	EXPENSES TURKISH LIRE	EXPENSES DOLLAR EQUIV.
Salaries		
5 specialists	188,141	20,905
23 foremen	194,810	21,646
3 drivers	27,960	3,107
SUB-TOTAL	410,911	45,658
Operating Expenses		
Gas and oil for 3 pick-ups	25,250	2,806
Tires for 3 pick-ups	4,500	500
Repairs for 3 pick-ups	9,000	1,000
Specialists' travel expenses	24,500	2,722
Office expenses	10,000	1,111
Audio-visual equipment and brochures	1,250	139
SUB-TOTAL	74,500	8,278
Amortization		
for 3 pick-ups	32,300	3,589
for audio-visual equipment	4,000	444
SUB-TOTAL	36,200	4,022
TOTAL	521,711	57,969

The economic analysis is as follows:

	WITHOUT C.E.S.	WITH C.E.S.
Gross income (1)	$4,196,431	$5,336,302
Cost of production (2)	2,897,659	2,897,659
Cost of picking (3) ..	543,720	691,410
Cost of extension service ..	—	57,969
Net income ..	755,052	1,689,264

(1) 23,423 acres × 1967.9 lbs./acre = 46,094,122 lbs. = 23,047 tons
23,047 tons × $231.54/ton = $5,336,302
Similarly:
23,423 × 1547.5 × $231.54/2000 = $ 4,196,431.

(2) 23,423 acres × $123.71/acre = $2,897,659.
The cost of production covers: rent, fertilizer, stalk-shredding, plowing, harrowing, smoothing, planting, seed, cultivation, thinning, water, irrigation, labor, making furrows and plant protection. These do not change with the change in yield.

(3) 18,124 tons × $30/ton = $543,720
23,047 tons × $30/ton = $691,410
Cost of picking covers: gin transportation, packing, harvest labor, labor supervision and field watchmen. These costs are directly proportional to the yield.

The benefit-cost ratio of the coordinated extension service in 1967, according to these figures, works out at:

$$(1{,}689{,}264 - 755{,}052) \div 57{,}969 = 16.1$$

The actual ratio is higher because the cost of extension service in this area prior to the new system has not been included in the economic analysis. Encouraged by these results, TOPRAKSU is trying to increase the number of irrigation foremen and to use the same method in other irrigation projects.

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Chapter VI
FARM MANAGEMENT FOR IRRIGATION PRACTICES

SOIL MOISTURE AS RELATED TO IRRIGATION

by
M. Formali*

Abstract

A general study of the soils of South Tarnak revealed that the newly cultivated desert land has a very poor internal drainage. The porosity of the soil is such that water will stand on the surface for long periods without penetrating beyond the upper twelve inches of the soil profile, resulting in damage to many crops.

Appraisal of South Tarnak's Land

Reconnaissance surveys conducted first by MKA and later by Joseph Mir of the Bureau of Reclamation suggested that the tract of South Tarnak's land presently under cultivation would be suitable for agriculture. Both surveys were only of a reconnaissance nature, requiring a detailed study of the delineated land to be undertaken prior to land development. It was unfortunate, however, that circumstances required the speedy development of that land without the blessing of a detailed land classification.

The land after development remained idle until 1966, with the exception of Block 1 (the poorest part of the farm) which was put in alfalfa in 1963. The alfalfa stand was very weak during the first year but improved slowly and steadily. It was plowed under for wheat, together with the rest of the land, in the fall of 1966.

The wheat stand looked good-to-very-good in the spring of 1967, but the final yield did not match the stand of early spring. To investigate scientifically the cause of the discrepancy between good vegetative stand and poor grain yield, a study was undertaken when the first seeded corn plants were 24 inches tall (August 15, 1968). The analysis of the first batch of samples indicated a general moisture deficiency to a depth of 42 inches at one site and 24 inches at another. These findings

* Head, Project Development Planning, HAVA.

are summarized in Table 1.

As the time and facilities were not sufficient, available moisture is estimated to be one-half of saturation percentage; also, the wilting percentage is interpolated to be one-quarter of the saturation percentage. These are generally accepted interpolations for broad studies of this nature.

An analysis of Table 1 indicates that 28 hours after irrigation the plants (corn) were under a high moisture stress that should not be allowed except at the ripening stage. Various studies indicate that wheat and corn should be supplied with an abundance of moisture, amounting to not less than 50 per cent of the available water, during their vegetative growth and until the seed

TABLE I

Moisture Content as Related to Irrigation at South Tarnak

	1	2	3	4	5	6	7
Location and Site	Soil Depth (inches)	Moisture Percentage 28 hrs. after Irrigation	Wilting Percentage	Moisture Equivalent	Saturation Percentage	Water Available to Plants	Soil Texture
Block 3B Upper one-third	0-6	8.4	8.9	17.8	35.6	none	SL
	6-12	9.0	10.1	20.3	40.7	none	SL
	12-18	15.0	12.9	25.8	51.7	none	SCL
	18-24	17.0	13.95	27.9	53.8	none	SCL
	24-30	14.5	11.8	23.6	47.2	none	SCL
	30-36	12.0	13.4	26.9	53.8	none	SCL
	36-42	13.0	13.9	27.8	55.4	none	SCL
Block 3B Lower one-third	0-6	14.0	10.4	20.7	41.4	little	SL
	6-12	16.5	11.6	23.1	46.2	little	SCL
	12-18	16.5	13.0	26.0	52.0	little	SCL
	18-24	12.0	14.4	28.7	57.4	none	SCL

is well formed. (Soil-Plant Relationships, p. 80; and Irrigation of Agricultural Lands, p. 580). To meet this condition, these soils, as referred to in column 2, Table 1, should have around 13.4 per cent, 15.2 per cent, 19.4 per cent moisture, corresponding to depths of 0-6, 6-12 and 12-18 inches. This moisture content should exist to a depth of three feet or more to favor root development throughout the three-foot root zone, because in the absence of available water, plant roots will not make a significant growth.

Soil moisture deficiency in South Tarnak is restricting root growth and confining it to the permeable top one-foot layer of the soil. This was observed by exposing the roots of a healthy corn

plant. Almost all its roots were in the first 10-12 inches of the soil, while normally and under favorable conditions they should have been within the range of 36-48 inches. This shows that due to the lack of moisture at lower depths, the plants failed to develop and extend their roots to the proper depths.

> "Any stratum which limits root growth reduces top growth accordingly, since for most species of plants, a rather definite relation exists between root and top growth. In addition to the direct root-volume limitations imposed by shallow soils, the water and air volumes are also limited. Since the total pore volume is limited, shallow soils are droughty in dry weather and easily saturated in wet periods. There are, therefore, in most climatic areas, only short intermittent intervals of favorable moisture conditions. Because of the wide fluctuation in moisture, the temperature will change rapidly and widely." (Soil Physical Condition and Plant Growth, page 57.)

Plants (wheat/corn) grown in South Tarnak can therefore obtain the nutrients and moisture from the first 12 inches of the soil only. This situation calls for heavy application of fertilizer and timely irrigation, leading to higher costs of production.

As we work with shallow depth, nutrients and water control become a delicate matter, especially water management. Negligence of a proper water regime can drastically reduce grain yield; shortage of water not only reduces crop yield but also minimizes the good effects of fertilizers.

The studies of other sites in South Tarnak also reveal the existence of a general moisture shortage in the first 12 inches, which is a layer of water-absorbing sandy loam, and a severe shortage of moisture below 12 inches, which is compacted sandy clay loam (Table 2). These shortages can be relieved, where possible, by a lower rate of water application than is presently practiced. A small head or a thin sheet of water flowing on the surface of the border irrigated land for about 12 hours will permit sufficient water to enter the soil for one irrigation. Changing irrigation practices, however, may remedy water problems but will cause land deterioration. Studies of other sites than those described in Table 1 disclose an unfortunate soil condition of compactness that does not permit water to penetrate.

Experimental results shown in Table 2 reveal that a 10-hour ponding and a 40-hour ponding of water at the northeast corner of Block 3A did not change the original water contents of the second foot layer of the soil at all, indicating that adequate water to support plant growth cannot penetrate the sandy clay loam zone of the soil. This may not be true with all of the land, but the indications are that a large portion of the land may be suffering from this lack of internal drainage. The lack of internal drainage will make it impossible to leach the soils, so that the constant addition of salts from (1) soil decomposition, (2) irrigation deposition and (3) capillary movement upward will eventually make the land of South Tarnak saline, or worse yet, alkaline, producing a red stop light for plant growth.

At present there is fortunately an ideal chemical condition prevailing in South Tarnak. In reference to Table 3, pHs are acceptable, salinity level is below that of saline soils (ECs = 4000 micromhos for saline soils), and the percentage of sodium, the trouble-making metallic ion, is a long way from making the land alkaline. Lime percentages are high but not high enough to cause chlorosis and yet favor alfalfa growth.

Water of the Arghandab river reaching South Tarnak is also luckily very good water, having an electrical conductivity of 240 micromhos at the South Tarnak farm, as compared with 320 micromhos for Helmand water. However, it is unfortunate to have such good water used on land that requires much to bring it to the productivity level of the average land under the water command of the Arghandab river. Even this water of high quality, applied at a rate of five feet per year for a double crop, will add 2,119.7 lbs. of salts to each acre every year. As the internal drainage does not permit leaching, the salt build-up from the water source alone will make South Tarnak saline within five years. (Agr. Handbook No. 60.)

TABLE 2

Moisture Content as Related to Duration of Irrigation, South Tarnak

Field Description	1	2	3	4	5	6
	Depth (inches)	Percentage Moisture, Hours after Normal Irrigation			Saturation Percentage	Remarks
		28 hrs.	52 hrs.	72 hrs.		
Block 3E, Plot 6, 1/3 down the field where good crop stand starts	0-12	14.0	14.2	13.42	32.0	10"-11" of top soil is SL
	12-24	15.48	14.67	15.1	70.3	11"-20" is SCL
						At 20" gravelly SCL (compacted)
Block 3A, Plot 1, Road Corner	24 HOURS AFTER IRRIGATION					
	0-12	15.6			58.8	
	12-24	15.3			74.8	
Block 3A, Plot 1, Road Corner	14 HOURS AFTER 10-HOUR ADDITIONAL IRRIGATION ABOVE NORMAL					
	0-12	17.1			56.6	
	12-24	14.6			78.5	
	SAMPLE AFTER 40 HOURS OF BASIN PONDING WHERE GROUND SURFACE WAS SATURATED					
	12-24	15.1			70.4	

Once a tight land such as South Tarnak becomes saline, it will be next to impossible to reclaim it. It will have to be abandoned. In order to avoid salinization of South Tarnak, which will be inevitable under present conditions, it would be necessary to loosen the soil and make it permeable. This process cannot be accomplished by mechanical ripping of the land, for the land will close up again. Besides, a drainage barrier layer will remain at a depth of three feet (the depth of ripping), preventing water percolation and causing salt accumulation. The loosening process can best be accomplished by plant roots penetrating to a depth of three feet or more. This can be performed by the roots of alfalfa, which already has proven its capability to penetrate the worst part of the South Tarnak farmland (Block 1) to a depth of two feet or more.

If the land is put in alfalfa and watered at

intervals determined by moisture-indicating instruments (tensiometers, gypsum blocks, plant indicators, etc.), saving the plants from coping with moisture stress before each irrigation. alfalfa should be able to produce lush growth in the calcareous soils of South Tarnak. As the plants grow strong, tap roots will penetrate the soil and grow in diameter. Upon the plant's foliage detachment and death, the roots will decay and leave behind numerous small channels for water percolation in the soil. These channels will not close up, because the tilth of the soil would be improved through structural development of the soil particles caused by the cementing action of the microbial gum and secretions. As the soils open up, percolating water—an absolute necessity for desert soils—will wash the harmful salts down the profile and out into the drains. Air, a must for root development, can enter the lower depths of the root zone. Water shortage at the lower depths will no longer be damaging. Microbial activities will increase productivity of the soil. In brief, a happy medium for better crops will be produced by the loosening and structural development of the land.

TABLE 3

Soil Chemical Condition at South Tarnak (Block 3B)

Soil Depth	pH	ECs/ mmhos	Lime (%)	ESP	Texture	Percentage Separate		
						Sand	Silt	Clay
0-6	8.3	330	11.32	Tr	SL	63.2	18.0	18.8
6-12	8.3	400	13.24	0.05	SL	61.2	20.0	18.8
12-18	8.3	470	13.37	2.40	SCL	55.2	23.0	22.8
18-24	8.4	410	15.33	0.08	SCL	49.2	26.0	24.8
24-30	8.5	400	16.74	0.65	SCL	49.2	26.0	24.8
30-36	8.6	400	14.78	0.90	SCL	53.2	20.0	26.8
36-42	8.5	460	13.69	2.70	SCL	51.2	20.0	28.8
0-6	8.3	630	12.37	0.15	SL	59.2	22.0	18.8
6-12	8.3	630	13.15	0.20	SCL	55.2	22.0	22.8
12-18	8.5	430	13.51	1.15	SCL	45.2	28.0	26.8
18-24	8.5	350	13.10	2.00	SCL	48.2	27.0	24.8

Summary

Salinity level of about 0.4 millimhos, acidity of pH 8.3, and a very low sodium content, matched with the sandy loam texture of the surface twelve inches and sandy clay loam texture of the rest of the soil profile, make the newly developed land very good agriculturally. But the physical make-up of this land is such that soil structure rectification is required as a first priority.

Literature Review

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2. Irrigation of Agricultural Lands. Monograph No. 11. Agronomy. A.S.A.
3. Irrigation Principles and Practices, O.W. Israelsen and V. E. Hansen
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SURVEY AND DEVELOPMENT OF GROUND WATER RESOURCES AND INTEGRATION WITH SURFACE WATER RESOURCES

Introduction

In a country like Ceylon, where there is a good distribution of rainfall over a major part of the land, it may seem strange that proposals should be made to investigate for ground water. The fact is that part of the rainfall that goes into deep percolation is lost to the sea through underground aquifers. The increase of population would finally find this country short of surface waters, and with this in mind investigations were begun to assess the total ground water potential.

Further, there are certain areas in northwest Ceylon with a very uneven distribution of rainfall. This is illustrated in Map I. There are about 4 to 5 months of continuous dry spells, with about 10 inches (254 mm) of rainfall during the entire period. Though rainfall during the rest of the year is satisfactory, there is no facility for storing the water in surface reservoirs. Due to the flatness of the land and the high permeability of the soils, it is uneconomical to impound water in surface reservoirs. However, the soil in this region is of red latasol group, which is highly suited for agriculture. This area was therefore selected for the first phase of investigation.

Ground water has been exploited on a very small scale in north Ceylon, which has a very karstic limestone formation underlying an earth cover of 10 feet to 20 feet in depth. In these areas shallow hand-dug wells supply water both for agricultural and domestic needs. This area is about 340 square miles in extent, and the population depends solely on this ground water for agricultural and domestic needs. Small scale exploitation is being done by private individuals by means of small hand-dug wells in the alluvial and lateritic formations to supply domestic needs in other parts.

In 1965 an organization in the Department of Irrigation was formed to make a systematic investigation to assess the ground water potential in selected areas, with a view to extend these investigations to other areas. The area selected for this purpose is the miocene limestone area in northwest Ceylon. This formation covers over 800 square miles, which is about 4 per cent of the total land area of Ceylon (Map II).

Geology and Water Bearing Formations

The general geology of Ceylon has been mapped from surface geological indications by the Geological Survey department (Map II). This map describes the classifications according to ages. The following water-bearing formations exist :

(1) Fractured quartzites, gneisses and crystalline limestone occur in the central zones of the island. Precipitation finds its way through fissures, and issues as springs through the exposed fractured areas. These are not general conditions, but there are springs that yield from 50-100,000 gallons per day.

(2) *Laterite.* The laterite capping varies from 20-40 feet in thickness and overlies biotite

gneisses. Permanent streams seldom occur in laterite areas. Water is contained in these formations, and the water level oscillates from 20 feet to 10 feet. Hand-dug wells in these areas give a yield of 1200 gallons per hour.

(3) *Post-Pleistocene Gravel* formations occur in thicknesses varying from 8 feet to 50 feet. These can be developed to give good supplies of water. Test pumping has yielded about 22,000 gallons per day. The Puttalam town supply is derived from such formation, with a series of wells which yield 2 million gallons per day.

(4) *Alluvium*. These vary in depth up to 100 feet, and sometimes clay layers intervene causing sub-artesian conditions.

(5) *Dune Sands* are found on the coast, except in the southwest, and vary in depth from 20 feet to 50 feet. Small supplies of water are found in these formations, and the town of Hambantota derives its supply from such a system.

(6) *Miocene Limestone* occurs in northwest Ceylon and to a small extent in the southeast. This formation is coarse grained and in certain sections vary karstic. The thickness varies from a few feet to about 200 feet. This sedimentary formation has been investigated in a part of northwest Ceylon. It occurs in a wedge-like formation, thin towards the east where it meets the basement complex, and thickening towards the west where it meets the sea. The specific yield and transmissivity vary due to the sizes of the solution caverns. This is dealt with in detail in another section.

Investigation

The Department of Irrigation formed a separate branch to investigate the ground water potential of certain areas with a view to expanding its project area. The branch was formed in 1965 with engineers, hydrogeologists, technical assistants, drilling superintendents and drilling crews. Foreign experts were obtained, Ceylon counterparts were attached to them and investigations commenced. The data available with the Geological Survey department was also used in the final evaluation.

Equipment had to be obtained from abroad. I included: Failing convertible W-1 Holemaster well-rig for use both as rotary and percussion; Joy Sullivan diamond core drill; electric well logger; McPhar electric resistivity apparatus; water quality testing equipment; water samplers; drill pumps; deep well turbine pumps and casing, with supporting equipment such as water dowsers, welding units, rock bits and drilling mud.

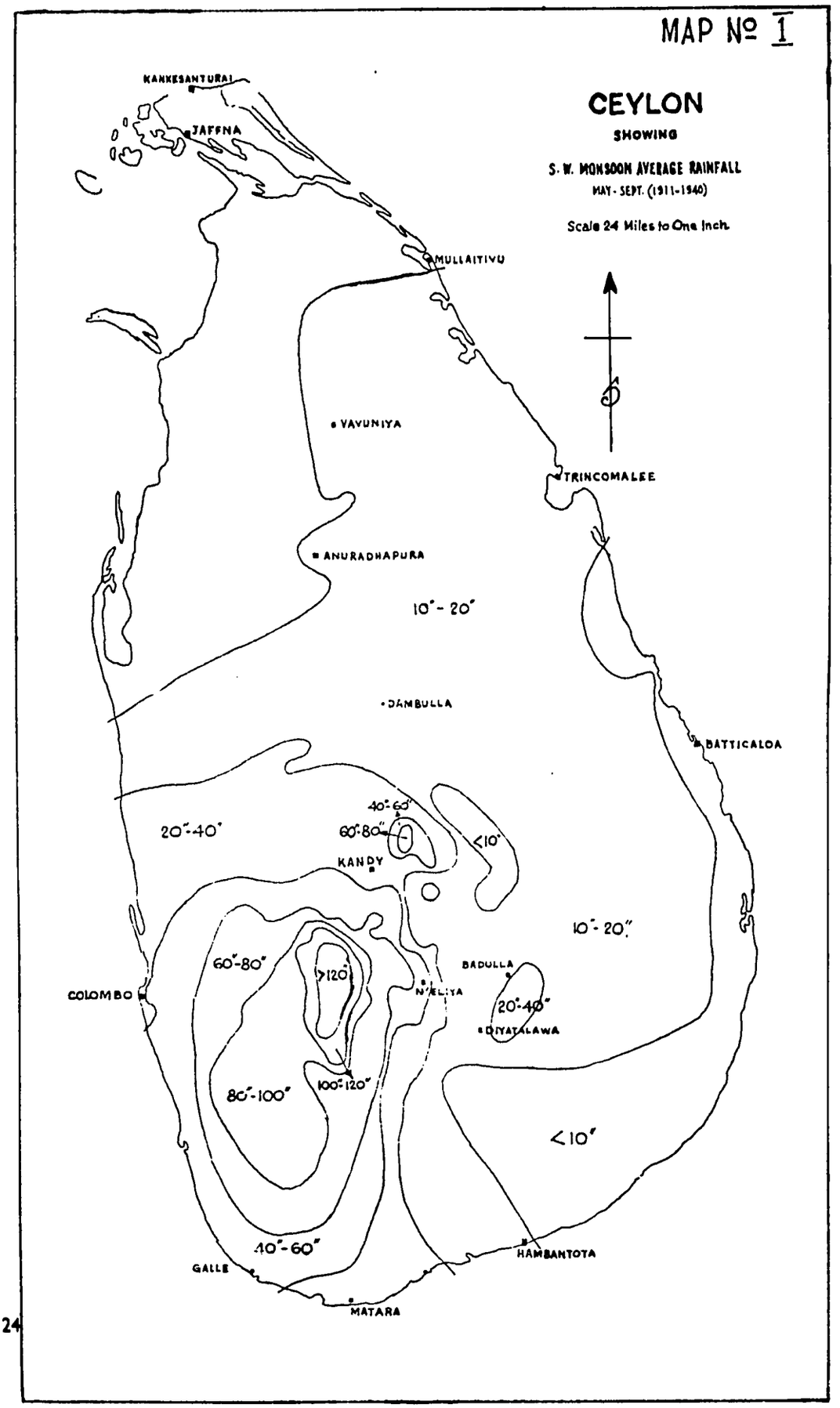
The drilling sites were chosen to enable the study of the stratigraphy of a large area with minimum drill holes.

Project Area

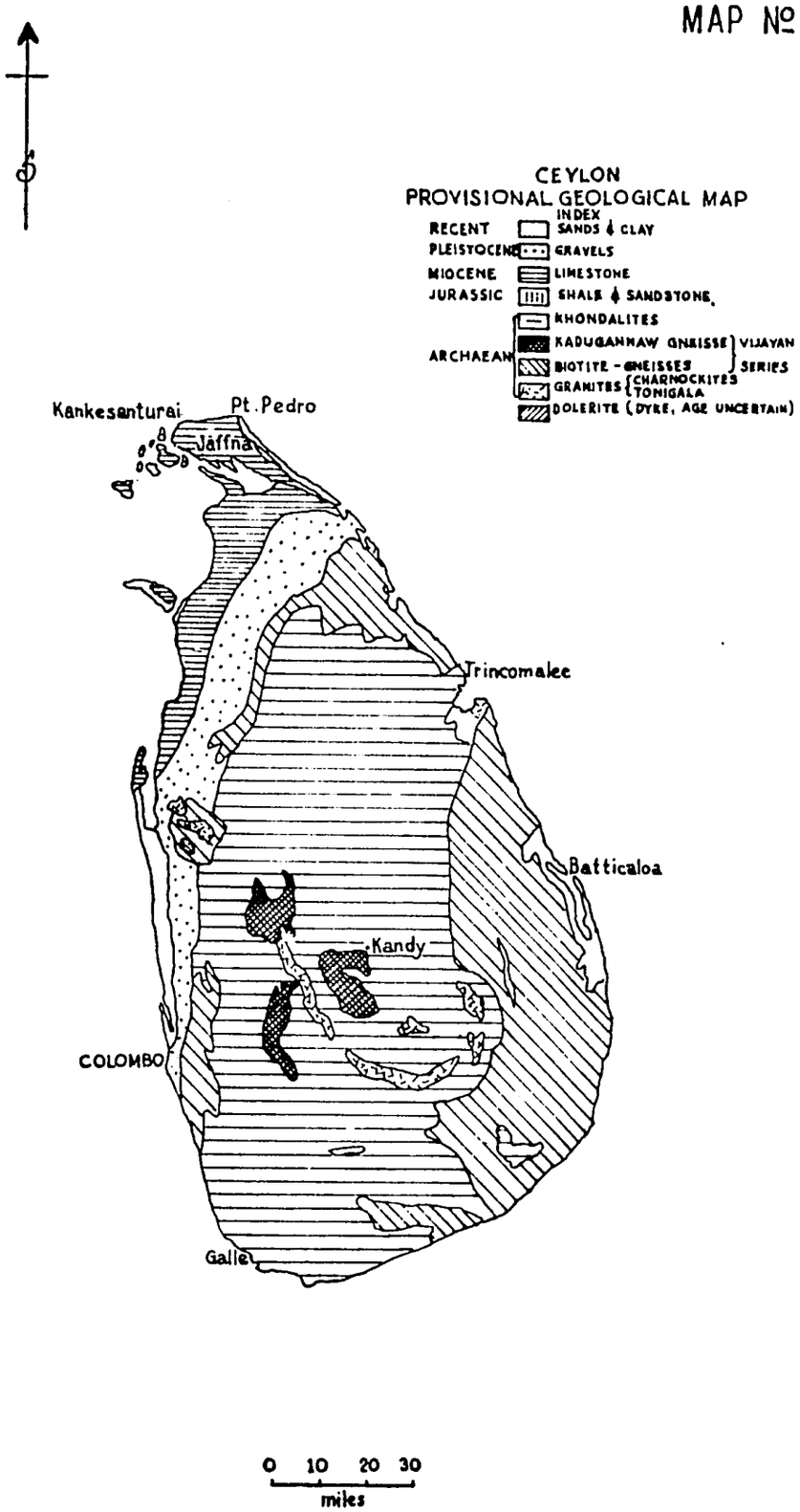
The first stage of investigation was the northwestern zone described in Map III. The drill holes are marked as P1, P2, etc., and GS1, GS2, etc. The "P" prefixes indicate holes drilled by the Irrigation department, and the "GS" prefixes those drilled by the Geological Survey department. The investigations and pumping tests revealed that the general formation of the overlying rocks did not follow a regular pattern of dip. Several geoelectrical and magnetic techniques indicated that there were faults and fractures intersecting the basement complex extending from the surface to the subsurface. Map III indicates this area along the western zone.

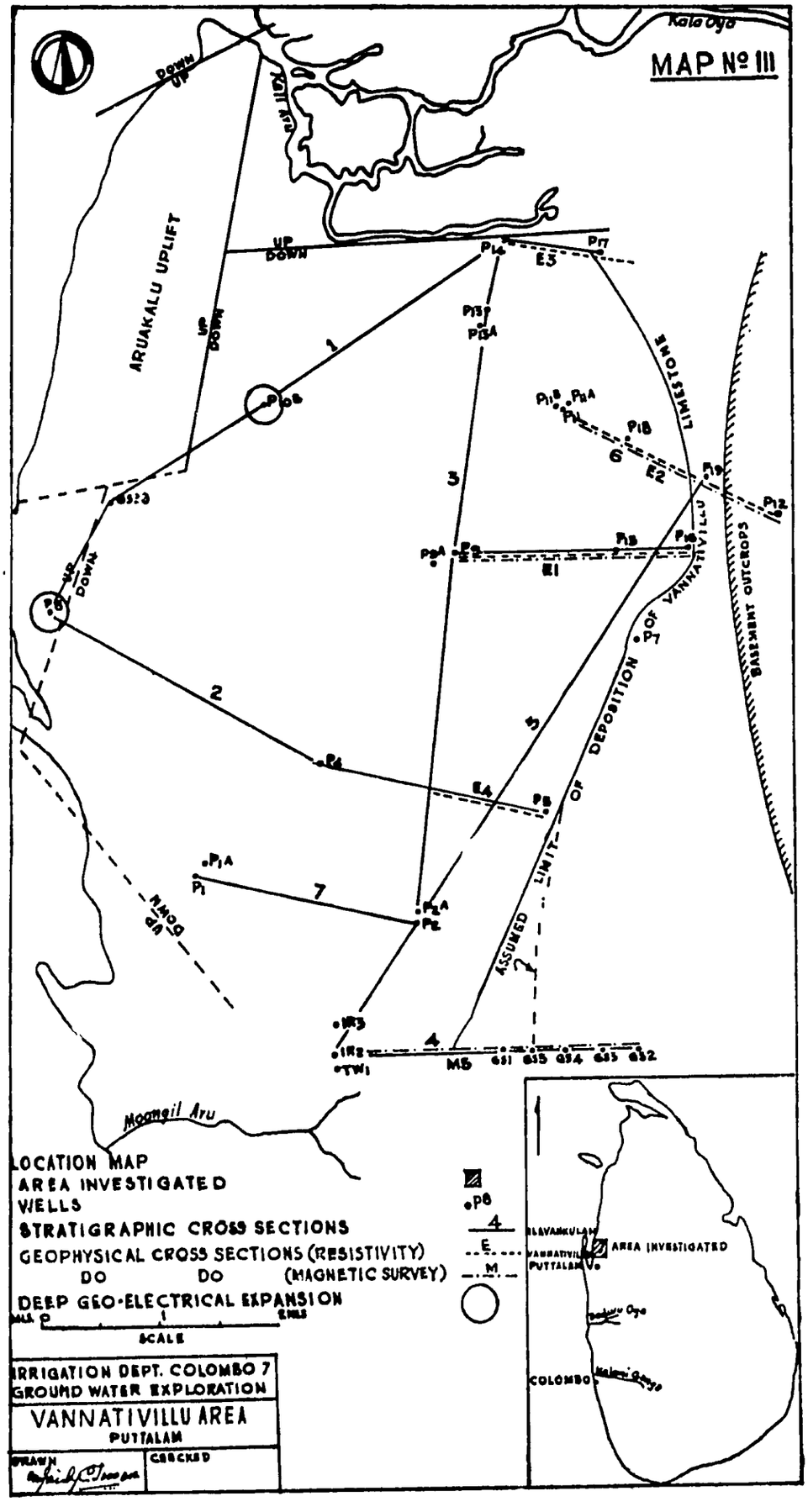
Hydrogeology

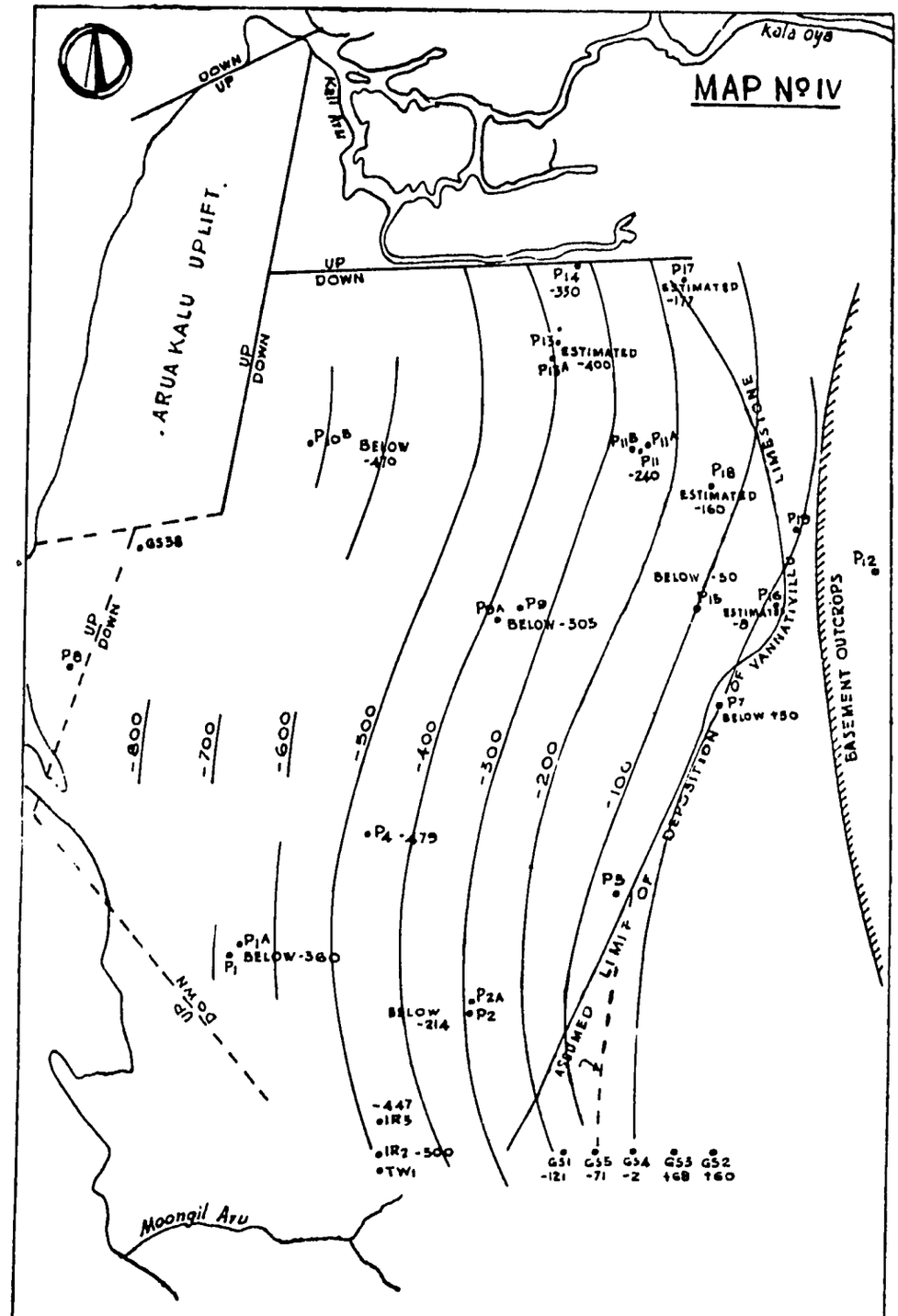
Map IV, based on drilling results and evaluation, indicates the final basement configuration. The basement surface is shown dipping west at 200 feet per mile. The trace of the contours is slightly sinusoidal. The drill hole data indicated that from the surface to the basement there are three types of formations : the alluvial cover; the Moongilaru formation; and the Vannathivillu limestone formation with Mannar sandstone formations. All are very good aquifers. There is a very distinct difference between the Moongilaru formation and the Vannathivillu farmation, but there are doubts regarding the Vannathivillu and the Mannar formations. It has, however, been interpreted as one unit to determine the aquifer thickness. The combined thickness of the Mannar and Vannathivillu formations exceeds 275 feet.


MAP № 1
CEYLON
SHOWING
S. W. MONSOON AVERAGE RAINFALL
MAY - SEPT. (1911-1940)
Scale 24 Miles to One Inch
KANKESANTURAI
JAFFNA
MULLAITIVU
VAVUNIYA
TRINCOMALEE
ANURADHAPURA
10"- 20"
DAMBULLA
BATTICALOA
40"-60"
60"-80"
20"-40"
<10"
KANDY
10"- 20"
60"-80"
>120"
BADULLA
COLOMBO
N'ELIYA
20"-40"
DIYATALAWA
100"-120"
80"-100"
<10"
40"-60"
HAMBANTOTA
GALLE
MATARA

MAP № II


CEYLON
PROVISIONAL GEOLOGICAL MAP
INDEX
RECENT
SANDS & CLAY
PLEISTOCENE
GRAVELS
MIOCENE
LIMESTONE
JURASSIC
SHALE & SANDSTONE
ARCHAEAN
KHONDALITES
KADUGANNAW GNEISSE
BIOTITE - GNEISSES
VIJAYAN SERIES
GRANITES
CHARNOCKITES
TONIGALA
DOLERITE (DYKE, AGE UNCERTAIN)
Kankesanturai
Pt. Pedro
Jaffna
Trincomalee
Batticaloa
Kandy
COLOMBO
Galle
0 10 20 30
miles


MAP No III
Kala Oya
ARUAKALU UPLIFT
LIMESTONE
BASEMENT OUTCROPS
LIMIT OF DEPOSITION OF VANNATIVILLU
ASSUMED
Moongil Aru
UP
DOWN
LOCATION MAP
AREA INVESTIGATED
WELLS
STRATIGRAPHIC CROSS SECTIONS
GEOPHYSICAL CROSS SECTIONS (RESISTIVITY)
DO DO (MAGNETIC SURVEY)
DEEP GEO-ELECTRICAL EXPANSION
SCALE
AREA INVESTIGATED
PUTTALAM
COLOMBO
IRRIGATION DEPT. COLOMBO 7
GROUND WATER EXPLORATION
VANNATIVILLU AREA
PUTTALAM
DRAWN
CHECKED



BASEMENT CONFIGURATION
—IN—
SUBSURFACE

MLS 0 1 2 MLS
SCALE

IRRIGATION DEPT COLOMBO 7 GROUND WATER EXPLORATION	
VANNATIVILLU AREA PUTTALAM	
DRAWN	CHECKED

BASED ON RESULTS AND EXTRAPOLATION OF DRILLING GEO-ELECTRICAL AND MAGNETIC OBSERVATIONS.
FAULT PATTERN INFERRED FROM AEREAL PHOTOGRAPHS AND SUBSURFACE STRATIGRAPHY BASED ON DRILLING
INTERPRETATION BY RON HANRECK

The sequence of the formation to the basement complex is as follows:

(1) *Alluvial Cover Composed of Sands, Soils and Laterites.* This is a porous medium which conducts water to the Moongilaru formation.

(2) *Moongilaru Formation* underlies the alluvial cover, and is composed of marine sediments with clays, coarse and medium grained sands and sandstones. This formation has a uniform thickening westwards, with rather a broad section running north-south hinging near P 9. This broad section indicates highly porous sediments capable of directly contributing to the recharge of Vannathivillu limestone. This formation is a good aquifer in itself, and tests carried out gave a transmissivity of 5.76×10^3 gallons/dy/ft. This will be investigated after studying the behavior of the underlying aquifer. (Vannathivillu—Mannar sandstones).

(3) *Combined Vannathivillu-Mannar Formation.* This formation underlies the Moongilaru formation and is referred to as one unit for reasons mentioned above. For a major section of this formation, there is a confining layer between the Moongilaru and this formation. This has been improved in view of the semi-artesian conditions observed in the drill holes, and also from the drill cuttings. During pumping tests, the behavior of the aquifer in certain tubewells confirms the leakage from the upper aquifer. This is discussed later. Map V indicates the structural contours on the upper surface of limestone. This formation shows a steady decline westwards, and shows clearly the assumed eastern limit of the deposition (Map V). The wedge-shaped areas north and south of P 16, in which the limestone was not deposited, contain thick masses of sands and sandstones, which form important regions of ground water recharge to the Vannathivillu limestone.

The piezometric surface of ground water in Vannathivillu limestone slopes gently north, as described in Map VI.

Geohydrology

From the investigation it was found that there were three distinct aquifers in this region : (a) surface soil and alluvium, including minor limestone; (b) Moongilaru formation; (c) Vannathivillu and Mannar formations.

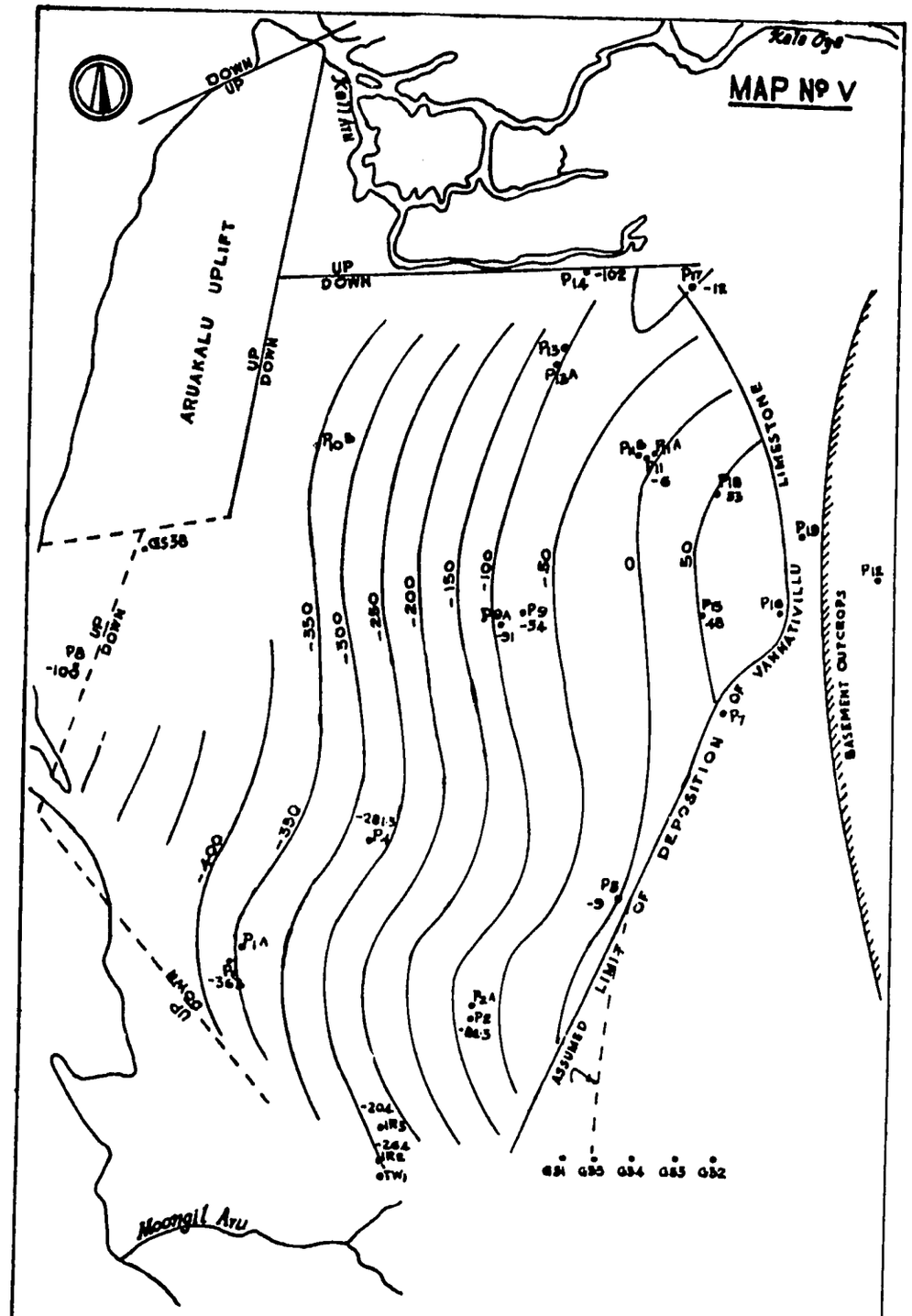
Alluvium Formation. Although this is a highly permeable formation there are perched horizons that retain water. Water is not available in large quantities, and as such, small hand-dug wells exist in this area. The water quality in this area varies widely and is of high salinity.

Moongilaru Formation consists of about 66 per cent sand, 30 per cent shale and the balance limestone. The shaly intercalations, though lenticular, act as confining media in some parts. This is an extensive aquifer, about 3.4 million acre-feet in volume. The effective porosity of the formation is 10 per cent, thus the water held in storage is 0.34 million acre-feet. The entire formation is saturated, and the level of saturation varies from +30 mean sea level in the east to +15 in the northwest. There is vertical percolation from this aquifer, and observations made near P2, P9 and P13 indicate that the vertical percolation near P2 is 0.05 gallons/day/ft.^{2}, and near P9 and P13 is 0.88 gallons/day/ft.^{2} The differential head over the Vannathivillu formation is 4 feet in the south, 1.6 feet in the area between P9 and P13, and −2 feet in the north.

Vannathivillu. This aquifer is of dense limestone for the top 30 or 40 feet, and very karstic limestone at about 50 to 60 feet. Underlying this is Mannar sandstone which is very porous. Pumping tests carried out in the wells indicated a strong isotropism in the variation of transmissivity and increases sharply northwards, rather than a westerly dip. It was also found that loss of circulation was heavy in the lower reaches of the Vannathivillu formation, which confirms the high karstic nature of the lower reaches. It has to be confirmed that the artesian nature of the Vannathivillu aquifer is due to the presence of the clayey members in the lower Moongilaru formation and the upper Vannathivillu denser limestone, which gives rise to the leaky aquifer.

Pumping Tests and Ground Water Flow

Test pumping conducted in all wells was

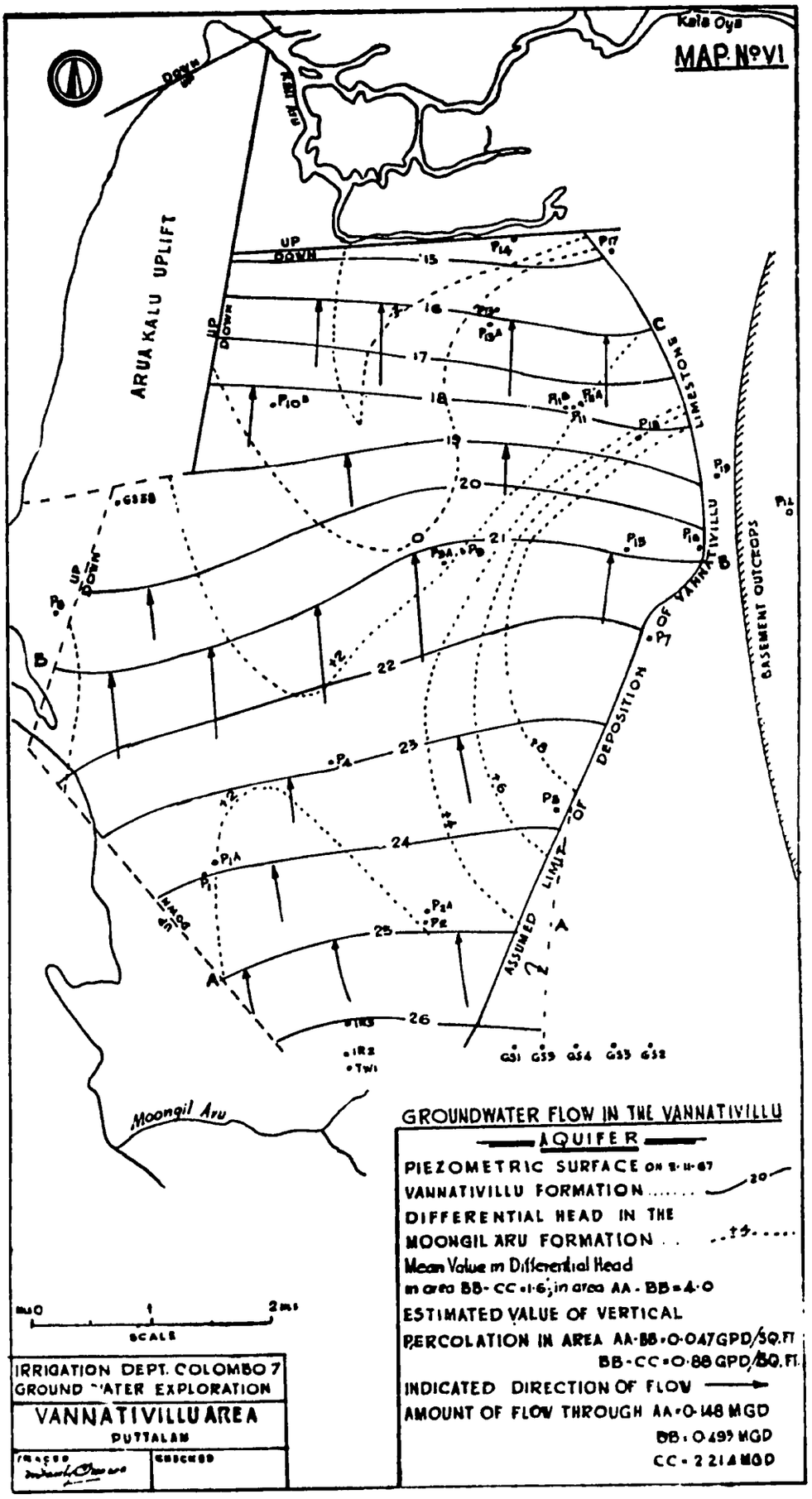


STRUCTURAL CONTOURS ON UPPER SURFACE OF VANNATIVILLU LIMESTONE FORMATION

MILS. 0 1 2 MILS.
SCALE

IRRIGATION DEPT. COLOMBO 7 GROUND WATER EXPLORATION	
VANNATIVILLU AREA PUTTALAM	
TRACED	CHECKED

INTERPRETATION BY RON HANRECK


MAP No VI
Kala Oya
ARUA KALU UPLIFT
UP
DOWN
LIMESTONE
VANNATIVILLU
BASEMENT OUTCROPS
DEPOSITION
OF
ASSUMED LIMIT
Moongil Aru
GROUNDWATER FLOW IN THE VANNATIVILLU AQUIFER
PIEZOMETRIC SURFACE ON 2-11-67
VANNATIVILLU FORMATION
DIFFERENTIAL HEAD IN THE MOONGIL ARU FORMATION
Mean Value in Differential Head in area BB-CC = 1·6; in area AA-BB = 4·0
ESTIMATED VALUE OF VERTICAL PERCOLATION IN AREA AA-BB = 0·047 GPD/SQ.FT
BB-CC = 0·88 GPD/SQ.FT.
INDICATED DIRECTION OF FLOW
AMOUNT OF FLOW THROUGH AA = 0·148 MGD
BB = 0·495 MGD
CC = 2·214 MGD
SCALE
IRRIGATION DEPT. COLOMBO 7
GROUND WATER EXPLORATION
VANNATIVILLU AREA
PUTTALAM
TRACED
CHECKED

evaluated by the Theis nonequilibrium method, the Theis recovery method and Jacobs modification. The nonequilibrium method gave the most consistent results. This equation is expressed as

$$S = \sqrt{\frac{1.87r^2s}{Tt}}$$

where

S = drawdown or recovery in feet
T = coefficient of transmissibility of the aquifer in gallons per day per foot
r = distance in feet from the pumped well to the observation well
s = coefficient of storage of the aquifer
t = time in days that the well has been pumped

The equation is applicable when (*a*) the aquifer is infinite in extent; (*b*) it is homogeneous; (*c*) its transmissibility is the same in all places; (*d*) it is confined; and (*e*) the coefficient of storage is constant.

The above formula can also be expressed as

$$S = \frac{114.60}{T} W(u) \quad \text{when } u = \frac{1.87r^2 s}{Tt}$$

to plot the well function curve to determine the T+S values.

The other method used was Jacobs modification to check on the values obtained by the Theis method.

From results obtained the usual graph was drawn and a peculiar phenomenon was observed. There was always a break in the smoothness of the curve instead of a uniform gradient. The time drawdown curve when plotted for P2 and P9 wells also indicated a break, indicating recharge boundary being reached about 1 hour and 20 hours respectively after the pumping started. This gives rise to the opinion that there is leakage from the Moongilaru formation. The ground water flow net analysis as described in Map VI shows that under the natural differential head, Vannathivillu formation receives recharge from Moongilaru formation. Thus, under pumping conditions, a larger quantity of water will leak into it. Quantitative analysis to this effect has not yet been completed.

Ground Water Potential

The total volume of the Vannathivillu formation is 6.4 million acre-feet, which should contain about 0.64 million acre-feet at a porosity of 10 per cent. This is the amount stored, but extraction can only be the quantity that goes into recharge every year. There is about 4,000 acres of sandy formation that comes into direct contact with the Vannathivillu formation. This formation is assumed as the area, and assuming a percolation of 15 inches from rainfall, we have about 5,000 acre-feet of water going into storage from recharge.

As discussed earlier, there is leakage occurring from the Moongilaru formation as direct percolation through the alluvial deposits to the Vannathivillu formation. Assuming a percolation of 1 acre-foot and the area being 12,000 acres, we have 12,000 acre-feet as an additional contribution to the storage. It has still not been assessed how much exactly would be available to the Vannathivillu formation. Therefore, of the total actual potential of 17,000 acre-feet, only 5,000 acre-feet will be extracted for the present from the Vannathivillu formation.

The direction of flow in a formation that is isotropic is easily determined from the piezometric levels. The Vannathivillu formation presents a problem, however, as it is anisotropic and possesses very high secondary porosity. Studies made from periodic checks on the piezometric levels and pumping tests indicate a northerly direction of flow (see Map VI). This may seem strange in view of the westerly direction of the dip, but it has been confirmed by the transmissivity values in wells P2, P9 and P13 which increase in a northerly direction.

To confirm the northerly direction of flow, geomorphological studies of river mouths in Ceylon were made which indicate that they have

buried channels a few hundred feet below the surface. A geoelectric traverse, run along the Kalaru in the northern boundary, confirms the presence of erosion channels. During the dry season, when there is no flow from the catchment of the Kalaru, the stagnant water in the stream showed a chloride content far below that in other parts. This also indicated leakages from the aquifer at these points, thus confirming a northerly direction of flow.

Studies were made to assess the normal flow through the aquifer without pumping. For this, static water levels in 20 wells were taken and the equipotential lines were drawn perpendicular to the lines of flow (see Map VI). The transmissivity values of two wells were used to calculate the discharge by using the formula :

$$Q = TIL$$

where

Q = discharge in gals/day
T = coefficient of transmissivity in gals/dy/ft.
I = hydraulic gradient in ft/mile
L = average width of flow channel in miles.

Flow Across Section	T (gals/dy/ft.)	I (ft/mile)	L (miles)	Q (gals/dy)
A—A	3.96×10^4	1.33	2.8	148,000
B—B	5.97×10^4	1.48	5.6	495,000
C—C	2.30×10^5	2.50	3.85	2,214,000

These sections are indicated in Map VI. The total annual flow is 3,000 acre-feet through the Vannathivillu formation reaching the sea .A similar amount should flow through the Moongilaru formation. This figure of 3,000 acre-feet is lower than the estimated recharge of 5,000 acre-feet as discussed earlier.

Well Grid System

The total quantity of water available for extraction from the Vannathivillu formation is 5,000 acre-feet per year. It was decided that water would be required for crop use for only 150 days of the year (5 months). Pumps of 300 gallons per minute capacity were selected and the final number of wells to be drilled was decided. In order to satisfy these conditions, it was found that 19 wells provided the suitable limit to balance with the recharge of 5,000 acre-feet of water.

The behavior of this well-grid system when the wells are in full production was predicted to find the final drawdown. The net drawdown was worked out from the formulae :

$$T = \frac{264\ Q}{h} \quad \& \quad S = \frac{0.3\ T\ to}{r^2}$$

where

T = coefficient of transmissivity in gals/dy/ft.
Q = discharge in gals/mt.
h = drawdown difference in ft. per log cycle of time
S = storage coefficient
to = time intercept on zero drawdown axis
r = distance in feet from discharging well to observation well.

Quality of Water

The water quality varies and behaves in the same way as the direction of flow of recharge. The chloride content increases as we go northwards. The quality, however, is quite suited for agricultural crops. The chloride content varies from 50 ppm. to 800 ppm. The final well spacing was decided on the basis of extracting more of the low chloride content water. The cause of variation in quality has not been analyzed yet.

Development

It was decided that of the total potential, only 5,000 acre-feet of water that goes into annual recharge be considered for extraction during the first phase of development. The extent covered by this water-bearing formation is 12,000 acres, of which approximately 10,000 acres are suited for agriculture. These lands had already been alienated for non-irrigated crops, so that distribution had to be made to provide some water to each allottee. Based on a duty of 4 acre-feet

of water per acre for both chillies and onions, it was found possible to command only about 1,000 acres. It was therefore decided that 10 per cent of each allotment would be provided with ground water until further investigations are carried out in the Moongilaru formation. Till then, the balance of 90 per cent would be cultivated with non-irrigated crops.

The ground water obtained from this area has proved to be very expensive; the total cost to government is U.S. $0.10 per 1,000 gallons. This includes the drilling, overhead, operation and maintenance costs. Since the government was keen to benefit from the water available, it was decided to charge $ 0.07 per 1,000 gallons for the present. The distribution is by pressure pipe lines supplying metered water at the head of each allotment. This is the first time such a system has been introduced in Ceylon. The conditions of the water issue are given in Appendix I.

Water Requirements for Crops

There is hardly any data on the consumptive use of water for chillies and onions. However, for design of the distribution system these values were necessary. Using Blaney-Criddle formulae and the meteorological data on sunshine hours, temperatures and rainfall, the monthly requirement was worked out. Diagram X gives the monthly requirements for chillies, onions and paddy. From this the daily requirement was obtained to design the distribution system and determine the pumping hours.

Diagram XI shows the pumping hours during the different periods of the crop growing season, the maximum rate of pumping being fixed at 300 gallons per minute and pumping not to exceed 14 hours per day. At this rate, it is expected that about 40 to 45 acres can be provided with irrigation water from each well.

Distribution System

Lands had been parceled and the allotments made before the ground water potential was investigated. When the well system was decided on, it was found that a well at a lower level had to supply water to a higher level. This was also limited by the minimum distance for spacing wells in order to prevent interference of well flows. Map IX illustrates a typical layout plan for a settlement of 10-acre units.

Evaluation of Water Costs

The area irrigated in each allotment is 1.25 acres for the first crop and one-third of this for the next crop. Thus, there will be two crops cultivated during this period: chillies and onions. A well provides irrigation for 44 acres. Assumed life period of the project is 30 years, with pump and well replacement taking place after 15 years.

	COSTS	$ (U.S.)
(1)	Construction cost of irrigation works: $\frac{800 \times 44}{30}$ ..	1,174.00
(2)	Replacement cost of well, pump and pump house at 15th. year ..	333.00
(3)	6% interest on items (1) & (2) ..	90.42
(4)	Wages of pump attendant @ $34 per month ..	408.00
(5)	Wages of watcher @ $30 per month ..	360.00
(6)	Wages of control & issue workman @ $30 per month ..	360.00
(7)	Cost of diesel @ 22 cents per gallon for 3,210 gallons ..	406.20
(8)	Cost of lubricants @ 10 per cent of (7) ..	40.62
(9)	Cost of running repairs @ 10 per cent of (7) + (8) ..	44.68
(10)	Cost of maintenance of pipes ..	100.00
(11)	Overtime to pump operator ..	100.00
	Total cost of pumping 32.4×10^6 gallons to cultivate the 44 acres ..	3,416.92

$$\text{Cost of 1000 gallons} = \frac{341692}{32.4 \times 10^6} \times 1000 \text{ cents}$$

$$= 10.5 \text{ cents, say, 10 cents}$$

The drilling and supplying of water, inclusive of distribution, is controlled by the government. It has been found that if no check is made on the

IRRIGATION REQUIREMENTS FOR CROPS

PUTTALAM

Temperatures - Puttalam Met: Station
Sunshine Hours - Mahailupallama "
BLANEY-CRIDDLE

MONTH	Temp °F	P in %	Rainfall in Inches	Effective Rain 80%	f in Inches	PADDY - MAHA (Growing Season - 15/11 to 31/3) U=1·0f	R	U-R	i in Inches 90%	Final i	PADDY - YALA (Growing Season - 1/5 to 15/9) U=1·0f	R	U-R	i in Inches 50%	Final i	CHILLIES-5½ MTHS. (Growing Season - 1/1 to 15/6) U=0·7f	R	U-R	i 70%	Final i	RED ONIONS-3 MTHS. (Growing Season - 1/7 to 15/9) U=0·7f	R	U-R	i 70%	Final i	CITRUS (Full Year) U=0·55	R	U-R	i 70%	Final i
OCT:	86·4	6·38	7·04	5·6	5·5	–	–	–	–	4·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3·02	5·6	–	–	–
NOV:	85·8	6·75	9·22	7·35	5·8	2·9	4·61	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3·22	7·35	–	–	–
DEC:	84·9	8·20	6·73	5·40	6·95	6·95	5·40	1·55	3·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3·85	5·4	–	–	–
JAN:	85·7	7·80	3·72	2·90	6·80	6·80	2·90	3·90	7·8	5·5	–	–	–	–	–	4·8	2·9	1·9	2·7	1·5	–	–	–	–	–	3·78	2·9	0·89	1·27	1·30
FEB:	88·3	9·25	1·17	1·42	8·15	8·15	1·42	6·73	13·50	12·50	–	–	–	–	–	5·7	1·42	4·3	6·2	7·0	–	–	–	–	–	4·50	1·42	3·10	4·40	4·40
MARCH	90·1	9·40	2·93	2·34	8·50	8·50	2·34	6·16	12·30	12·00	–	–	–	–	–	5·95	2·34	3·6	5·2	5·0	–	–	–	–	–	4·70	2·34	2·36	3·40	3·40
APRIL	89·5	9·40	3·98	3·20	8·40	–	–	–	–	–	–	–	–	–	12·0	5·90	3·20	2·7	3·9	3·0	–	–	–	–	–	4·67	3·20	1·50	2·15	2·20
MAY	88·4	8·45	2·60	2·10	7·46	–	–	–	–	–	7·46	2·10	5·36	10·7	13·0	5·30	2·10	3·1	4·5	6·5	–	–	–	–	–	4·13	2·10	2·00	2·86	2·90
JUNE	86·7	7·45	0·70	0·56	6·46	–	–	–	–	–	6·46	0·56	5·90	11·8	13·5	4·50	0·56	4·5/2 2·25 15 days	3·2	4·0	–	–	–	–	–	3·60	0·56	3·10	4·40	4·40
JULY	86·4	8·75	0·40	0·32	7·55	–	–	–	–	–	7·55	0·32	7·23	14·5	13·0	–	–	–	–	–	5·30	0·32	5·0	7·10	7·00	4·20	0·32	4·00	5·70	5·70
AUG:	86·8	7·85	0·30	0·24	6·80	–	–	–	–	–	6·80	0·24	6·56	13·1	14·5	–	–	–	–	–	4·76	0·24	4·5	6·40	8·00	3·77	0·24	3·53	5·05	5·10
SEPT:	87·3	10·02	1·40	1·10	8·70	–	–	–	–	–	4·35	0·55	3·80	7·6	6·0	–	–	–	–	–	6·10	1·10	5·0	7·10	3·00	4·82	1·10	3·72	5·30	5·30
		100%	40·19						36·70	42·00				57·70	72·00				25·7	27·00				20·60	18·00				34·53	34·70

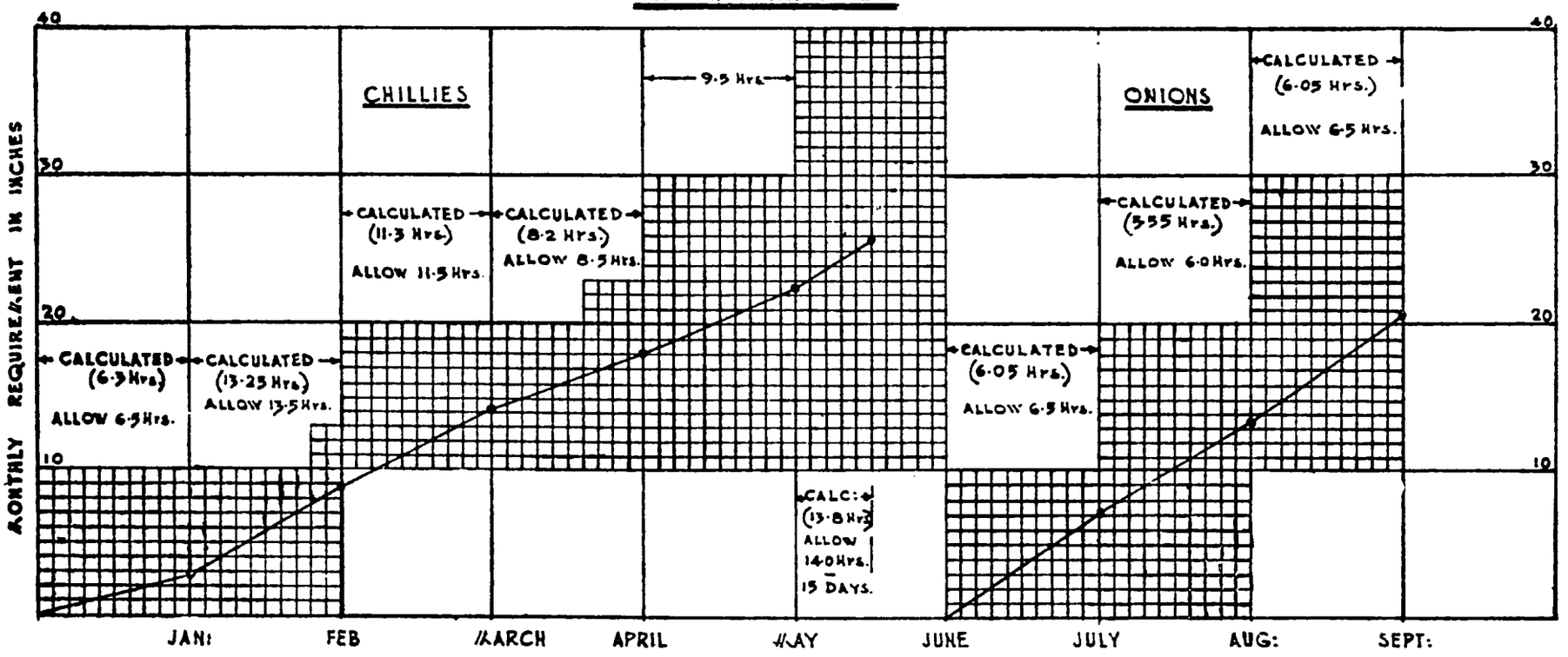
P = Percentage sunshine hours
R = Effective rainfall
U = Kf where K is constant varying for each crop {1·0 - For Paddy; 0·7 - For chillies & onions; 0·55 - For Citrus}

Final i = Present Irrigated amount

DIAG X

DIAG XI

PUMPING SHEDULE FOR CULTIVATION OF CHILLIES & ONIONS FROM TUBE WELLS AT VANNATHIVILLU

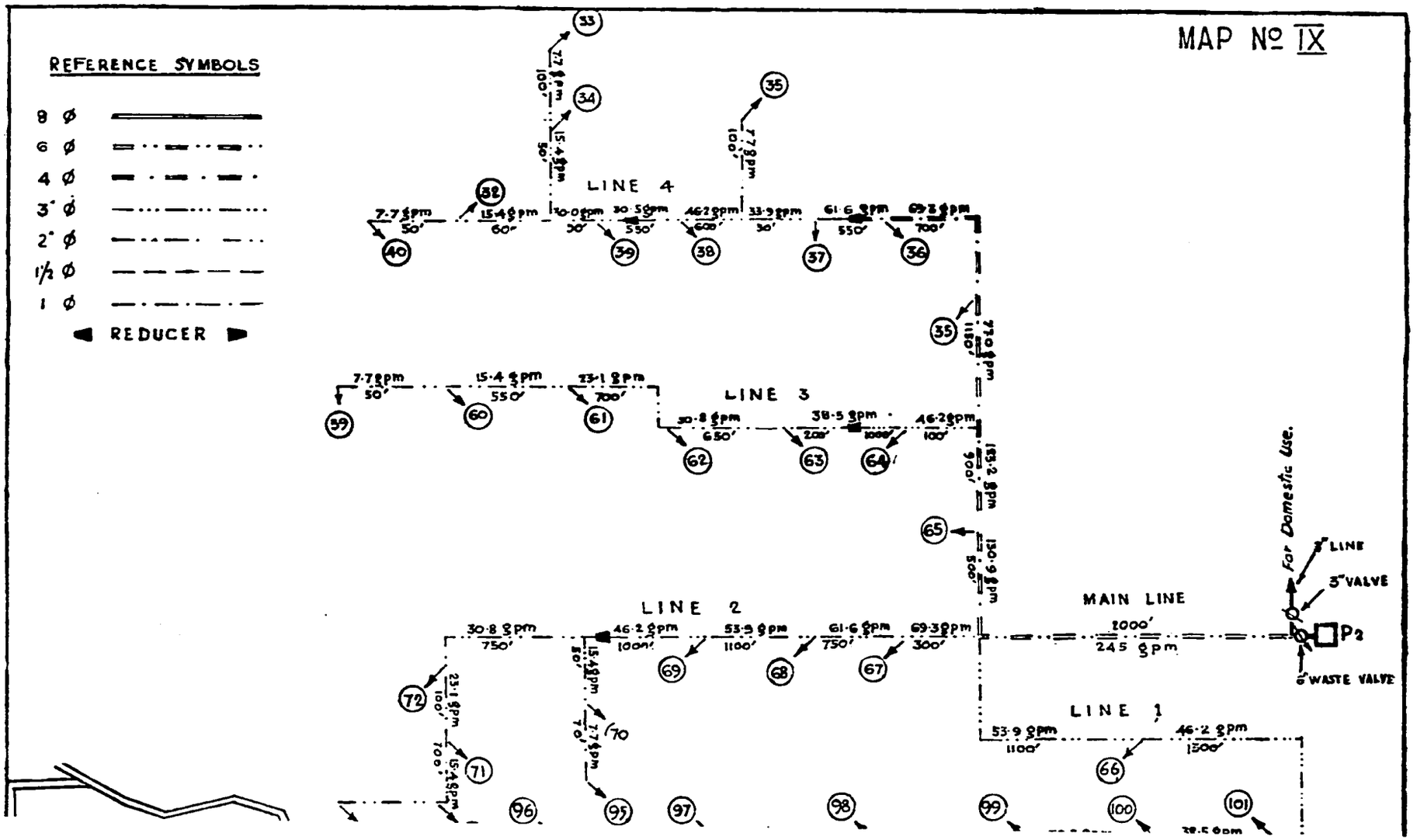


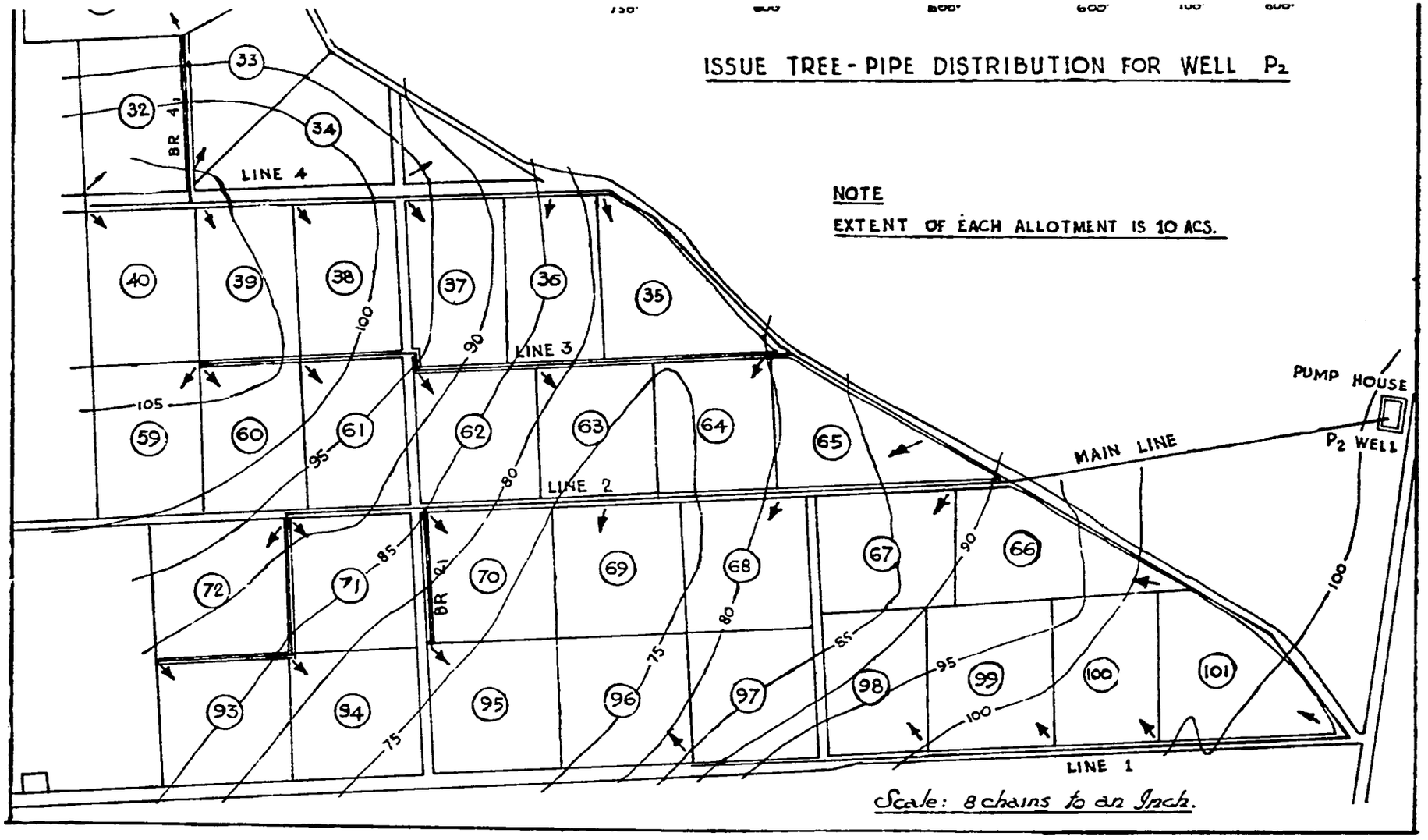
NOTE : PUMPAGE HAS BEEN WORKED OUT FOR A CONTINUOS PUMPING SCHEDULE FOR 300 G.P.M.

THE ACREAGE CULTIVATED WILL BE 50 ACRES CHILLIES.
17 ACRES (20 ACRES) ONIONS

WHEN CAPACITY OF PUMP IS DOUBLED THE COMMANDABLE ACREAGE HAS TO BE DOUBLED OR IRRIGATION TIME HALVED.

16


MAP Nº IX
REFERENCE SYMBOLS
8 Ø
6 Ø
4 Ø
3" Ø
2" Ø
1½ Ø
1 Ø
REDUCER
LINE 4
LINE 3
LINE 2
LINE 1
MAIN LINE
2000'
245 gpm
P2
For Domestic Use.
3" LINE
3" VALVE
6" WASTE VALVE


ISSUE TREE-PIPE DISTRIBUTION FOR WELL P2
NOTE
EXTENT OF EACH ALLOTMENT IS 10 ACS.
LINE 4
LINE 3
LINE 2
LINE 1
BR 41
BR 21
MAIN LINE
PUMP HOUSE
P2 WELL
32
33
34
35
36
37
38
39
40
59
60
61
62
63
64
65
66
67
68
69
70
71
72
93
94
95
96
97
98
99
100
101
105
100
95
90
85
80
75
Scale: 8 chains to an Inch.

extraction, then overmining of water may take place, leading to infiltration of sea water in the aquifer. Water to cultivate one acre is supplied by means of a globe valve and the allottee receives the water at the highest point in his allotment for cultivation. The method of irrigation for the crops will be either by means of furrows or basins.

The pumping system will function as a direct issue from the pump to the distribution lines. An overhead tank has been avoided to cut down on costs. Since these pumps are driven by diesel engines there will be no case of power failure affecting the system, and therefore temporary storage is considered unnecessary in the preliminary stage.

The distribution lines are all high pressure P.V.C. pipes which are buried 2 feet below the ground. The minimum size of pipes used is of 1½-inch diameter, and at the delivery point there will be an available head of 2 feet of water to aid flushing of any sediments in the pipes. Open lined canals have been avoided, even in sections where there is falling topography, to avoid evaporation losses. For the convenience of measuring the flow, a water meter has been provided instead of any other means. When once the water potential of the Moongilaru formation has been assessed, it is proposed to link that system to the present distribution system. However, the wells planned in the first stage of development will not be linked to each other in view of the high cost of pipe lines.

The system of distribution (Map IX) costs approximately $35,000, of which the different components are :

		$ (U.S.)
(1)	Well drilling and pump	.. 10,000.00
(2)	Distribution system with valves & meters	.. 22,000.00
(3)	Access to pump site (road)	.. 1,000.00
(4)	Overheads	.. 2,000.00
		35,000.00

This will be the cost of providing irrigation facilities for 44 acres. Therefore the initial outlay for one acre is $800.00

Irrigation with Surface Water Sources

The recharge boundary, as discussed earlier, is a few miles away from the aquifer itself. Under normal circumstances, precipitation will be the only factor for recharge. Proposals for extending canals from surface water schemes up to the periphery of these areas are underway. These canals are to be used as irrigation canals, and any percolation from them and from the irrigated areas will go into deep percolation to contribute to the recharge of the aquifer. In the northern area of the limestone formation, there are already irrigation canals that can substantially contribute to the recharge of the aquifer. This will be considered when working out the water potential in that area.

Summary

Rainfall over the island of Ceylon is unevenly distributed in the dry zone, with about 10 inches of rainfall from May to September and 50 inches from October to April. There are distinct wet and dry zones covering 6,000 and 19,000 square miles respectively. The dry zone, 19,000 square miles in extent, has surface reservoirs along a major portion of it. This major portion consists of pleistocene and archean formations. A smaller part of about 800 square miles consists of miocene limestone formation, which presents a problem for the construction of surface reservoirs.

The general geology of Ceylon has been mapped and a provisional geological map of the whole island is available. Detailed geological surveys of localized areas, with a view to prospecting for minerals, dam foundation work and ground water studies, have been done and these maps are also available. However, maps were not available for the areas where ground water existed. Therefore, a systematic investigation of these areas was commenced in 1965. It is also worth mentioning that although ground water investigations were done in certain areas, these were for the purpose of domestic use of small towns and not on a large scale. A systematic investigation of the miocene limestone area commenced in 1965, taking small sections at a time, to study the geology of the subsurface as well as to

study the ground water potential in these areas. For this purpose an area of 20 square miles in the miocene belt was selected for a systematic investigation.

The studies were conducted with the aid of two Failing rotary drills and a Joy Sullivan diamond core drill. The results were evaluated by preparing a series of maps, cross sections and well logs to study the basement configuration and stratigraphy.

The basement configuration declines fairly regularly to the west at a rate of 200 feet per mile, and wedges out to the east. The Vannathivillu limestone formation, together with the undifferentiated Mannar sandstones, also behaves in the same fashion as it moves west, but towards the east it does not come into contact with the basement but with the overlying Moongilaru formation. The Moongilaru formation also behaves in the same way as it moves west, but towards the east it comes into direct contact with the basement. The Moongilaru formation has old drainage channels eroded into its surface, and thus comes into direct contact with the Vannathivillu formation at certain sections. The 20-square mile project area has about 600,000 acre-feet of water in storage, but this is water in reserve and it is not proposed to mine it in the early stages. The proposal is to utilize only the average annual increment from rainfall and later from the artificial recharge from surface canals.

The direction of flow in the aquifer does not follow the direction of dip but more or less the strike direction. The piezometric level of the water slopes gently northwards, declining from +26 mean sea level in the south to about +15 towards the northern boundary. The coefficient of transmissibility varies from 40,000 to 576,000 gallons per foot per day in the Vannathivillu formation, and 5,000 gallons per foot per day in the Moongilaru formation. The storage coefficient in the Vannathivillu formation varies from 5.5×10^{-5} to 2.96×10^{-4}

The variation in the piezometric levels and the transmissivity confirms the direction of flow. This shows that there are large solution caverns in the north which aid the flow in a northerly direction. The drilling of wells shows that the loss of circulation in the northern area is much higher than in the south.

The flow net analysis shows that there is a movement of 11,000 acre-feet of water out of the Vannathivillu formation. This is made up of 3,000 acre-feet entering the limestone in the south, 3,000 acre-feet leaking into the limestone and 5,000 acre-feet entering laterally from rainfall recharge. Of this quantity only 4,500 acre-feet, which is about 10 per cent less than the rainfall recharge, is considered for utilization. The water quality varies from 100 to 700 parts per million, varying in an east-west direction.

A system of 19 wells has been planned. These wells have been spaced on a one-mile grid so that the best quality water can be utilized to advantage. Each of these wells will be equipped with a pump of 300 gallons per minute capacity for the cultivation of 1,000 acres.

The wells are to be installed with diesel driven vertical turbine pumps, with each well commanding about 50 acres. The distribution will be by means of pressure pipe lines supplying water through a water meter and globe valve at the highest point of the individual land parcel. This is the first time in Ceylon that a metered water supply for agricultural purposes has been provided, at a cost of $0.07 per 1,000 gallons. The payment for water costs is to be made every two months. The maximum draw-off per month by a particular individual has also been limited, as excessive draw-off by the upper reaches would render the lower reaches short of water. The control of the wells and the distribution system is in the hands of the government to ensure that there is no overmining of the aquifer. The government (water supply) agency, however, has the right to overmine during times of drought, as the quantity overdrawn can be assessed by means of artificial recharge. A private agency does not have the technical know-how to do the job. If in any particular year there has been low rainfall, the water necessary to recharge the aquifer will be made on spreading grounds near the basement-Moongilaru boundary.

REFERENCES

Ground Water Hydrology—David Keith Todd.
Irrigation Principles and Practices—O. W. Israelsen & V. E. Hansen.

Appendix I

CONDITIONS OF SALE OF GROUND WATER FOR CULTIVATION OF SUBSIDIARY FOOD CROPS BY ALLOTTEES OF M. C., L. M. C. AND V. E. SCHEMES IN VANNATHIVILLU, PUTTALAM DISTRICT

1. A meeting of allottees shall be held at least one month prior to the commencement of the agricultural calendar, presided over by the government agent, at which the Irrigation department and Agricultural department are to be represented.

2. At this meeting decisions shall be reached by a majority vote, which should not be less than 60 per cent, on the following :

(*a*) intention of undertaking cultivation for the ensuing season;
(*b*) date of issue and duration for nursery preparation;
(*c*) date of first issue for growing season of crop;
(*d*) last date of issue for same crop.

3. The following schedules of issues shall be maintained :

Month	Crop	Max. hrs./day	Max. days/month	Issue to commence
Dec.	Chillies	8	7	7 a.m.
Jan.	do.	9	31	7 a.m.
Feb.	do.	13½	28	5.30 a.m.
Mar.	do.	11½	31	6 a.m.
Apr.	do.	8	30	7 a.m.
May	do.	8½	31	7 a.m.
June	do.	8½	15	7 a.m.
July	Red Onions	5	31	7 a.m.
Aug.	do.	4	31	7 a.m.
Sept.	do.	5	15	7 a.m.

4. The above issues shall be subject to the following :

Ratio of extent of chillies to red onions is 1:1/3. *Example*: per 1¼ acres of each allotment the maximum supply shall be 960,000 gals. for 1¼ crop-acres of chillies, and 0.42 crop-acres of red onions per year.

5. The water shall be delivered into the allotment by means of a globe valve and measured with a water meter. These appurtenances, though situated within the allotment, shall be the property of the government. However, the safety of these shall be the responsibility of the allottee.

6. The allottee shall operate the globe valve to obtain his requirements of water during the specified period of issues as in para. 3. The allottee shall not fix any appurtenances to the free end of the valve, which shall always be delivering into the atmosphere during period of draw-off from same.

7. He shall endeavor to regulate the quantity of water in such a manner that he may not use up the maximum quantity stated in para. 5 before the maturity of the crop. Any assistance required in this respect will be rendered free by the Irrigation department.

8. At the commencement of issue the meter reading shall be jointly recorded by the Irrigation department and the allottee. Thereafter the allottee shall notify the Irrigation department when the last issue has been drawn per crop, when the meter reading shall again be recorded jointly. The Irrigation department shall have the right to inspect the meter and valve in operation at all times.

9. Water supplied as above shall be charged at the rate of 40 cts. ($0.07) per 1,000 imp. gals. consumed. Payments shall fall due at the end of every month.

10. A good faith deposit of Rs. 100 ($17) shall be made to the government agent before the initial water issue.

11. Anyone in arrears for two months will have his water supply cut off.

ESTIMATION OF WATER REQUIREMENTS FOR VARIOUS CROPS IN DIFFERENT PARTS OF INDIA, USING CLIMATOLOGICAL DATA

by

B. S. Mal, N. D. Rege, and P. C. Gupta*

Synopsis

The irrigation deltas and duties for various crops generally being used in different parts of the country for planning, designing and operation of irrigation schemes, need reassessment in the light of the new concept of water management with emphasis on optimum production per unit of water applied. It is not only the total consumptive water requirement but its dosages and frequency at the different stages of growth of the plant that need to be known. This matter has assumed great importance in recent years when many short-duration, high-yielding varieties of cereals and pulses have been evolved, and farmers in irrigated areas are adopting them on a large scale, introducing multiple cropping and intensive irrigation wherever possible.

Measured data on the subject so far available in the country is not sufficient to form a basis for the purpose. Further research is being carried out, but it will be some time before usable specific results are obtained for adoption under different climatic and soil conditions. Meanwhile, it is considered desirable to estimate the water requirements for various crops, utilizing the climatological data that has been collected for many decades by the Meteorological department.

Several empirical formulae and procedures using climatological data have been evolved in other parts of the world to estimate the consumptive water requirement of different crops. It seems possible to use the formulae and methods, with some modifications as necessary, for estimating the water requirement of crops in India also. Two such methods—the Blaney-Criddle method of estimating consumptive use and the consumptive use-pan evaporation ratios method—are being tried and show promise of providing reasonably accurate values of consumptive use, within the same order of accuracy as the estimates of field irrigation efficiency and conveyance efficiency, which also enter into the calculation of total irrigation water requirement.

* Joint Commissioner (Engineering), Deputy Commissioner (Soils) and Assistant Commissioner (Engineering) respectively, in the Department of Agriculture, Ministry of Food, Agriculture, Community Development and Cooperation, New Delhi.

Introduction

Irrigation in India is as old as civilization itself. The earliest village communities settled along river banks, where annual inundation of lands coupled with rainfall provided enough moisture for raising crops. Gradually irrigation came to be practiced in the interior also by means of wells, tanks and diversion canals. A large number of run-of-the-river projects have been built in the last one and a quarter centuries. Several big storage works have been undertaken recently, although a very large number of comparatively small tanks and storage reservoirs have been in use in India since early times. During the last 30 years or so, tubewell irrigation has also developed in many parts of the country.

In India, at present, about 90 million acres (gross) are under irrigation. This represents about 21 per cent of the cropped area. India has made significant contributions towards the development of the science of hydraulics and the development of irrigation works and techniques. Unfortunately, the aspect of water management with reference to crops and soils has not received sufficient attention so far. In many parts of the country, particularly in the southern peninsula, irrigation till recently was synonymous with paddy cultivation only, which meant supplementing rain water to keep the paddy field continuously flooded with water. In fact, even today paddy forms about 45 per cent of the total irrigated area.

All states in the country have adopted deltas and duties for various crops in their regions based primarily on their experience of protective-type irrigation systems in operation there. These are being used by irrigation engineers in designing new irrigation projects. These guide lines might have served in the past. But the new concept of water management, with emphasis on optimum production per unit of water applied, necessitates special attention in estimating the water requirements of various crops in this country. In recent years, much work has been done in evolving short-duration, high-yielding varieties of cereals and pulses which are being adopted on a large-scale by farmers in irrigated areas. This, coupled with emphasis on multiple cropping and intensive irrigation rather than extensive irrigation, has put additional responsibility on irrigation engineers, agricultural scientists and extension workers to see that an adequate quantity of water is supplied to the crop when it is needed.

Availability of Data on Consumptive Use

During the last few years, research workers have been trying to assess the water requirement of crops at different research stations in the country. These have been reviewed in the two bulletins (1, 2) brought out by the Indian Council of Agricultural Research and the Indian Agricultural Research Institute, New Delhi. They contain some useful information on the subject and indicate the lines on which the work is to be continued further. However, measurements on the amount of water used by various important crops in different parts of India are not yet sufficient to arrive at suitable criteria for design and operation of irrigation systems.

Availability of Climatological Data

The Meteorological department in India has been collecting data on climatological factors such as temperature, humidity, wind velocity, cloud cover, rainfall, etc., from stations situated in different parts of the country. Monthly averages for these factors are published periodically. The latest information available covers the period 1931-60 (3).

Empirical Methods of Estimating Consumptive Use

It is well known that many climatological factors operate singly or in combination in influencing uptake of water by the plant to meet its need for transpiration. When moisture is readily available, the evapotranspiration in an irrigated field has been found to correlate well with such climatic factors as temperature, humidity, sunshine, etc. By using the available information on some of these factors, it has been possible to compute the consumptive use of water by the plants. The irrigation requirement at the field can then be arrived at by taking into consideration

other factors, such as transit losses, seepage, etc. It has also been observed that these computed figures come very near to the measured figures for different crops through field estimations.

As indicated earlier, the water requirement of different crops can be measured or worked out through research. But until this data is available, technical personnel must make estimates for use in planning the irrigation system, fixing irrigation frequency, etc. Many methods to estimate consumptive use of water from climatic data have been proposed and used in several countries. All have limitations, and one has to be cautious in trying to use them without some reasonable check on their applicability.

In India, the methods that appear to show promise of giving satisfactory results are : (i) the Blaney-Criddle method of estimating consumptive use; and (ii) the consumptive use-pan evaporation ratios.

(A) The Blaney-Criddle Method

This method has been widely used all over the world. It requires the use of a constant K, which is experimentally derived and can be used in similar climatic zones to obtain seasonal values (4).

Blaney and Criddle observed that the seasonal demand for water used by crops during the normal growth period was very closely correlated with average temperatures and daylight hours. They further indicated that coefficients developed by them could be used to transpose the consumptive use data measured for a particular area to other areas for which only climatological data was available. The net amount of irrigation water necessary to satisfy the consumptive use is arrived at by subtracting the effective rainfall from the consumptive water requirement during the growing season.

Many factors have to be taken into consider-

TABLE I

Sample Calculation of Estimate of Consumptive Use of Wheat at New Delhi

Period	Midpoint	Days to midpoint	Percentage of growing season	Mean air temperature (°F)	Percentage of daylight hours (p)	Consumptive use factor (f)	Climatic coeff. (k_t)	Growth stage coeff. (k_c)	Consumptive use coeff. (k)	Consumptive use (inches) (u)
Nov. 5 – Nov. 30	Nov. 18	13	8	67.1	6.09	4.09	0.85	0.42	0.36	1.47
Nov. 30 – Dec. 31	Dec. 15	41	25	60.3	7.24	4.37	0.73	0.84	0.61	2.67
Dec. 31 – Jan. 31	Jan. 15	72	44	57.7	7.37	4.25	0.68	1.24	0.84	3.57
Jan. 31 – Feb. 28	Feb. 14	101	62	62.3	7.06	4.40	0.77	1.23	0.94	4.14
Feb. 28 – Mar. 31	Mar. 15	131	81	72.8	8.37	6.09	0.95	0.64	0.61	3.71
Mar. 31 – Apr. 15	Apr. 7	154	95	78.2	4.34	3.39	1.04	0.12	0.12	0.41
				Season Totals		26.59			0.60	15.97

ation if the consumptive use of water is to be determined accurately. The data on rainfall and temperature is normally more readily available than other climatic data. The daylight hours for a month or season vary only with latitude. Information on the monthly percentage of daylight hours for latitudes 0° to 65° north can be found from several publications (4 & 5). The Blaney-Criddle procedure has generally given sufficiently accurate results for estimating *seasonal* consumptive use.

Many efforts have been made to modify the Blaney-Criddle method to determine monthly use as well. One of these modifications, originally developed for use in the northern plain states in the U.S.A. (5), seems to work fairly well in parts of India during the winter season. Much more work on this approach will be necessary before it can be used with confidence. Table 1 gives an example of this method.

(B) Consumptive Use-Pan Evaporation Ratios

J.E. Christiansen (6) at the water research laboratory, Utah State university, Logan, has published a procedure for estimating pan evaporation when measured data is not available. The procedure provides an estimate of evaporation based upon average values of temperature, wind velocity, humidity and sunshine percentage, and upon elevation and latitude. Other workers have established ratios between consumptive use and pan evaporation for various crops and at various stages of growth. These can be used with measured or computed evaporation quantities to estimate consumptive use. This method and procedure is applicable both in arid and humid climates.

The computed or measured evaporation provides the simplest and most desirable index of irrigation requirements. The computed evaporation may in many cases be a much more reliable index than measured evaporation under non-standard conditions The variations in pan exposure or errors in operation and measurement often give data from non-standard installations a constant bias.

The consumptive water use requirement may be satisfied by rainfall, by irrigation or by moisture derived from ground water. Of these resources the most usually available are rainfall and irrigation. It is because of the variability of rainfall during the growing season of the plant that proper moisture requirements have to be met by supplements of irrigation water. Also, all the rain that is received cannot be effectively utilized if the moisture retention capacity of the soil has already been satisfied either through irrigation or previous saturating rain showers. In such a condition, most of the rainfall goes waste either through run-off or percolation.

It is therefore necessary to calculate the effective rainfall which can really meet the consumptive water requirement of a crop. Studies made by D.M. Hershfield (7) in estimating effective rainfall under non-flooded conditions analyzed weather data collected at 22 stations for a period of 50 years, and used it for budgeting soil moisture. Hershfield has developed a nomogram to relate effective rainfall to monthly rainfall and depth of application. Unfortunately we in India so far have no data on effective rainfall. The need for such data can very well be judged if it is borne in mind that effective rainfall is influenced by the character of the soil and rooting depth of the plant.

For arriving at an irrigation design, it is necessary to estimate the consumptive water requirement on a month-by-month basis and subtract the effective rainfall. When the required irrigation frequency is less than a month, it is usually best to assume that there will be no rainfall during the period of peak use The difference between the requirement and effective rainfall gives the amount of water that must be provided by irrigation or other means. It is quite difficult to estimate the amount of water that a plant may expect from the ground water, and if this is important, the estimate must be based upon local field experience and judgment. In most cases we can therefore assume that the water not provided by rainfall must be supplied by irrigation.

The water utilization and management unit in the Ministry of Food, Agriculture, Community Development and Cooperation (Department of Agriculture) has been entrusted with providing guidance in the formulation of agricultural development schemes in the irrigated areas of various states of India, with emphasis on the water management aspect. Most of these schemes, which are of a pilot nature, are being executed by the states themselves. A few have been undertaken with USAID technical assistance. The water utilization and management unit has used available meteorological data for computing the consumptive use of different crops, and has studied its utility in working out the total requirement of irrigation water, doses and frequency of application. For example, pan evaporation has been calculated for the Bellary pilot project (being started under Tungabhadra command with the collaboration of USAID experts). The comparison (Table 2) between estimates of pan evaporation made by Christiansen's method, using climatological data, and the Class A Pan evaporation measurements (8) for the same period indicates that Christiansen's method is suitable for this area.

TABLE 2

Comparison between Estimates of Pan Evaporation by Christiansen's Method Using Climatological Data, and Class A Pan Evaporation Measurements†

	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Measured (inches)	131.2	7.9	10.2	14.8	14.3	15.6	13.2	11.2	10.6	10.2	8.6	7.6	7.0
Calculated* (inches)	138.8	8.6	10.1	14.3	14.7	15.8	13.8	12.5	12.3	11.0	9.4	7.6	7.7
Measured/ Calculated	95%	93%	100%	102%	97%	99%	96%	91%	87%	93%	92%	100%	89%

*$C_M = 1.0$

†Soil Conservation Research Center, Bellary.

Examples of computing the consumptive use of groundnuts in the Bellary region of Mysore state and of wheat in Delhi are given in Tables 3 and 4 and Figures 1 and 2. They employ computed figures for pan evaporation from Christiansen's method, and ratios between consumptive use and evaporation as determined for groundnuts in Israel (9) and for wheat at Roorkee, India (10).

Irrigation Water Requirement

While the consumptive water requirement of the crop can be computed by either of the two methods indicated, it must be remembered that total irrigation requirement differs from consumptive water requirement. The total requirement includes not only the water for plant growth (including the water required by plant tissues), but also the likely losses in conveyance from canal

TABLE 3

Consumptive Water Use by Groundnuts at Bellary

Month	E (inches)	E_t/E	E_t (inches)	Accumulated E_t (inches)
December	7.7	.39	3.0	3.0
January	8.6	.70	6.0	9.0
February	10.1	.94	9.5	18.5
March	14.3	.73	10.4	28.9

E = Pan evaporation computed by Christiansen's method ($C_M = 1.0$)

E_t = Evapotranspiration or consumptive use

E_t/E = Ratio of evapotranspiration to evaporation calculated from water requirements of groundnuts in Israel (9). [See Figure 1].

to field and in the field itself. In other words, the water that is lost in transit, in seepage as well as in field application, has to be added to the computed figure of the consumptive water requirement to arrive at total irrigation requirement. The irrigation requirement can be worked out by dividing consumptive use by the product of *field* efficiency and *conveyance* efficiency (expressed as a ratio).

Until research provides more accurate information, planners and builders of irrigation systems must use empirical methods for estimating the water required for crop production. Techniques developed in various parts of the world can be modified to provide reasonably accurate values of consumptive use to fit Indian conditions. In all probability, consumptive use estimates can be made with the same degree of accuracy as estimates of field irrigation and conveyance efficiency, which also enter into the calculations.

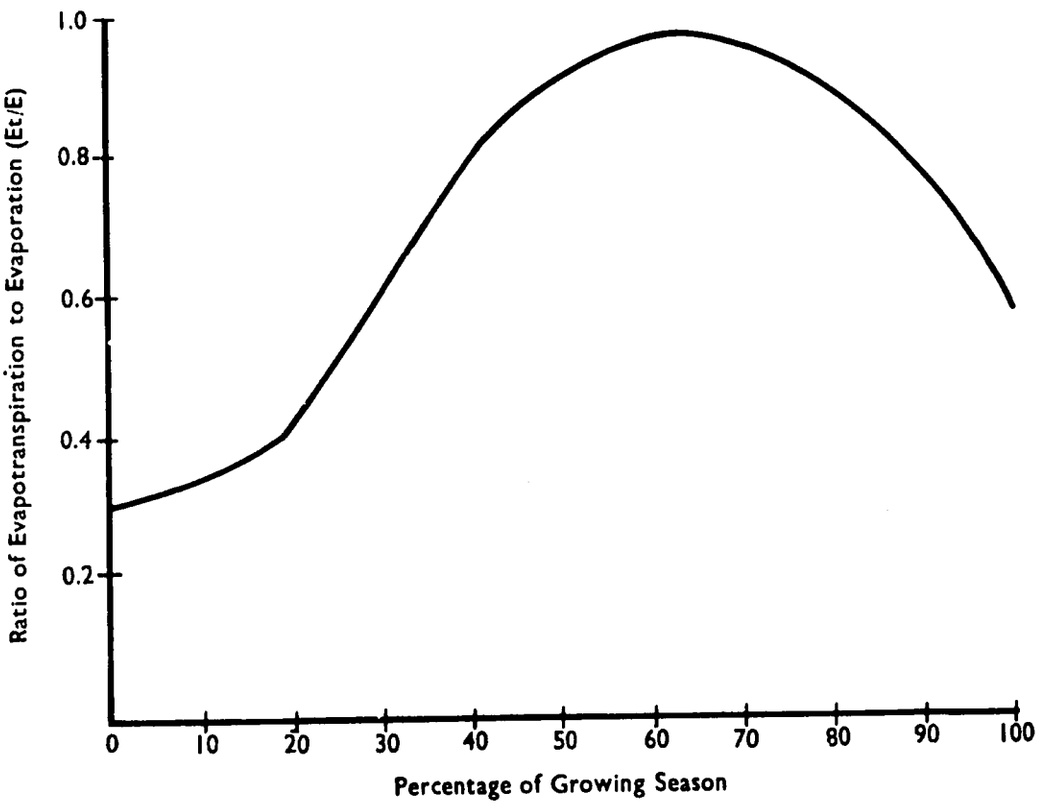


FIGURE 1. Groundnuts, Southern Coastal Plains, Israel

TABLE 4

Consumptive Water Use by Wheat at New Delhi

Period	E for period (inches)	Days to midpoint	Percentage of growing season	Et/E	Et for period (inches)	Accumulated Et (inches)
November 5						
	4.5	13	8	0.10	0.45	
November 30						0.45
	3.9	41	25	0.54	2.11	
December 31						2.56
	3.9	72	44	0.80	3.12	
January 31						5.68
	4.8	101	62	0.84	4.03	
February 28						9.71
	8.4	131	81	0.78	6.55	
March 31						16.26
	5.7	154	95	0.28	1.60	
April 15						17.86

E = Pan evaporation estimated by Christiansen's method.

E_t = Evapotranspiration or consumptive use.

E_t/E = Ratio of evapotranspiration to evaporation calculated from water requirements of wheat at U.P. Irrigation Research Institute, Roorkee (10). [See Figure 2].

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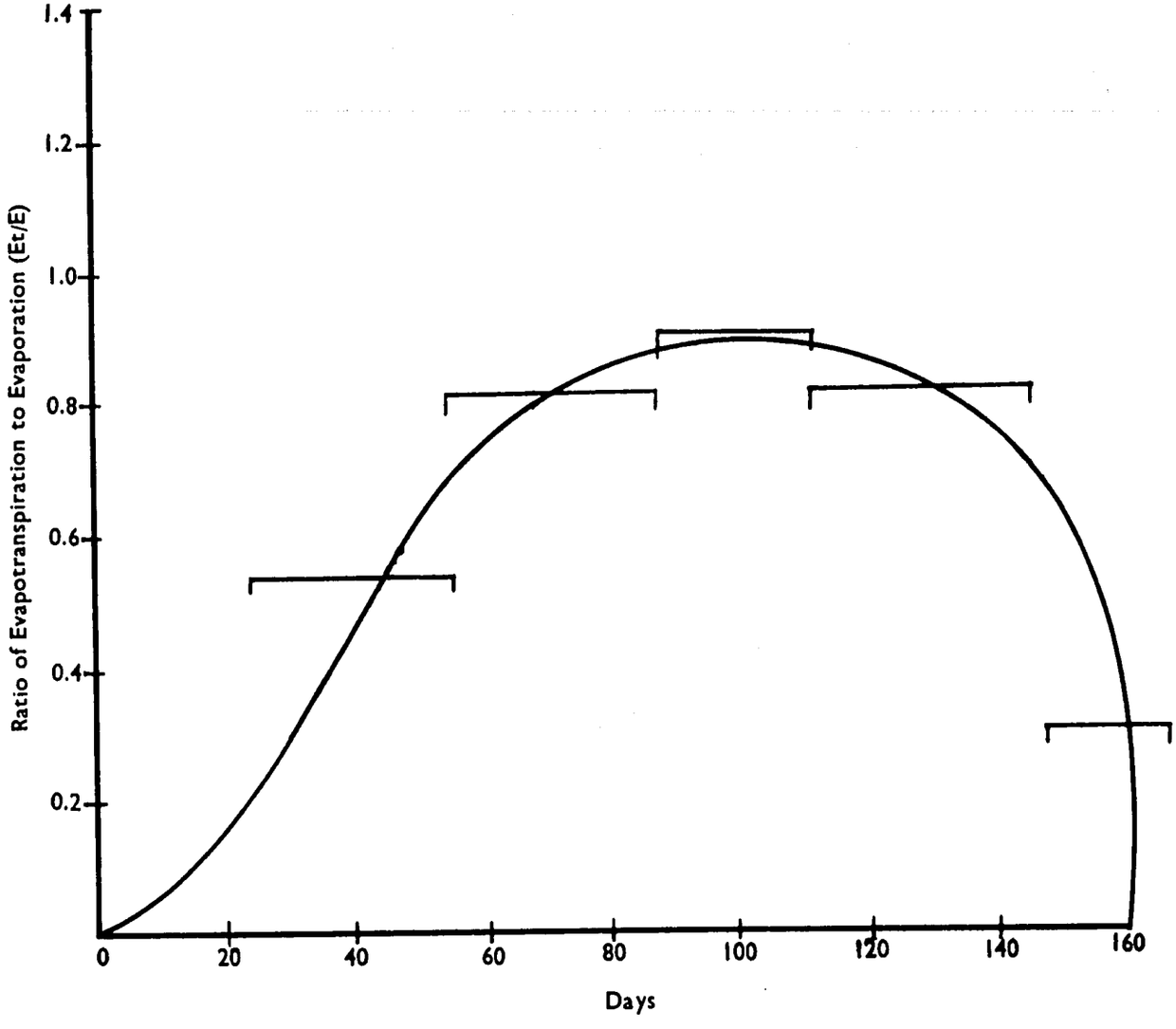


FIGURE 2. Wheat, Roorkee, India (1965-66)

THE INFLUENCE OF CREDIT UPON WATER DEVELOPMENT AND EFFICIENT USE OF WATER

by

Naim Shouka and Muqbel Dahabrah*

Jordan is generally considered a semi-arid to arid country, being mostly desert. Possibilities for increasing production depend mainly upon the development of its water resources, which will increase the area under irrigation. Jordan has limited natural resources and a high rate of population growth.

The total population of the country is about two million. The total area is 97,740 square kilometers (37,500 square miles), of which about 13.5 per cent is under cultivation. Eighty-seven per cent of the total area receives less than 200 mm. (8 inches) annual rainfall and is unsuitable for cultivation, except in small areas where irrigation is feasible. The attached map shows the 200 mm. isohyet pattern.

About 4.6 per cent of the cultivable land is irrigated, with a potential to increase it by 1.2 per cent. Dry farming areas, including fallow land, comprise about 73.1 per cent of the cultivable land. There is scope for extending dry farming by 21.1 per cent of the total cultivable land.

Agriculture is the major economic sector with respect to employment and national income. Agriculture and related activities employ about two-thirds of the labor force and contribute from 17 to 30 per cent of the national income, depending on the season. Water scarcity, unpredictable fluctuation in precipitation and maldistribution of annual rainfall over the season are crucial factors affecting the success of Jordan's agriculture. Consequently, much effort and thinking have been given to the possibility of increasing the amount of land under irrigation. Efficient use of available water has been a national target, too.

The development of major national irrigation schemes is the responsibility of the Natural Resources Authority (formerly the Central Water Authority). The role of the Agricultural Credit Corporation (ACC) is focused on minor irrigation works. This corporation continues to provide sufficient capital to individual farmers and groups of farmers for water projects. Most of the loans are medium-term, for 10 years, and a few loans are long-term, not exceeding 20 years. The ACC was constituted by a special law, entitled the Agricultural Credit Corporation Act, 1959, and Act 12, 1963, with an authorized capital of 7 million dinars ($ 19.6 million). It has jurisdictional and financial independence, and is administered by a director general, a deputy director general assisted by a number of executives, and a board of directors. The head office is in Amman, the capital, with 15 branches distributed over the country. Locations are shown on the map.

This corporation, by its sound policies and procedures in issuing credit, has accomplished a substantial degree of agricultural development. Credit is extended according to feasibility studies of the technical and economic aspects of projects.

* Head of Credit and Research Section, and Soil Irrigation Engineer respectively, Agricultural Credit Corporation, Amman, Jordan.

Loans are disbursed in installments as the work on each project progresses, and are strictly supervised. The costs of engines, pumps and pipes are paid directly to the selling firms, a procedure intended to ensure the proper use of credit. The costs of building concrete conduits, powerhouses and reservoirs, and of digging cisterns and artesian wells, are paid in installments to the borrowers, according to the work accomplished and under effective supervision. Repayment is scheduled on an annual basis, and a real estate mortgage is taken for the appraised value of the land and building mortgaged. These values are based on current sales value.

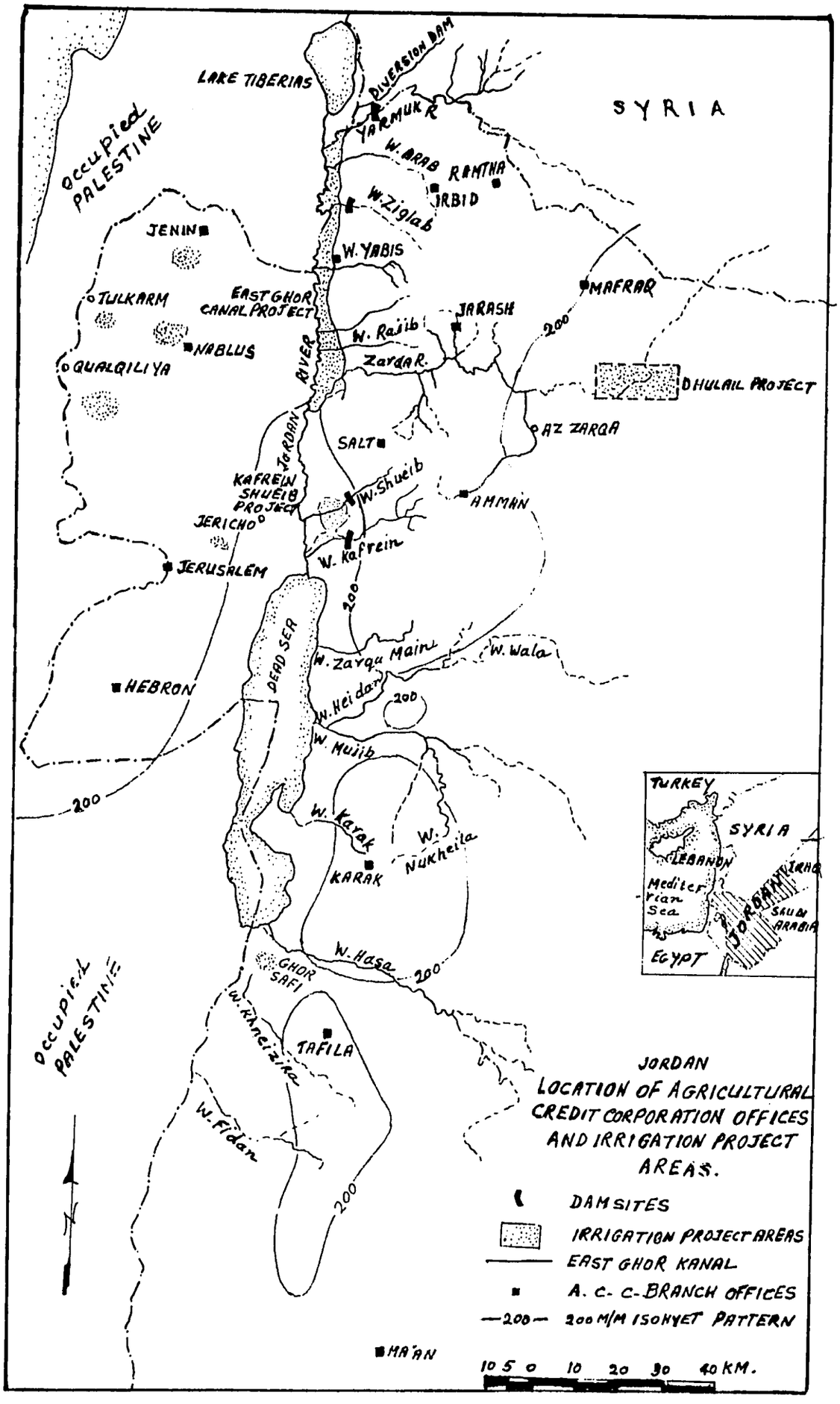
The following tables show the activities of the corporation in the development of water resources for the period 1960 to 1967.

IRRIGATION PROJECTS

Year	Artesian wells	Cisterns	Reservoirs	Engines	Pumps	Pipes (meters)
1960-61	6	88	16	16	15	4,666
1961-62	1	92	18	26	25	5,754
1962-63	5	234	29	16	17	13,439
1963-64	6	726	59	49	45	23,534
1964-65	7	214	42	48	40	26,665
1965-66	5	64	47	60	48	47,578
1966*	11	401	83	62	39	33,095
1967	3	229	42	23	16	19,510
Total	44	2,052	336	300	245	174,241

Year	Concrete conduits (meters)	Non-concrete conduits (meters)	Spring improvements	Dams	Power-houses
1960-61	23,984	—	—	—	—
1961-62	26,751	3,285	—	—	11
1962-63	28,176	955	2	1	21
1963-64	45,335	2,520	—	—	27
1964-65	17,425	1,580	—	—	34
1965-66	16,596	13,325	—	—	41
1966*	27,305	4,840	—	2	23
1967	17,945	3,450	7	—	17
Total	203,517	29,955	9	3	174

* Figures are for 9 months only.


LAKE TIBERIAS
DIVERSION DAM
YARMUK R
SYRIA
occupied PALESTINE
W. ARAB
RAMTHA
IRBID
W. Ziglab
JENIN
W. YABIS
TULKARM
EAST GHOR CANAL PROJECT
MAFRAQ
JARASH
W. Rajib
NABLUS
QUALQILIYA
RIVER
Zarqa R.
DHULAIL PROJECT
AZ ZARQA
JORDAN
SALT
KAFREIN SHUEIB PROJECT
W. Shueib
AMMAN
JERICHO
W. Kafrein
JERUSALEM
200
DEAD SEA
W. Zarqa Main
W. Wala
HEBRON
W. Heidan
W. Mujib
W. Karak
W. Nukheila
KARAK
TURKEY
SYRIA
LEBANON
Mediterrian Sea
IRAQ
JORDAN
SAUDI ARABIA
EGYPT
W. Hasa
GHOR SAFI
occupied PALESTINE
W. Kneiziza
TAFILA
W. Fidan
JORDAN
LOCATION OF AGRICULTURAL CREDIT CORPORATION OFFICES AND IRRIGATION PROJECT AREAS.
DAMSITES
IRRIGATION PROJECT AREAS
EAST GHOR KANAL
A. C. C. BRANCH OFFICES
200 M/M ISOHYET PATTERN
MA'AN
10 5 0 10 20 30 40 KM.

Since the establishment of the corporation, farmers have had the opportunity to acquire sufficient capital on convenient terms and conditions for irrigation development. This has helped them to embark on a larger number of projects and to make effective use of water resources. Such activities covered surface and ground water. Digging of artesian wells has been concentrated on the West bank, especially in the Nablus, Qalquilia, Jenin, Tulkarim and Jericho areas. It is very important to remember that since the Israeli-Arab conflict of June 1967, ACC branches on the West bank have ceased issuing loans. That conflict has seriously affected the country's economy and hindered the corporation's activities very much. On the East bank many artesian wells were dug in the Wadi Dhuleil, Zerka, Mafrak and Ghor Safi areas. It is estimated that more than 3,232 cubic meters per hour of ground water have been added to the available water supply for irrigation in the country. This has contributed to increased agricultural production. Improvement of springs and building of reservoirs, concrete conduits and pipe networks for the distribution of water to farms, have increased the efficiency of water use.

During the period from 1960 to 1967, the corporation issued loans amounting to 6,887,166 dinars ($19,284,064) for different agricultural projects, of which about 1,370,544 dinars ($3,837,523) was invested in irrigation projects. Figures are shown in the following table :

Year	Total agricultural loans (J.D.)	Irrigation loans (J.D.)	Percentage of irrigation to total loans
1960-61	457,681	66,124	13.13
1961-62	470,197	82,622	17.78
1962-63	1,036,306	104,251	10.06
1963-64	902,807	275,025	28.47
1964-65	833,472	160,996	19.32
1965-66	1,206,991	235,132	19.48
1966*	1,293,935	231,057	17.80
1967	685,777	214,337	31.10
Total	6,887,166	1,370,544	

* Figures are for 9 months only.

In conclusion, the ACC has continued to be effective in the development of minor irrigation projects. Farmers are being convinced that agricultural production of the country will increase by using credit (on convenient terms and conditions) for the purpose of irrigation development, and have responded very well. Expansion of irrigated lands and effective utilization of ground water will increase income and will give more opportunity for development. The ACC has improved its loan procedures from experience gained, and has greatly contributed to the national economic development of Jordan.

FARM MANAGEMENT THROUGH LEGISLATIVE MEASURES, CREDIT AND MARKETING FACILITIES

by
Muhammad Iqbal and K. R. Qureshi*

Introduction

Farm management in simple terms means the scientific organization of the farm for maximum returns. It relates to efficient organization and skillful operations of the farm for securing maximum continuous profits, consistent with the welfare of the farmer's family.

Farm management has two facets: farm organization and farm operation. The former deals with the decision-making functions of the cultivator to develop a particular type of organization, keeping in view the kind and amount of crop to be grown and the amount and form of the two factors of production—land and labor. The latter deals with actual work on the farm—formulating the work schedule for the season as well as for daily operations. The decisions to be made here involve fixing priority amongst different operations, selecting the best farming method and the work schedule, etc.

Farm management generally involves frequent decisions by a farmer to adjust with the complex environments. The price structure, technical advances and social factors compel him to change the organization and operation of the farm. This paper discusses the technique of farm management in relation to legislative measures and credit and marketing facilities.

I. Legislation and Farm Operation

Farming is the single largest profession in the occupational structure of West Pakistan, and more than half of the national income is derived from the agricultural sector. A number of legislative reforms were introduced in the farming sector to protect the interest of the farmers.

Land has great value and prestige in the socio-economic setup of the country. It is also a means of subsistence. Legal protection was therefore provided in ownership, transfer and maintenance of land, so that the rights of the farmers are safeguarded. To help farming operations, many laws have been introduced from time to time. Similarly, to regulate farm production and to facilitate its disposal, the necessary legislation has been passed. The purpose generally is to help in the operation and management of farm business as well as to stabilize the agricultural operations in the larger interest of the country. Sometimes legislative measures are adopted for public welfare to regulate procurement prices, distribution and cropping patterns, etc. It is true that sometimes the farmer and his operations are affected by such legal measures. But to meet the

* Superintending Research Officer and Superintending Economist, respectively, Planning and Project Preparation Directorate, Reclamation Division, West Pakistan Water & Power Development Authority, Lahore.

growing needs of urban population, to obtain funds for development, to get more foreign exchange for the country and for maintaining stability in the economy, these steps have been considered necessary. We shall study in broad perspective the scope of different acts relating to land, labor and capital, and find out their impact on farm management.

(A) LEGISLATION PERTAINING TO LAND

(1) *The Land Revenue Act of 1887 and amendments*

This act clearly established the state's rights in land, and defined the interests of the state. The principle of land taxation, the rates and the method of collection were also laid down. At that time the main source of revenue was land, and so on a historical basis it was stipulated that the state should get its finances from the land. Later on, amendments were introduced from time to time to change the scope and extent of revenue assessment.

(2) *The Consolidation of Holdings Act of 1936*

It is well known that a large number of holdings in West Pakistan are divided and fragmented into small pieces, which leads to difficulty in cultivation and management. The subdivision due to hereditary laws and other reasons adversely affect productivity. It was realized that if this process continued, the land would be further fragmented and the income of the farmer reduced. So this act was introduced to consolidate the scattered holdings for better farming operations.

(3) *The Land Alienation Act of 1900 and amendments*

This act prohibited the transfer of land to non-agriculturists. At that time, lands were being alienated to the moneylenders by farmers under the pressure of heavy indebtedness. The moneylenders were not versed in farming know-how and were mostly absentee landlords. The working farmers had no safeguards against forceful ejection from their hereditary property, which provided them with a means of livelihood. This act reserved the land for those who were traditional farmers, and helped a great deal to preserve and ensure proper utilization of land resources.

(4) *The Colonization of Government Lands Act of 1912 and amendments*

Vast tracts of uncultivated land were scattered in different parts of the country and the state established its claim to these lands. After the introduction of irrigation and other land development programs, land was available for cultivation, and a procedure of colonizing these lands was therefore laid down. This act described the method of transfer of the rights of ownership to the colonists and defined the status of the farmers working on these lands.

(5) *The Abolition of Jagirs Act of 1952*

The Government of India granted large tracts of land to people in recognition of their services to the crown. These *jagirs* were notoriously mismanaged. The full potentiality of the land resources was never exploited and the farmer's rights were not protected. The system that developed out of the superior rights of the *jagir* holder gave birth to different socio-economic maladies. This act abolished the superior rights of the *jagir* holder and gave proprietary rights to the working farmers, who were deemed to use the land for greater advantage.

(6) *The Soil Reclamation Act of 1952 and amendments*

This act provided for the speedy reclamation and improvement of areas damaged by waterlogging and salinity, and for preventing further damage to agricultural lands. Relief measures, such as the installation of tubewells and laying of drains, were to be introduced on the areas already deteriorated or threatened. The executing body constituted under this act was empowered to alter, improve or extend water rights, rehabilitate villages, provide communication systems, encourage development of fisheries, poultry, dairy, livestock and other activities, and arrange agricultural credit. Provisions were made to conduct research and surveys on problems related to land reclamation and allied fields. A fee for the above-

mentioned activities was to be collected in areas thus improved.

(7) *The Land Utilization Act of 1954 and amendments*

This act endeavored to put the land resources to profitable use by empowering the state to requisition areas remaining uncultivated for more than two years. The land thus acquired was leased out for development for a specific period, after which it reverted to the owner. The owner was entitled to the profit earned through this reclamation period.

(8) *The Land Reforms of 1959*

These reforms completely changed the agricultural structure in the country. Proprietary rights of land were adjusted among landlords and farmers. Large estates were divided into convenient parcels and the landless farm workers were given ownership rights. The landlords were compensated for lands thus expropriated by the state and transferred to new owners. Ownership was fixed at 500 acres under irrigation and 1,000 acres in non-irrigated areas. The rights of tenants were further safeguarded. The minimum holdings were fixed at 12½ acres, and it was provided that no subdivision should take place under the hereditary law. *Jagirs* of all types were abolished These reforms had far-reaching social, political and economic effects.

(B) LEGISLATION PERTAINING TO LABOR

(1) *The Tenancy Act of 1887 and amendments*

This act intended to regulate the landlord/tenant relationship. Traditionally, the tenants were subject to much oppression by the landlord, resulting in their poor economic and social standing. This act safeguarded the tenants' rights and guaranteed the landlord's interest in the land.

(2) *The Land Improvement Loans Act of 1884 and amendments*

Under this act the state could give loans to owners of land for effecting permanent improvements like leveling, sinking wells, contouring, etc. The loan was repayable in easy installments and along with the land revenue.

(3) *The Agriculturists Loan Act of 1884 and amendments*

This act provided for the grant of loans to owners and occupiers of arable land for the relief of distress, the purchase of seed or cattle, the purchase of land and any other purpose not specified in the Land Improvement Loans Act. The loans were also made for construction of farm buildings and houses, and were repayable in installments along with the land revenue.

(C) LEGISLATION PERTAINING TO MANAGEMENT

(1) *The Canal and Drainage Act of 1873 and amendments*

The act, besides describing the construction and maintenance of irrigation and drainage channels, enumerated the water rights of farmers. The procedure to exercise their rights and the method to safeguard their interests, as well as the rate at which water charges were to be paid, were laid down.

(2) *The Sugarcane Act of 1934 and amendments*

This act regulated the disposal of the crop in areas where the sugar factories operated. It assured the sugarcane growers a fair price for their produce, and the sugar manufacturers a regular and adequate supply to run their plants at optimum capacity. The sugarcane grown in the area reserved for a sugar factory was not to be sold to an outside agency. Similarly, the sugar factory was obliged to buy sugarcane from this area as long as the local growers continued to meet the factory's requirements.

(3) *The Cotton Control Acts of 1947 and 1949 and amendments*

These acts were intended to maintain and increase cotton production, secure its equitable distribution and availability at fair prices, and improve quality for domestic use and export. Cotton zones were created and varieties to be

grown in each zone were prescribed. This ensured quality, and reduced chances of mixing cotton of different staple lengths. The government took upon itself the responsibility for production and distribution of quality seed. A system of inspection was created to watch quality and guard against mixing.

(4) *The Pest Control Act of 1959*

This act prescribed the procedure to guard against and ward off insect and pest hazards. The farmers were obliged to remove or bury crop stubble, kill the pests, control weeds and carry out other plant protection operations. In case of failure, the government was empowered to perform these duties on their behalf and free of any cost.

(5) *Rice Borer Legislation*

No act exists on the subject, but the district authorities have traditionally made use of other acts to enforce precautionary measures against rice borer, which appears as an epidemic in some parts of the country. Mostly, section 144 of CPC is made use of. Nurseries are not allowed to grow plants in April and May, because this is the time when the borer starts laying eggs. The absence of rice at this time helps in the automatic eradication of the pest.

(6) *The Agricultural Produce Marketing Act of 1939 and amendments*

This act was intended to regulate the purchase and sale of agricultural produce, and to establish systematic and uniform markets and their proper administration. The commodities covered in the scope of this act were food crops, vegetables, fruit. livestock and animal products, etc. It provided for better warehousing, standardizing and grading facilities at market sites. The market committees organized under this act provided information about current and anticipated demand for commodities, and fluctuations in prices. The committees also provided amenities for visiting farmers and their animals. This act ended to some extent the exploitation of farmers, most of whom are illiterate. It endeavored to ensure better returns for the farm surpluses offered for marketing and thus enhance profits of the cultivator.

(D) Impact of Legislative Measures on Farm Management

Efforts have been made to safeguard the interests of cultivators through various legislative measures so that they should manage the lands for greater productivity. The state lands were transferred to the cultivators and restrictions were put on alienation of land to the moneylenders. The *jagirs* were abolished and a ceiling on holdings was imposed in an effort to encourage peasant proprietors, who have not only worked hard but have also tried to maintain the productivity of their farms. Through these acts, a ban was imposed on further fragmentation and division of land below the subsistence level, so that efficiency of farm operations should not decrease. The consolidation of fragmented farms is being carried out with the same objectives. With the enforcement of reclamation and utilization acts, the land resources of farmers have been developed and thus they are in a better position to apply other improved practices to enhance their income.

With the regulation of the landlord-tenant relationship, the tenants were safeguarded against summary ejectment and had more incentives for agricultural production.

Since canals are the chief source of soil moisture, the regulations regarding the smooth running of canals and water supply have eased management decisions. Acts have been promulgated which put restrictions on crop disposal, *e.g.* sugarcane near factories, or selection of varieties, as in the case of cotton. These acts no doubt limit the farmer's freedom to act according to his judgment, but on the other hand have helped in getting higher and guaranteed prices. Similarly, through the Marketing Act, better returns for produce have been assured. Laws have also been enforced to manage crops in a way that pests are kept to a minimum. Although some of these acts are not in line with the practices followed by farmers and have put an extra burden on farming, yet they have helped in reducing pest hazards and complete destruction of crops.

(E) Scope for Future Legislation

Though a lot of ground has been covered under different legislations, certain aspects need to be considered and given a legal shape. There is great scope for further enactments. For instance, it is admitted that the best kind of management is practiced by the peasant proprietor himself. Such a class, therefore, needs every encouragement from the government, and those who operate their own land should be given the maximum facilities. Similarly, a way has to be found to decrease the tenant farms, and the land reforms should be modified to create more peasant proprietors.

The size of holding is one of the factors restraining the growth of agriculture. Far introducing commercial elements in general and mechanization in particular, the size of holdings has to be increased. Although the splitting of holdings has been disallowed so that the farm below subsistence level cannot be divided, yet no efforts have been made to raise the status of holdings which are already below the subsistence level. It is possible that cooperative farming could be introduced under some legislation. The private sector can also come in to manage these small farms on a commercial basis. The government could provide necessary facilities for supplementing the crop production with other economic activities like cottage industries, cattle farming, poultry, etc., so that surplus labor is gainfully engaged at the farm.

Under the inheritance law, land has to be distributed among the heirs. The practice of distributing the land to all the sons of a deceased person has contributed greatly to the fragmentation of holdings. It is expected to increase further with the inclusion of daughters. It would be much better if the land is transferred to one of the heirs and the rest are paid compensation, so that the land is operated as one unit by one person who is really interested. Credit can be made available on easy terms to pay compensation, and can be realized from the new owners in easy installments.

Most of the valuable land is subject to erosion in the hilly tracts of the province. Since the land once lost in this process may never be cultivated again, it is important that certain minimum practices be specified by which the owners of land can avoid erosion.

It has been observed that there is an abrupt rise and fall in acreage in certain areas under cash crops in different years. Such fluctuations may cause losses to the economy. It is necessary, therefore, that certain minimum crop acreages are specified for farmers according to the size of their holdings.

The goal cannot be achieved merely by introducing different laws, unless these are enforced vigorously. A machinery can be created to see how well laws are being enforced and the bottlenecks can be removed. There are certain laws, like the West Pakistan Pest Control Ordinance, 1959, which have never been imposed seriously, with the result that no improvement has resulted from them. It is necessary that information regarding the impact of an act is thoroughly examined and the discrepancies removed. The suggestions of the implementing staff have to be considered for improving the situation.

II. Credit and Marketing Facilities

For efficient farm management, credit is needed for production, marketing and consumption. In making decisions of what and how much to produce and what techniques to employ, the farmer's operations are limited by the available financial resources. As farming in Pakistan generally is of a subsistence character, it does not yield enough surplus for heavy production investment. Similarly, the introduction of better livestock, fertilizer, improved seeds, implements and irrigation arrangements on a satisfactory scale is impossible without proper credit facilities.

Closely allied to the provision of credit for production is the problem of marketing the produce and of buying inputs. The farmers, being generally poor, are forced to market their produce immediately after harvest at low prices in order to pay off their debts. For a stable and steady income on farms it is essential that credit for

marketing is made available. Similarly, the farm supplies are not readily available and many a time the farming operations are disturbed because of the lack of finance for farm inputs.

Money must also be provided for social expenditure. Money is required when the farmer has medical expenses, or has a bad season or is involved in some calamity or misfortune. If a farmer is unable to obtain credit for his personal needs it is difficult to carry on the farming operation effectively. Two separate studies* indicate that from 50 to 60 per cent of the entire rural debt is derived from social expenditure. On small farms, which predominate in the western region, the social expenditure coupled with low productivity at a subsistence level frequently leads the farmers into burdensome debt.

(A) CREDIT FOR FARM MANAGEMENT

Though farming in Pakistan is not carried on along business lines, still it cannot dispense with borrowing. For any farm operation, three types of credit are necessary:(i) *long-term credit*, involving investment in tubewells, construction of embankments, terracing of fill sites, drainage, etc; (ii) *intermediate credit*, required for the purchase of more expensive implements, cattle, and sometimes for the erection of buildings; (iii) *short-term credit*, required for financing current requirements like the purchase of seeds, fertilizers, cattle feed, etc.

(1) *Credit Facilities*

Credit for farming operations is obtained from moneylenders, relatives and friends, landlords and other well-to-do people, and commission agents. Some finance is also provided by different institutions which have become active in recent years.

Some studies indicate that a great reliance has been put on relatives and friends as a source of credit (Table 1). Presumably this has been "distress borrowing". Reliance upon this source was needed because the professional moneylenders have disappeared from the scene in West Pakistan. A new class is developing but so far is very insignificant. As regards landlords and other well-to-do rural people, recent inquiries show that they are not a major source. A striking feature of the survey is that the cooperatives have a comparatively small share in the loan advances. This is regrettable in view of the great efforts made during the last sixty years to popularize cooperative credit. Credit advanced by the government has also been on the low side. Sometimes the farmer is left at the mercy of village shopkeepers and market intermediaries, who exploit his needs between sowing and harvest time.

(2) *Institutional Credit*

The sources of institutional credit in Pakistan are: (a) credit supplied by government; (b) commercial banks; (c) cooperative credit; (d) the Agricultural Development Bank.

Credit Supplied by Government. Credit is supplied by the provincial government under the Land Improvement Loan Act, 1883, for the construction of wells, storage, land preparation, drainage and reclamation, etc. Funds are also made available for the relief of distress as well as for the purchase of seed, cattle, fertilizer and agricultural implements under the Agriculture Loan Act of 1958.

These loans, which are called *taccavi* loans in West Pakistan, are given in cash. The period of repayment varies according to the purpose for which the credit is obtained Security of land or other collateral is demanded for the loans advanced. In most cases a personal bond and sometimes a surety's signature is needed. In emergencies, however, a loan is sanctioned after a simple inquiry. Interest of 5½ per cent per annum is charged on *taccavi* loans in West Pakistan. During the fifteen years ending 1964-65, Rs. 133 million had been advanced in West Pakistan under these acts, or less than Rs. 10 million a year. This is an insignificant amount compared with the credit needs of the farmers, which were estimated by the Credit Enquiry Commission in 1958

*Hasan Ali Syed, *Need and Supply of Credit*, Board of Economic Enquiry, Lahore, 1951; and Socio-Economic Research Project (Panjab University), *Survey of Economic Conditions*, 1959.

at Rs. 3,000 million. The Second Plan suggested that the *taccavi* loans should be made on a progressively declining scale and eventually replaced by institutional credit.

Commercial Banks. Commercial banks constitute the most important organized credit agencies in Pakistan, but their contribution to farm credit is rather small. They have always avoided agricultural finance for various reasons, including the legal complications involved in mortgaging land and hypothecating crops for security of loans. A large number of scattered farm units and the difficulties in reaching the interior are the main hindrances. The banks start financial operations when the agricultural produce is ready for marketing through various intermediaries.

Cooperative Credit Societies. Based on democratic principles, voluntary aspect and approach for a common purpose, cooperatives are regarded as an ideal source of farm credit. The primary society is the base of the movement, which can be formed by 10 or more persons (maximum 100). The area of operation is generally a village. The liabilities of members are limited. The working capital is derived from entrance fees, deposits and share capital, if any. Loans are given for productive purposes, as well as for unproductive purposes in moderate amounts, *e.g.* for marriage ceremonies and for redemption of old debts, etc. Loans are usually given on personal security and sometimes on the security of property, and repayment is allowed in easy installments.

The progress of cooperative credit societies has not been very encouraging. In 1966-67 their number was only 15,000, with a membership

TABLE I

Sources of Credit for Various Classes of Borrowers (as percentages of total)

	Cooperative Societies	Relatives and Friends	Proprietors	Shopkeepers	Taccavi	Moneylenders	Total
Land Proprietor	19.1	63.3	9.5	2.8	4.9	0.4	100.00
Owner-cum-Tenant	11.1	53.8	14.9	1.7	0.9	17.6	100.00
Occupancy Tenant	11.2	51.5	19.1	—	18.2	—	100.00
Non-occupancy Tenant	5.7	65.4	24.1	2.2	2.5	0.1	100.00
Laborer	9.9	56.6	30.9	1.5	0.9	0.2	100.00
Artisan	7.5	70.8	18.5	2.5	0.1	0.6	100.00
Shopkeeper	3.7	69.3	22.9	4.1	—	—	100.00
Inservice	14.6	47.4	37.8	0.2	—	—	100.00
Miscellaneous	13.6	63.1	20.2	8.1	—	—	100·00
Average	13.2	63.2	16.9	2.5	2.9	1.3	100.00

of about 700,000 and a working capital of Rs. 150 million A large number of farm units are not able to profit from these societies. Many factors have been responsible for the failure of the movement in Pakistan, *e.g.* the diversion of funds for non-credit uses, political intervention, the weakness of the cooperative departments, etc. In addition, there are deficiencies in the internal working of the societies, like a low credit limit for individual borrowers. But essentially the cooperative principles have not been well appreciated in the context of the socio-political conditions of farming.

Agricultural Development Bank. The Agricultural Development Bank of Pakistan was established in 1965. The subscribed capital of the bank is Rs. 100 million, out of which Rs. 90 million has been subscribed by the central government and the remainder by the two provincial governments.

The bank provides credit both in cash and kind for farm operation. It gives preference to small agriculturists. Loans may be for short, medium or long terms. They are generally required to be secured by mortgaging of immovable property. Wherever possible, loans are disbursed in kind. Payment is made by the bank directly to the supplier. There has been a progressive increase in the amount advanced, and the ADBP has become an important source of credit for farm development. It gave loans amounting to more than Rs. 700 million, of which Rs. 400 million was advanced in West Pakistan. During the last three or four years the tendency has been to provide long-term development loans, particularly in West Pakistan. There has been an increase in specialized loans by the bank against hypothecated crops. Such loans are popular among the agriculturists since land is not to be mortgaged. They are also easier to supervise and recover.

(3) *Problems in Farm Credit*

Farm credit presents problems of great magnitude and complexity. Credit is needed by millions of farmers, most of whom have no security which is acceptable under ordinary banking conventions. The farms are spread over the entire country in its remotest parts. Farmers are generally illiterate, and easy victims of fraud and exploitation. It is therefore exceedingly difficult to organize and supervise credit.

(4) *Supervised Credit*

There are some farms which need credit and are credit-worthy in the sense that they have the capacity to repay the loan from the produce of their land. But this is not the case with a large proportion of farms, which are operating at a subsistence level. If through better agricultural techniques yield per acre can be increased, non-subsistence farms can be raised to subsistence farms. The need is to arrange some sort of supervised credit in the farming operation. The concept of supervised credit means that if technology and credit are supplied together under proper provisions, even the subsistence farmers can be made credit-worthy and their productivity and living standards markedly improved.

The main objectives of supervised credit are: (a) to make available credit to farmers not usually regarded as credit-worthy by the lending institutions because of the small size of their farms, the lack of adequate security in the form of land and other collaterals, and low repayment capacity; (b) to encourage the use of better techniques which farmers otherwise would not adopt due to ignorance, conservatism or lack of financial resources; (c) to create self-confidence in farmers facing financial difficulties due either to an emergency or to low financial resources initially; (d) to turn non-credit-worthy farmers into credit-worthy farmers by increasing their productive powers.

There is a need and usefulness of supervised credit in Pakistan. The farms in the western region are operated on small and normally uneconomic holdings scattered all over the country. They have few securities to offer, and even those who have, cannot be deprived of them either legally or on practical considerations. If such farmers could be helped through advances of credit and also advised about its use, they could produce more and become economically sound. The Agricultural Development Bank can perform

these functions. The scope of these activities should be extended in due course to cover the entire demand.

(B) Marketing Facilities

The economic position of the farmer does not depend merely upon the total amount of farm produce but also on the money value of the surplus that he has to sell in the market. He has little control over the price which prevails in the market, and his cost of production may be regarded as more or less fixed and not easy to reduce. But the farmer's sale proceeds can be increased by better handling of the produce and reducing to the minimum the portion going to various intermediaries between him and the consumer.

It is difficult to say what proportion of the produce on the average is sold by the farmer and what is kept for his household requirements. The proportion, of course, will differ in different localities and with different agriculturists, according to the economic strength and the nature of the commodity concerned. The surplus sold will be greater in the case of commercial crops than food crops. The average farmer, one may say, produces mostly for his family needs, and sells only what is necessary to meet his monetary obligations to the government, moneylenders and for different household expenses.

There is, however, no definite information as to the proportion of the produce sold in the village and that taken to the market by an average farmer. Some studies about the former Punjab indicate that 60 per cent of wheat, 30 per cent of cotton and 60 per cent of oil seeds were sold in the village or village market. The proportion of the produce sold in the market tends to diminish as farmers are debt-ridden or carry on subsistence farming in tiny holdings. Also, the proportion of produce sold in the market diminishes where the means of transport and communication are not adequately developed.

The sale in villages (apart from the portion that is directly sold to non-farming consumers living in the same village) is made by various kinds of middlemen, through whom it reaches the larger markets and distant consuming centers. They are mostly agents of the market traders, moneylenders, small businessmen and industrialists, who are active during the harvest season. The Agricultural Enquiry Committee (1951-52) referred to the "general complaints amongst the farmers that too large a share of the market value of the produce which they grow went to the middlemen". The grower's share in the money spent on food has been estimated between 35-50 per cent.

(1) *Difficulties in Marketing Farm Produce*

The reasons for the low prices a farmer receives in the market are many. Sometimes smaller value is obtained because of the low quality of the produce. This may be due to: indifferently selected seed; natural calamities affecting the crops while growing; inefficient methods of harvesting which lead to mixing with stones and dirt; lack of proper storage facilities resulting in deterioration through exposure to rain, dirt and rats; and lack of standardization and grading of produce.

Some useful work has been done in introducing improved varieties of seeds, though a very small field is covered as the proportion of improved varieties differs from crop to crop. Some work has also been done to tackle the problem of diseases. The technique of harvesting, however, remains a problem, and unless mechanization is introduced things may not improve much. The lack of proper storage facilities leads to deterioration in quality, and the farmers thus get less value. In the case of cotton, the government has taken steps under the Cotton Control Act to prevent deterioration of quality in certain cotton growing areas. Legislation on similar lines suited to the circumstances of different commodities would go a long way to prevent deterioration of the produce. With the exception of a few commodities, there is no organized grading of agricultural produce. It is imperative to introduce grading at the first stage of marketing under the control and supervision of the existing Cooperative and Marketing department.

(2) *Transport and Communications*

One reason why only a small percentage of

produce is taken by the farmer to the market is the bad condition of roads. Communications from the field to the village and from the village to the market are often extremely poor and defective. This leads to an increase in the cost of transportation and a multiplication of small dealers and middlemen. In the words of the Agricultural Enquiry Committee, "the success of any plan for agricultural development is largely dependent on the facilities afforded for primary produce to reach the consumer at minimum cost"

(3) *Storage Facilities*

Another defect in the system of marketing is the lack of proper storage facilities and absence of licensed warehouses. The availability of storage facilities has several advantages. Price fluctuations are reduced, supplies are spread more evenly over a period of time and thus production and consumption are both increased. The farmer, due to the lack of financial resources, sells most of his produce a month or so after harvest. He seldom thinks it worth-while to construct expensive storage structures. In the villages, godowns may be constructed by the cooperative societies to provide facilities for storage to members, and enable them to keep their produce safe until a favorable time comes for selling. The cooperative societies can combine the functions of providing finances and storage facilities. Similarly, there should be properly constructed and licensed warehouses at the more important markets. This will enable the farmer to obtain, at reasonable rates, advances against the security of the produce stored.

(4) *Market Operations*

There are a number of middlemen operating in the market. In the well-developed markets, which are very typical of areas where transportation and irrigation facilities are available, the commission agent has made his appearance and facilitates the transactions. He also supplies capital to the village traveling merchant on the condition that the produce will reach him regularly. Similarly, there is another type of commission agent who acts for all sellers of the countryside, including the cultivators, village moneylenders and all sorts of merchants. In addition, there is another intermediary called the broker. He is found in all the markets, sometimes acting for one seller and sometimes for the buyer. In the majority of markets, however, brokers operate in the interest of the buyer. The essential thing is to have more regulated markets in all the agricultural areas to improve marketing facilities in the country.

(5) *Market Facilities*

There is a large number of primary markets scattered all over the country. Their size, institutional setup and organization differ from locality to locality. They may belong to a local body or an individual. Most of these markets operate without set rules and regulations. They are unorganized and different malpractices are rampant. Some of these have agents acting for buyers and sellers, collecting commission from both parties to the disadvantage of the farmer Settlement of price under cover, use of false weights and taking a variety of charges from the farmer are some of the common abuses. But the number of such markets has been decreasing as more and more regulated markets have come up. At harvest time, a large number of markets springs up on roadsides and other important producing areas.

A regulated market comprises a notified area embracing several villages with a centrally located market. The market is a well-planned place and has facilities for store rooms, weighing and financing. Means of communication are well-developed. The controlling authority (market committee) charges a fee for the business done and thus makes the market self-sufficient. A market committee is normally constituted and has representatives of different interests, including those of the growers. It standardizes the various market practices and ensures fair dealing. Licenses to the brokers are issued and a penalty is prescribed for any breach of the law.

(6) *State Intervention in Marketing*

In recent years the state has intervened directly in the marketing of farm produce. To

ensure a stable price level over a period of time, the system of minimum price fixation has been introduced. For instance, a minimum price has been fixed recently by the government for three years in the case of wheat, rice, sugarcane and maize to give incentives to the farmer. The government is willing to purchase these commodities at fixed prices. When crops are plentiful, the procurement operation may assume the character of a price support scheme. When prices increase above the minimum level, government stocks are released and the improved supply may bring the price lower and thus stabilize the price level. In planning cropping patterns and in disposing of the crop, the price fixed by the government may determine a farmer's operations. Similarly, in the case of cotton, there has been instability in the market. Under the Cotton Act of April 1951, the government was empowered to fix minimum prices to regulate the baling and pressing charges and to regulate the movement of cotton. In 1952, floor prices for cotton were fixed and the government purchased cotton at the support price. In this way, to save the interest of cotton growers minimum prices were fixed, export duties were changed and a cotton board was constituted. Whether the farmers benefited from these reforms as envisaged is, of course, a different question.

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THE ROLE OF SUPERVISED CREDIT IN PROMOTING GOOD IRRIGATION PRACTICES

by
Ali Oktay Ersoy*

I. Introduction

It is not my intention to speak about the need for and importance of irrigation development, which is the main subject of this seminar. Neither shall I invite the distinguished delegates from NESA countries to think on the importance of the problem. But I would like to say that the hope in balancing the present world food/population ratio is intensive agriculture through irrigation. This will be the case in the near future unless a radical change in technology takes place.

Today crop yields per hectare are as low as one-quarter of the yields in developed countries. This is the reason for the present food deficit and social miseries. But we have a chance to protect millions against starvation through irrigated agriculture at least 30-40 years from now. On the one hand science is to develop a permanent solution of the problem, and on the other hand conventional measures depending upon irrigation are given full attention.

II. The Need for Credit in Promoting Good Irrigation Practices

There are two stages in irrigation programs: development and utilization. The development of water resources as well as irrigation itself requires extra cost. The development stage is usually considered as a public service. Public funds are used more in this phase, although small irrigation works are undertaken by individuals.

Large irrigation projects necessitate the control of surface water through big dams and reservoirs. Planning and machine work stages in it are purely governmental. This ends with the delivery of water to the head ditches. There the third stage starts and the human factor is involved. This is the on-the-farm development stage, and unless this stage is completely and satisfactorily realized, the whole task and all expenses will be wasted. The cost of on-the-farm development is to be borne by the farmers concerned.

* Director, Supervised Agricultural Development Loan Division, Agricultural Bank of the Republic of Turkey.

Not only on-the-farm development but also promoting good irrigation practices require extra costs. Money is needed to convey the water from the head ditches to the farm with proper arrangements, to level the land, to acquire knowledge on the water requirements of various crops, to get the soil tests done, to make satisfactory soil and seed bed preparation, to use the right kind and right amount of fertilizer and manure at the right time, and to apply the water in a proper way. The water charge alone makes the production costly. Even if water is brought by the farmer to the farm from streams in the neighborhood or out of a deep well or ordinary well, development and utilization require extra costs. Now we come to the problem of meeting these extra costs which the farmer must somehow bear. Farmers generally need credit assistance to meet those costs, because :

— The margin of profit in agriculture is low as compared with that of industry, especially in the developing countries.

— Agriculture is the sector in which, generally, families of small means are concentrated, especially in the developing countries.

— Ever-improving technology requires farmers to make larger investments in their operation.

— Agriculture is more risky as compared with industry.

— Capital accumulation in agriculture is very small.

— The formation of capital is not good; in the farm inventory, land is usually the biggest item and there are not many movable assets or ready cash.

— In the supervised credit program, statistical work on the farm inventories of 5,000 farms has shown that 80 per cent of the assets-in-value are composed of farm land and farm buildings.

Therefore, promoting good irrigation practices as well as developing water resources generally require farmers to seek credit.

III. Supervised Credit

(A) Definition

Supervised credit means adequate credit plus technical guidance plus effective supervision Supervised credit is not only a system best suited to meet the needs of farmers for irrigated farming, but can also be considered as insurance for the whole investment both by the government agencies and farmers. This system has been developed in the U.S.A. and has been in operation in many countries for more than 20 years.

(B) Application Principles

It depends on farm and home planning and farm management techniques. It aims to secure maximum yield from a unit of land. It necessitates teaching farmers to use water properly for irrigation purposes. Converting separate pieces of subsistence type farmers' lands into economic farming units is one of the main objectives of the system. Its main characteristics and working principles can be briefly described.

Eligible farmers are selected, and all farm assets, resources and capabilities are studied. Every loan project and farm plan depends on the work plan developed, and the long-term farm plan is revised by annual plans. Farmers are provided with technical assistance, including marketing information, by extension services and/or by the technicians of the institutions which carry out the supervised credit system. Farmers keep their own farm and home records, and cooperate fully with the extension services and the credit agency. Credits are personalized. Enough credit is provided in the appropriate time on appropriate terms. Farmers first assign their own resources to the project and then ask for credit. This credit must be enough to meet the need. Loans are utilized, whenever possible, in kind. Payments are generally made to the contractor, constructor or seller, rarely to the farmer, even when these payments depend upon work reports. Improved appraisal methods are used, and loans are expended under

the guidance and within the effective control of the extension service and/or credit agency.

(C) Cooperative and Individual Approach

The supervised credit system may be implemented in two ways : providing credit to groups, or to single farm families. In irrigation development the cooperative approach has many advantages. Development may require funds and means which are beyond the capacity of individual farm families. For feasible projects and economical utilization of water, not a drop of water is to be wasted. This may be realized if a group of farmers who need water unite and use it. A large percentage of irrigation projects designed can become economically feasible if they are to serve a relatively large area involving a group of farmers. Group activity helps to generate a suitable psychological atmosphere for this kind of enterprise. Further, irrigation works by groups help to lessen the cost. Uniting farmers into a group helps to generate more power than simply adding the powers of individuals together. Cooperatives, or associations, or groups of this nature serve as an intermediate step between government services and individual efforts. They eliminate many problems created when working with individuals. We should not expect that governments can help all of the farmers through the individual approach.

So we come to the point that directing services to individuals may mean a waste of time, capital, manpower and energy. However, the cooperative approach has not yet been developed as a successful system in many NESA countries. Therefore, while working towards this goal, we should continue support to the individual approach.

(D) Importance of Supervised Credit in Development and Maintenance of Irrigated Agriculture

On-the-farm development generally depends on credit. Taking into consideration its importance. and recognizing that until it is realized all investments for the first (planning) and second (construction) stages are fruitless, any government is bound to offer loans to finance the third stage.

Besides the provision of funds, there are many problems to be solved. Farmers in most of the NESA countries are so needy and their education level is so low, that many of them rarely hesitate to use specific funds for other agricultural or non-agricultural purposes. They are usually reluctant to undertake costly developments, because it is hard to convince them that the increasing yields and extra income from investments can compensate for the extra costs involved. They should not be criticized for their reasoning. Unless they are very well instructed in the proper utilization of water, unless they are provided with enough credit and technical assistance, and unless they learn to think and work economically, they will be right in their reluctance.

That is why supervised credit is important and why it should be programmed in all big irrigation projects. In fact, all big projects are cleared by the help of feasibility reports which spell out the utilization of water with fullest benefit, the realization of all on-the-farm development, the change of cropping pattern, the adaptation of crop rotation and the introduction of modern agricultural practices, along with all necessary production inputs. But in reality some of these requirements occur at the very beginning, and government investments remain idle and unproductive for a good many years.

To avoid this, the supervised credit method can be successfully utilized, although supervised credit has one especially weak point: whether or not we provide this credit to all farmers in the area for the sake of the overall project. This question arises when a considerable number of farm families in the area do not qualify for a supervised loan. In this case the cooperative approach does not work and projected goals are not reached. This happened in the Seyhan project on the southern coast of Turkey, when an IDA loan for irrigation development was obtained by the Turkish Government. After a few years of experience and observation the Turkish Government had to enter the picture, and even on-the-farm development, land leveling and drainage work are now being conducted by the government. These investments will be returned

to the government through water charges. But since the farmer's initiative is now completely lost, we do not know how to get him to use water wisely and economically. In solving the weaknesses of supervised credit in cases like this, I still prefer not to leave out the credit method but to soften it. The main principles should stand.

In short, irrigation development and irrigated agriculture are costly operations. For these, credit is needed. But all extra costs are to be compensated through modern practices and increasing yields. For that, technical assistance and guidance are needed. All these factors are found in the package of supervised credit.

IV. Credit Facilities for Irrigation in Turkey

(A) Problems and Programs

Climatic conditions in Turkey make irrigation necessary. A rapidly growing population and comparatively limited land and water resources make the maximum agricultural production from irrigated land a critical need. It has been estimated that one-fourth to one-third of this increased production must come from irrigated land. In 1962, of the 25.3 million hectares of agricultural land only 1.1 million hectares were irrigated (4.4 per cent), and 60 per cent of this (800,000 hectares) was being irrigated by private enterprise, mainly small irrigation works.

The first irrigation project with sound technical standards was constructed in the period 1908-1913 in the Konya-Cumra plain. The First Five Year Development Plan (1963-67) gave great emphasis to the development of water resources. In addition to the 1.12 million hectares in 1962, another 515,000 hectares were to be put under irrigation by the end of 1967. The Second Five Year Plan (1968-1972) anticipated an increase of 425,000 hectares in the area of irrigated land, thus reaching the figure of 1.98 million hectares. In the same period (1968-1972) construction of 4,000 wells and 250 small lakes was also programmed. Wells for small irrigation works to be dug by farmers with their own resources were not included in these figures.

Irrigation development requires the action of several government agencies. In Turkey there are two main agencies dealing with irrigation development: DSI (State Hydraulic Works), which is in charge of construction of big dams, big irrigation projects, primary and secondary canals; and TOPRAKSU (Soil Conservation and Farm Irrigation Service), which brings the water to the head ditches. From then on the third stage, on-the-farm development, starts.

This stage requires the cooperation of farmers with TOPRAKSU, because on-the-farm development is to be carried out on their land on their account but with the technical assistance of TOPRAKSU. At this stage, associations, cooperatives or groups play a big role, serving as an intermediate body between government agencies and individual farmers. At present TOPRAKSU cooperatives, of which the establishment and functions were explained in the previous NESA seminars, are the sole organizations to act for the purpose. We have about 600 of them. But they are not yet effective enough to meet the need.

Article 20 of the law establishing the general directorate of TOPRAKSU entitles the agency to force farmers to take appropriate measures of soil conservation and farm irrigation. The same article even goes so far as to ask the agency to take these measures in case of farmer reluctance, the charge to be paid by the farmers in 15 years. (This authority has not been used so far). Forced land consolidation is also mentioned among these measures.

Article 21 of the same law establishes a fund to be used for loans to farmers by the two cooperating agencies, TOPRAKSU and the Agricultural Bank. These loans are called TOPRAKSU loans (TOPRAKSU loans will be explained later).

In spite of all these legislative measures and coordinated efforts, the on-the-farm development stage is still the problem area.

(B) Loan Methods

(1) *Conventional Loans*

The Agricultural Bank law (1937-3202)

anticipates granting loans to farmers for all agricultural purposes, including irrigation. Besides that, it specifically mentions (article 10-2) long-term loans for irrigation development. The bank has been making these loans for at least 30 years. But the fact is that irrigation expenses are considered among the operating costs and operating loans provided to meet all operating costs. Since availed amounts of operating loans are generally short of the need, this part of the loan system is not working satisfactorily.

As to long-term (up to 20 years) irrigation loans, there is a working system established in this field. Extension offices of the Ministry of Agriculture in the provinces and towns develop loan projects, and the bank finances them. Roughly 500 irrigation loans in the amount of $1 million ($ 1=9 Turkish lire) are extended annually. The method has its weaknesses. The project is not a complete one. It generally contains a cost report and a drawing. The financial contribution of the farmer from his own sources is not required. The extension services are too busy, and extension officers are not specialists in this field.

(2) *TOPRAKSU Loans*

These loans depend on (a) the law establishing the directorate general and (b) a project agreement providing AID funds. These loans have been granted since 1960. Loans depend on projects developed by the field organizations of TOPRAKSU stationed in provincial seats. These are long-term loans. Roughly 1,200 loans in the amount of $ 2.5 million are extended each year. Some of the items for which loans have been granted are :

Canals	3,633,000 feet
Wells	2,568
Pools	1,490
Pipes	933,900,000 feet
Motor pumps	3,086
Pumps	497
Deep wells	33

The weakness of this method is that though the average number of parcels per farm family in Turkey is over nine, only one or two of them have a soil or water problem that is worked on. Loan projects deal only with the soil and water problems of the farm, omitting all other needs.

(C) SUPERVISED CREDIT

These loans depend on interministerial project agreements, and are financed out of an AID fund plus the resources of the bank. This is a complete project method, in operation since March 1964 in pilot areas. The number of branches authorized to make these loans has increased to 70 in four years. (The Agricultural Bank has 720 branches in the country). The method is still in the experience and development stage, though the number and volume of loans have surpassed the other irrigation loans. The supervised loan project may contain one or more items to solve one or more problems. It is not only an irrigation loan. Irrigation, soil conservation, land consolidation, farm machinery, livestock development, farm building constructions, etc. may be planned in one project. No matter if one or more (or all) of the problems on a farm are attacked through credit; an operating loan must also be provided.

All the principles of supervised credit mentioned earlier are applied in the Turkish system. *Turkiye Cumhuriyeti Ziraat Bankasi* (the Agricultural Bank of the Republic of Turkey) employs agricultural technicians in this program. These technicians prepare farm and work plans, and supervise the implementation of the plan and utilization of credit.

A TOPRAKSU loan project in the supervised credit system becomes a part of the farm and work plans. It may contain work plans developed by other agencies related to agriculture as well. Therefore, bank technicians (we call them "credit engineers" if they are university graduates, and "credit technicians" if they have had lycee level education) may be assigned as: coordinators (to coordinate services of various agricultural agencies to farmers); interpreters (to work as a kind of interpreter between the farmer and the bank and other agencies); supervisors (to supervise the implementation of farm or credit plans); reporters (to report the results of joint

efforts and accomplishments); or demonstrators (to demonstrate successful results for the benefit of others).

Through this method, in the first four years $12 million has been actually loaned in pilot areas to 6,000 farm families. When the project covers the whole country, in our estimate 60,000 farm families will be granted supervised credit each year. These figures comprise all loan items granted in supervised credit. Loans for irrigation development or for operating needs are about 15 per cent. Among 23,042 loan items provided to the first 5,000 farmers, 6,480 were for improvement and development, and 16,562 for various purchases.

The program is in operation in 1,212 villages in 15 out of the 67 provinces. It covered 54,370 hectares on 47,685 parcels of land, as of the end of April 1968.

In the first 5,000 loan projects there were 971 TOPRAKSU loan projects, 635 motor pumps and 3,289 loans for construction and/or repair of barns. The average loan is $3,000 and the average amount outstanding with farmers is $1,550. The Second Five Year Development Plan of the country anticipates a wide coverage of the system in the country, and work plans for 1968 ordered the concerned agencies to expand the supervised credit project areas.

The weaknesses of the system are:

— Difficulty in obtaining the full cooperation of other agencies.

— Lack of credit discipline and understanding by the farmers, which is a must in the supervised credit program.

— The farmers' lack of knowledge concerning the benefits they could enjoy if their land and water resources were properly utilized.

For a better visualization of the three methods mentioned we may use an example. Suppose a farmer needs a motor pump and asks for credit. If the extension agent provides a certificate of need for it and the bank loans money, it is a conventional irrigation loan. If TOPRAKSU develops a project which contains, for example, a description of the need, a topographic chart, a discussion of alternatives, the work plan, technical terms, a breakdown of costs, the qualifications of the pump, land leveling costs (if needed) and a projection of increased yields, and if a TOPRAKSU engineer supervises the activity, it is a TOPRAKSU loan. If the initiative is taken by the bank engineer and TOPRAKSU is requested to develop a project; if the cropping pattern and relation of crop are set; if other needs of the farm (machinery, equipment, operating loan needs) are worked on; if the budget of the farm is planned; and if all these are arranged in long-term and annual farm plans, then it is a supervised credit. At present all three methods are being practiced in the bank.

V. Summary and Conclusions

Crop yields can be considerably increased through irrigation if accompanied by other appropriate measures.

Extra costs caused by irrigation are to be met through credit. Unless wise utilization of credit is secured and technical assistance provided, even the credit may constitute an extra burden on the budget of farm families, because conveying the water to the farm does not mean much if it is wasted or not properly applied, and the charges for it may mean more expensive production. Therefore, wise and economical utilization of water is a must.

All these factors are combined in the supervised credit system. It is recommended that this system be adopted in all areas where irrigation development is being carried on.

Chapter VII
IRRIGATION INSTITUTIONS — FARM RELATIONSHIPS

CRITERIA RELATING TO AGRICULTURAL ASPECTS FOR THE DESIGN AND OPERATION OF IRRIGATION SYSTEMS

Summary

The main considerations in an irrigation project are the engineering feasibility with regard to water availability, site conditions for diversion or storage structure, and the controlling levels and the agricultural aspects to utilize the available supplies. Once the site and the command areas are fixed, it remains to plan, in consultation with the Agriculture department, for the optimum utilization of the water resources. It is at this stage that the four factors, *viz.* crop pattern, water requirements, intensity of irrigation and rotation, which are more or less interdependent, play an important role in determining the design of the distribution system.

Success of an irrigation project depends largely on sound land and water management, which requires a cooperative approach by the organizations concerned. Demonstration farms and experimental stations in less developed areas greatly help in bringing home to the farmers the benefits of modern techniques of irrigated agriculture, with improved varieties of seeds, chemical fertilizers, etc.

Introduction

India has always had a predominantly agricultural economy. On account of the wide annual and seasonal variation in rainfall, both in quantity and incidence, irrigation has been practiced in the country from time immemorial. The introduction of high-yielding varieties of crops, use of fertilizers, etc. and the urgency to increase food production to feed a rising population has made development of irrigation all the more necessary.

Irrigation works in India in ancient times consisted of a large number of dug wells, small tanks and diversion works on perennial streams. The earliest canals constructed were inundation canals, utilizing the monsoon flows of the rivers when the water level was high. The Eastern and Western Yamuna canals, taking off from the Yamuna river and constructed during the Moghul period, were instances of these.

The construction of large-scale irrigation projects can be considered to have commenced during the British rule in the mid-nineteenth cen-

tury. The initial work consisted of remodeling existing structures; this was followed by a large number of diversion works with extensive canal systems, such as the Godavari and the Krishna delta canals, the Upper and Lower Ganga canals, the Tribeni canal, etc. Many of these projects were established as a protection against famine.

The impetus to construct storage reservoirs to utilize the large water resources of the country for agricultural production came in the wake of independence, with the commencement of India's Five Year Plans in 1951.

Types of Irrigation Systems

Broadly speaking, irrigation projects in India are classified into two main categories: major/medium and minor schemes. The former consist of storage and diversion works tapping large catchments and thereby providing an assured water supply. Such works enable a great diversity in crop pattern and the growing of perennial crops.

Minor irrigation works, as the name implies, comprise schemes using surface flows by small diversion structures and tanks, and ground water from dug wells and tubewells. Deep tubewells tapping underground reservoirs provide an assured water supply for agricultural production.

The two types of schemes quite often play a complementary role, particularly with the recent trend towards the integrated use of surface and ground waters in the command areas of large projects.

Design of an Irrigation System

An irrigation project, particularly of the major/medium type, essentially consists of headworks (storage or diversion structures) for control and regulation of water, and the canal system comprising the main canal (also branch canal, depending on the topography of the command), distributaries, minors, watercourses and field channels. With regard to the responsibility for the construction and maintenance of watercourses and field channels, the Planning Commission has made the following suggestions to the state governments:

(1) The project authorities should be responsible for the construction of watercourses with capacities ranging from one to three cusecs (depending on crop pattern, topographical and other considerations) at government cost.

(2) The survey and alignment of field channels beyond the point to which watercourses are constructed at government cost should be the responsibility of the project authorities. Responsibility for excavation of these channels should be entrusted to the beneficiaries.

(3) The maintenance of watercourses constructed at government cost, as well as field channels excavated by local people, should be the responsibility of the beneficiaries.

For determining the sectional area of other channels, the full supply discharge in different reaches is required to be assessed. In large projects, the distributary or minor is taken as a unit. Discharge required at the head of the distributary is arrived at by dividing the command under it by the duty fixed at the distributary head. Allowance, usually at eight cusecs per million square feet of wetted area for unlined canals and two cusecs for lined canals, is made for transmission losses in arriving at the discharge at the head of the main canal.

Duties generally adopted at the distributary head in preparing irrigation forecasts vary in different states, depending on the nature of soil, type of crop, etc. Those adopted in the state of Maharashtra are given as an example from a zone where rainfall is below 30 inches (Table 1).

For detailed designs, the discharge statement of a canal is prepared from the tail upwards by integrating the designed discharges, outlet by outlet, and transmission losses, reach by reach. The discharge at the outlet is calculated for seasonwise requirements and the highest figure is used in working out the canal capacity.

Subject to the availability of water, the

storage capacity of an irrigation reservoir is based on the total annual water requirements at the canal head, with due allowance for evaporation and seepage losses, account being taken of the run of the river which can be diverted directly into the canal. Water availability for diversion works is fixed on the basis of 10-day flows in the river. Aiming at utilization of average flows will involve considerable carry-over, and, therefore, substantially heavy storage. On the other hand, planning for utilization of flows of greater dependability will result in large quantities of water remaining unused. Major and medium irrigation projects are therefore generally planned to use 75 per cent of dependable flows.

TABLE 1

CROP	DUTY ACRES/CUSEC
Sugarcane	50 to 70
Kharif (monsoon)	130 to 200
Cotton	100 to 200
Rabi (winter)	150 to 200
Hot weather	50 to 100
Two seasonals	130 to 140

Agricultural Aspects to be Considered

The main points for consideration in working out the water requirements of an irrigation project are :

(1) crop pattern in relation to supply pattern;
(2) water needs of crops at different stages of growth;
(3) intensity of irrigation in the culturable command area of the project;
(4) rotation system of supply.

(A) CROP PATTERN

Assumption of a certain crop pattern is necessary when formulating an irrigation project. To be realistic this has to be in conformity with local soil and climatic conditions. Choice of crops will further depend upon the requirements and availability of labor, possible double cropping, local food habits, water availability and economic returns to the farmer. Adequate water supply will permit growing of two seasonal crops, such as long-staple cotton. Where a perennial supply is available, cash crops like sugarcane and bananas can be grown. In order to minimize costs and transmission losses in canals, such heavy water using crops when cultivated with others are best restricted to the upper reaches.

Table 2 shows irrigation seasons and crops in a typical Indian state, Maharashtra.

TABLE 2

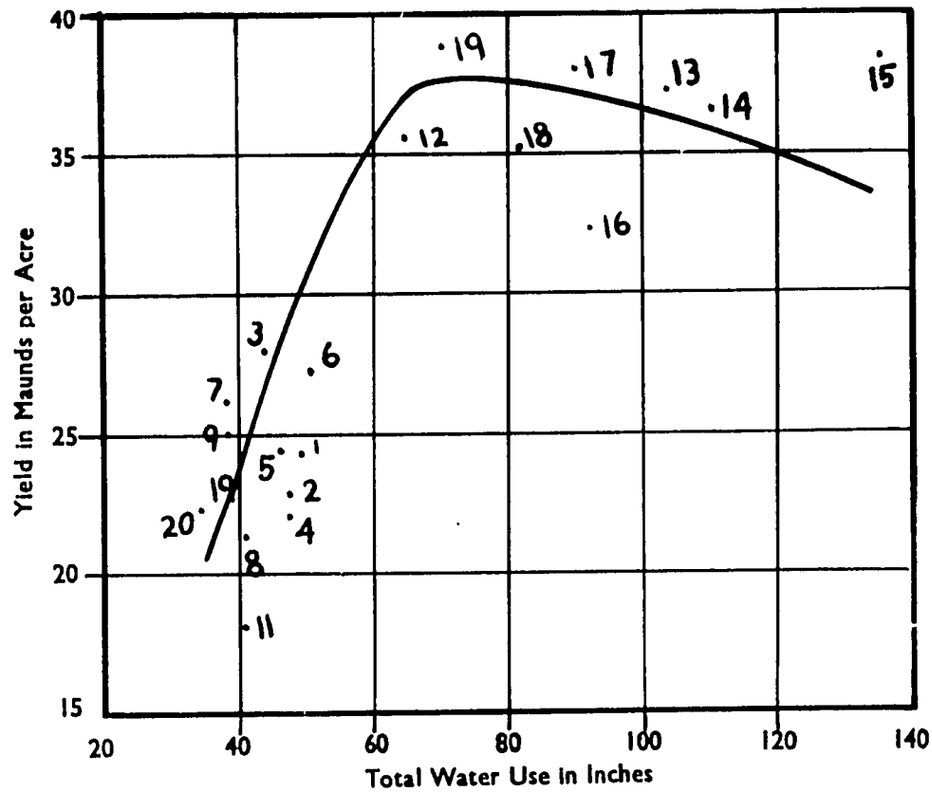
SEASON	BASE PERIOD	USUAL CROPS
Kharif	June 15-Oct. 14	Paddy, Groundnut, Sorghum, Maize, Vegetables.
Rabi	Oct. 15-Feb. 14	Wheat, Gram, Maize Sorghum, Vegetables.
Hot weather	Feb. 15-June 14	Maize, Groundnut, Fodder.
Two seasonals	June 15-Feb. 14	Chillies, Onions, Turmeric, Cotton, Tobacco.
Perennials	12 months	Sugarcane, Garden crops.

(B) WATER REQUIREMENTS

Irrigation in essence is a method of soil moisture control for crop production. This crop-water relationship is dependent on a number of factors, such as type and texture of soil, climatic condition and temperature variation. Evaluation of each one of these is a matter for research. Experimental farms are therefore usually set up in the command area of large projects to determine this relationship for typical climatic and soil zones. Irrigation and fertilizer requirements of crops, critical periods of crop growth in the context of soil moisture and other relevant agricultural aspects are also studied in such trial-cum-

demonstration farms. One more factor that needs due consideration at the planning stage is the contribution of rainfall in the command area to crop growth and the reduction to be allowed on that account.

Generally, experimental assessment of the duty on crops is made, both for the maximum yield and for the most economical use of water. Experiments carried out for the rice crop at a government agricultural farm in Uttar Pradesh in a particular season revealed that yield rose sharply with increasing water use up to 70 inches, after which it started falling gradually. Such experiments have proved that over-irrigation not only leads to wastage of water but also results in reducing yield. The following graph is illustrative :



Water Requirements of Rice - Variation of Yield with Total Water Use

Experiments at the farm in 1962 had indicated that the delta for maximum yield was about 64 inches, whereas for the most economical water use it was 58 inches. Where water resources are short of total needs, a careful decision must be made whether to use water for optimum production per unit of water rather than per unit of land.

It is not only the total watering, however, but proper dosages at appropriate times that affect the yield. Experiments conducted on dwarf wheat varieties at the Indian Agricultural Research Institute, New Delhi, revealed that irrigation at the crown root initiation stage was critical, and that a delay of two weeks resulted in a yield reduction of about nine maunds per acre. Table 3 shows the effect of irrigations at different stages of the growth of dwarf wheat.

TABLE 3

Treatment	Stages of Growth						Total Irrigations	Yield mds/acre
	Crown Root	Late Tillering	Jointing	Boot	Flowering	Dough		
1	1	1	1	1	1	1	6	51.4
2	1	1	0	1	1	0	4	51.3
3	1	1	0	0	1	1	4	52.3
4	0	1	0	1	1	1	4	44.0
5	0	1	1	1	1	0	4	45.2
6	0	1	0	1	1	0	3	42.3

C.D. at 5% = 5.9

1 indicates irrigation given ; 0 indicates irrigation not given.

(C) INTENSITY OF IRRIGATION

The total culturable area in India at present is about 480 million acres, of which nearly 390 million acres (gross) are cultivated. The total usable surface water resources have been estimated at about 450 million acre-feet, against the total resources of about 1,356 million acre-feet. The gross area that can be provided with irrigation facilities by using available surface and ground water resources has been assessed at about 200 million acres—145 million acres by surface flows and 55 million acres by ground water. These figures are likely to increase when more detailed assessment of surface and ground water resources and their use is made.

Intensity of irrigation is the ratio of the area irrigated to the actual irrigable command. Since the water resources of the country are not sufficient to irrigate the available land, the intensity of irrigation generally adopted is less than 100. This implies that the entire culturable area in the command is never provided with irrigation facilities in any particular year. Providing irrigation to a smaller or larger area is essentially a socio-economic problem, to be viewed in the context of the large proportion of the population that derives its sustenance from the land. Extensive irrigation by covering more culturable command at a somewhat lower area intensity benefits a greater number of cultivators.

This does not imply that less water than is required for plant growth is delivered in the canal system, but that water is not given to the total holding of any one owner, the criterion being maximization of agricultural production with the most economical use of water as determined by experiments.

Where adequate water resources are available and soil conditions are suitable for raising two or three crops without creating water-logging and salinity problems, intensive irrigation can and should be envisaged. Each case, however, has to be decided on its own merits and no hard and fast rule can be laid down.

(D) ROTATION SYSTEM

In the case of canals, rotation means periodical concentration of the irrigation supply in a particular reach. The time interval between two waterings may be termed the rotation period. This depends on the type of crop, the soil condition and the climate. Thus, in the state of Maharashtra, for instance, while sugarcane can stand an interval of about 12 days during the monsoon and 14 days in winter, it must be watered every 10 days in the hot weather. The number of waterings required on an average for various crops is given in Table 4. These may vary from project to project.

The rotational periods will depend upon the

needs during the various stages of crop growth and the moisture deficiency in the soil.

TABLE 4

CROP	WATERINGS
Sugarcane	30 to 35
Kharif crops (groundnut, bajra, etc.)	2 to 3
Wheat and other rabi crops	3 to 4
Two seasonals	10 to 13

Integrated Use of Surface and Ground Water

In the context of the introduction of high-yielding varieties of crops, the existing canal systems may need some remodeling and a supplemental source of supply to provide for timely dosages of water and adjustments in irrigated acreages. Ground water is a very suitable supplemental source for this purpose.

Most of the irrigation systems in India consist of unlined canals, from which there is a considerable loss of water due to seepage. The magnitude of these losses is variable and depends upon the type of soil. These losses provide considerable recharge to the ground waters. A coordinated use of canal and ground waters by shallow wells and tubewells in the project command not only helps in extending irrigation but also in keeping the water table low, and thereby works as an anti-water-logging and anti-salinity measure.

Water Management System in India

There are three methods in vogue in India for the control and supply of irrigation water to farmers.

In the southern states, water is supplied to specified areas included in the localization scheme. Under this scheme a soil survey of the command area is carried out, and areas suitable for various crops, such as sugarcane, irrigated wet and dry crops, etc., are delineated. Only such crops as are prescribed for these areas may then be cultivated. The supply of water to such areas, therefore, follows the needs of a fixed crop pattern.

In the states of Gujarat and Maharashtra, the farmer in the command area has to decide in advance what crops he would like to grow, and must apply to the irrigation engineer for sanction of his crop proposals. Such sanctions are granted according to water availability and the irrigation policy of the state for the year. Heavy water using crops like sugarcane, bananas, etc. are usually restricted on the basis of soil suitability, topography and natural drainage facilities. This considerably helps in checking damage through water-logging.

In the northern states of Punjab, Uttar Pradesh, etc. water is supplied to the farmers on an areawise basis. The share of each farmer is proportional to the area as part of the total culturable command of the outlet. There is no restriction on the farmer as to the crop to be grown and its extent, so long as the water drawn by him is within his fixed share.

Each of these systems has a historical development growing out of local conditions. It has been proposed that they should be examined in greater detail, so as to evolve a method suitable for different regions and conforming to present day improved agricultural practices within the framework of the new agricultural strategy.

WATER MANAGEMENT AS PRACTICED BY THE EAST GHOR IRRIGATION PROJECT

by
Fahd Natur*

Once an irrigation project is properly designed and constructed its success depends on the way it is operated and maintained. With this understanding, the water management aspect of the East Ghor project was given due importance in planning and execution.

The main objective of proper water management practices is to give water where it is needed, when it is needed and in the amounts needed. Unfortunately, this objective is always met with the extra costs of constructing and operating irrigation works built to operate on the basis of a free demand system. That is why the East Ghor project settled for a modified demand system.

In this system the farms have a weekly turn for irrigation. They can get water for 6 hours, 12 hours, 18 hours or 24 hours, and they can take any discharge they request up to the maximum considered manageable by a farmer: 35 liters/second for furrows and 50 liters/second for borders. The farmers have to apply for the water, which is measured at the farm delivery boxes (constant head orifices) when they get it. They are charged for water consumed on a volumetric basis at the end of each month. They pay one fil per cubic meter for the first 1,800 cubic meters per dunum per year, and two fils per cubic meter for any excess. (1 U.S. dollar = 350 fils; a dunum = ¼ of an acre). This water charge is only to meet the operation and maintenance cost of the project.

Appendix "A" contains the text of the water ordinance and Appendix "B" gives details of the procedure of water distribution.

To do this work we divided the project area into four sections of about 30,000 dunums each. Each section has a watermaster who is a college graduate in agriculture. Three of our watermasters have degrees in irrigation science and the fourth has a degree in general agriculture. Each watermaster has under him four ditchrider advisors and 35 to 42 ditchriders. A ditchrider is responsible for 50 to 60 farm units to which he delivers water within the week.

The ditchrider has a beat of about four kilometers, and is responsible for supervising this

* Head of Operation and Maintenance Division, Natural Resources Authority, Amman, Jordan.

beat twice within his 12-hour shift, using his own bicycle. On-the-job training for ditchriders is constantly carried on by the watermasters. Training of farmers in the proper amounts of irrigation water and the measurement of water is also the responsibility of the watermasters.

A farmers' advisory committee, organized from among the farmers of the project area, meets with the director of the operation and maintenance division and the watermasters every three months to discuss water management. This committee serves to maintain good relations with the farmers, and to train them to take over responsibility for the operation and maintenance of the project in the future.

APPENDIX A

ORDINANCE NO. 89 FOR THE YEAR 1966, EAST GHOR CANAL IRRIGATION PROJECT, WATER ORDINANCE

Issued in accordance with Article 68 of the Natural Resources Authority, Temporary Law No. 37, for the year 1966.

Article I. The ordinance shall be called "The Water Ordinance for the East Ghor Canal Project for the year 1966" and shall be implemented from the date of its promulgation in the Official Gazette.

Article II. The following words and expressions shall have the meanings assigned to them herebelow, unless the context indicates otherwise.

(a) "Authority" means the Natural Resources Authority.

(b) "Vice President" means the Vice President of the Natural Resources Authority.

(c) "The Law" means the Natural Resources Authority, Temporary Law No. 37, for the year 1966.

(d) "Project Area" means the East Ghor Canal Project Area designated by paragraph No. 14 of Article No. 2 of the law.

(e) "Farm Unit" has the same meaning it has in the law.

(f) "Land Owner" or "Lessee" signifies the same meaning defined in the law.

(g) "Jordan River" means the natural and historical watercourse of the River Jordan.

(h) "Land Classification" signifies the meaning defined in the law.

Article III. The Authority shall be considered as the only body empowered to provide the project area with water necessary for irrigation, and distribute the same to farm units situated within the project area.

The Authority shall be also empowered to maintain and administer the irrigation and drainage systems in the Project Area in the light of the State Water Policy. No one other than the Authority shall have the right to carry out any of those works without obtaining the Authority's written approval to this effect,

Article IV. All surface and underground waters lying within the Project Area and feeding the Project Area, whatever their sources and the purpose for which they are used might be, shall be considered subject to the Authority's supervision and control.

Article V. The Authority's Board shal. specify the cropping pattern after seeking the advice of the Minister of Agriculture in respect of the Project Area.

Article VI. The fiscal year in respect to the project shall be regarded as the period falling between the first of January and the thirty-first of December of the same year.

Article VII. The planting of bananas and generally all other trees, rice, sugarcane and perennial fodder plantations, and the culturing of fish shall be subject to a permit issued by the Vice President.

Article VIII. Application for a permit to

plant the crops stated in Article VII shall be submitted to the Vice President, who shall have the right to refuse the issuance of the permit or decrease the area to be planted to the limit which he considers proper, without giving reasons. In case the applicant objects to the Vice President's decision the matter shall be transmitted to the Authority's Board, whose decision in this respect shall be final.

Article IX. In case the quantities of water available at the project area decrease, the land owner, holder or lessee shall not have the right to claim any compensation consequent to such decrease.

Article X. In case the water available exceeds the requirements of the Project Area, the Vice President shall have the right to sell water to applicants from among the farmers of the project area or the adjoining areas, for seasonal plantations, at the price decided in this ordinance and in quantities which do not prejudice the rights of the farmers of the Project Area, provided that the costs of water withdrawal should be at the applicant's expense. In this case a water purchaser has no right to claim any established water rights or any compensation if the Authority ceases to sell him any water, for any reason whatsoever, in excess of what it agreed to sell him for the irrigation of his lands and plantations. Besides, he shall also have no right to plant bananas, fruit or forest trees whatever their kind might be, as also he shall have no right to plant any perennial feed plants, such as alfalfa and similar or others, long-term plantations or water consuming plantations.

Article XI. The Authority shall have no right to sell its waters to farmers referred to in Article X except after ensuring the water requirements of the project area.

Article XII. Agreements for the sale of water between the Authority and those who apply for it shall be drawn up according to an official form stipulated by the Vice President.

Article XIII. The Authority shall not be held responsible for any damages caused to lands, crops or plantations, or all of these taken together, as a result of floods, change of water qualities or quantities or other reasons.

Article XIV. No one other than the Authority shall have the right to use the wasteways, the main canal, the laterals or the waters in the Project Area without obtaining the Vice President's written approval to this effect.

Article XV. Land classes 1,2,3 and 4 are considered to have the priority right in irrigation in the Project Area. No lands other than those of the above classes shall be irrigated, except after the Authority will decide their reclassification.

Article XVI. It is not permissible to pump water from the Main Canal except according to a decision to be taken by the Authority's Board.

Article XVII. It is not permissible to drill wells in the Project Area for obtaining underground waters except according to a decision to be taken by the Authority's Board.

Article XVIII. It is not permissible to plant rice in the Project Area except after obtaining the written approval of the Vice President, provided that the applicant should first obtain written permission to this effect from the Minister of Health.

Article XIX. In seasons when the flow of the Yarmouk and/or the side-wadis decreases, water shall be distributed among farmers as follows :

1. Lands permitted to plant bananas and citrus trees, and where practically planted with such trees, and other kinds of trees, shall receive daily water due them at a rate not exceeding $14m^3$ per day for every dunum planted with bananas, and $7m^3$ per day for every dunum planted with citrus and other trees.

2. The water quantities remaining in the canal shall be divided equally among lands situated within the Project Area according to their respective irrigable areas. The farmer shall be free to dispose of the water released to him in

planting the area of land he desires with the plantations he selects. However, his attention should be called to the fact that according to information available at the Authority, quantities are apt to gradually decrease. Farmers therefore would not have the right to claim any compensation for their plantations should the project waters fail to provide their requirements.

Article XX. Every land owner or sub-lessee who desires to obtain a quantity of the project waters for the irrigation of his farm units, or for domestic consumption, has to submit an application to the Authority's offices concerned or to the official delegated for this purpose. His application should be on the form specified by the Authority and should indicate thereon his water requirements, the time of delivery, and other information requested by the Authority from time to time. The Authority shall be entitled to provide his requirements in the light of its potentialities and the availability of water, or else reject the same without indicating reasons and without prejudicing the rights granted to the applicant if entitled according to this ordinance.

Article XXI. The Authority shall have the right to collect charges on the delivered waters as detailed in Article XXII of this ordinance and in compliance with the conditions put, and the instructions issued, by the Authority from time to time. If a land owner or a sub-lessee delays, or refrains from payment of these water charges at the appointed times, or if he contravenes any of the Authority's conditions or instructions, the Authority shall have the right, in addition to all other rights granted to it according to laws and regulations in force, and after allowing him the period of time it deems appropriate for rectifying his fault, to withhold water from him without being held responsible for the consequence of such withholding.

Article XXII. The Authority will charge for water as follows :

(a) 1-1800 m^3 per dunum per year, one fil per cubic meter

(b) Two fils per cubic meter for any excess.

Article XXIII. Every farmer who intends not to crop his farm or a part of it during a cropping season (summer or winter) shall inform the Authority before the start of the season and shall pay to the Authority 300 fils for every dunum he intends to leave fallow. If the Authority finds out that a farmer did not crop his farm or a part of it without informing the Authority he shall pay 500 fils for every dunum left fallow. Also, if the Authority finds out that a farmer left as fallow a larger area than he informed the Authority he intends to leave as fallow, then he shall pay 500 fils for every dunum left fallow instead of 300 fils.

Article XXIV. The Authority shall charge for the water used for seed-beds, for domestic use, or for industry according to the rates that the Authority designates from time to time.

Article XXV. Lands situated in the Project Area and withdrawing their water from the Jordan River shall be subject to the provisions set up by the Authority's Board for this purpose from time to time.

Article XXVI. The Vice President shall have the right to issue the instructions necessary for enforcing the provisions of this ordinance.

APPENDIX B

OPERATION

General

1. Water will be delivered to a farm unit after the Notice of Water Delivery for the farm unit is signed by the owner of the unit and by the Director of the Water and Maintenance Division. This notice is completed after the farm unit is allotted to the new owner.

2. Water will be delivered to a farm unit that is not yet allotted to a new farmer after a Temporary Agreement is signed by the old owner of the land and by the Director of the Water and

Maintenance Division. The Temporary Agreement is completed after the old landowner applies and the old ownership is checked by the Lands Division of the East Ghor Canal Authority.

3. Water is delivered to each farm unit once weekly (weekly rotation basis). Each farm unit has a regular turn on a designated day of the week.

4. Water will be given to lands which are not parceled into farm units and which had previous water rights from the side streams projects, in quantities equal to their previous water rights, free of charge. Water in excess of the previous rights can be sold to these lands after completion of a Temporary Agreement as described in paragraph (2) above. This arrangement can be followed until the Water and Maintenance Division receives the completed laterals and structures in each area from the construction forces of the East Ghor Canal Authority. After laterals are completed, all water delivered will be sold for standard charges to the farm units.

5. Water will not be delivered to any farm unit that does not have an official Notice of Delivery or a Temporary Agreement as described above. The Watermaster and the Operation Clerk of each section are responsible to deliver water in the manner prescribed above.

6. Water will not be delivered to any farm unit unless an application for water is submitted by the owner or the person officially authorized by the owner. The authorization of an individual other than the owner must be filed at the headquarters office of the division and must include the designated period the individual is authorized by the owner, to prevent involving the Water and Maintenance Division or East Ghor Canal Authority in any legal disputes between the two parties. In all cases the owner is responsible for payment of water charges.

7. The applicant for water can request delivery of water for periods of six hours, twelve hours, eighteen hours or twenty-four hours. The Water and Maintenance Division has the right to change the periods requested if this is deemed necessary.

8. The applicant for water will be given the quantities of water he requests if water availability and the system capacity permit. The Water and Maintenance Division has the right to alter the quantities requested if this is deemed necessary.

9. Diversion of water from one farm unit to another through the lateral system is not permitted unless the first unit cannot be irrigated completely from its own delivery box.

10. Diversion of water from one farm unit to an adjacent unit is permitted if the owner of the two units is the same person, and if this diversion is done within the lands of these farms units, and if this diversion does not conflict with any of the rules and regulations of the Water and Maintenance Division.

11. A farm unit will be denied water delivery for one or more of the following reasons.

(a) Failure of the owner to pay the water charges during the specified period for payment. In this case when the water application passes the water charges accounting clerk, he will write on any application of the owner who did not pay within the specified period "did not pay" and sign it. Any such application will not be processed. The Accountant and the Watermaster are responsible for supervision of this action.

(b) If the owner or the operator of the farm unit tampers with the gates or steals water.

In this case the Ditchrider shall send an immediate report to the Watermaster through the Ditchrider's advisor. All the stolen quantities of water will be charged to the unit and water delivery to the farm unit will be denied until the owner or operator comes and meets the Watermaster at the office of the section and the necessary measures are taken. The water delivery will be denied for a minimum period of at least one week.

If the same owner or operator steals water a second time, the Watermaster shall deny him water delivery until the owner or operator comes to the headquarters office of the division and meets with the Director of the Division or his assistant. He will be charged for all stolen water and the case will be sent to court. The water delivery will be denied for at least a one week period.

If the same owner or operator steals water for a third time he will be sent to court, charged for all the stolen water, and his unit denied water delivery until he reports to the Vice President of the Natural Resources Authority in Amman.

(c) If the owner or operator of the farm unit tampers with, endangers or damages any of the canals, drains, structures or rights-of-way, water delivery will be denied to his farm unit upon the written instructions of the Director of the Water and Maintenance Division or his Assistant. This denial of delivery will continue until the owner or operator returns everything to its original state. A complaint against him will also be sent to court.

(d) If the owner or operator of the farm unit misuses the water and this water floods the roads, canals structures, or adjacent farm units or erodes the soil, the Ditchrider shall report this to the Watermaster who shall deny water delivery until convinced that the owner or operator has performed all the necessary work needed for the proper use of water without causing damages.

(e) If the owner or operator of the farm unit uses the irrigation water to irrigate class 6 lands that do not have water rights, the Watermaster shall indicate the class 6 lands without water rights in his section to the Ditchrider.

12. If a farm unit does not receive the water on its regular turn for a reason that is the responsibility of the owner or operator, it will not be given the water until its turn in the following week.

13. Farm units denied water delivery will be given water on their turns if the reason for denying the delivery is removed and all the necessary measures are taken.

14. Water for seedbeds : If a farmer takes water from the lateral for small seedbeds, using a pail or the like, this water will be free of charge. If, however, he wants to get this water from his delivery box completely on demand he will be charged five fils per cubic meter for this water.

15. The Watermaster can give water to a farm unit twice a week (if the operator requests) if the farm unit is cropped with short rooted crops that cannot tolerate a weekly rotation, such as lettuce and cucumber, or if it has newly planted small seedlings.

16. Water for non-agricultural uses will be permitted only after submitting an application and receiving approval from the Vice President of the Natural Resources Authority.

17. If more than one owner shares a farm unit they should all sign the Water Delivery Notice and designate one of them to be the only person who will apply and pay for water. Such action does not exempt any shareholder from payments of water charges.

Application for Water

1. When applications for water are completed, they should be put in the mail boxes provided for this purpose along the Main Canal or laterals prior to 12 : 00 o'clock noon at least two days before the rotation turn of the farm unit.

2. A separate application should be filed for each farm unit.

3. An applicant for water can alter or cancel his application prior to 11: 00 a.m. of the day that precedes the rotation turn of the unit.

This alteration or cancellation should be made by the applicant personally at the office of the section.

4. Late applications are not processed.

5. All information required in the application form should be filled in the form.

Collection of Applications

Water applications are collected from the mail boxes after 12:00 noon every day. The Watermaster in each section sends his car to collect these applications.

Processing of the Applications

1. The Operation Clerk in the section organizes the applications and puts the applications for each lateral together. He checks the applications to insure that they have properly applied for their rotation turn.

2. The Operation Clerk stops the processing of all applications for units for which he has written instructions of water delivery denial

3. The Operation Clerk transfers the processed applications to the Water Charges Accounting Clerk who checks them and writes "did not pay" (with his signature) on any application of owners who did not pay the water charges within the specified period.

4. The applications are returned to the Operation Clerk who stops the applications marked with "did not pay".

5. The Operation Clerk adds up the quantities of water applied for on each lateral. If these quantities exceed the capacity of the lateral, the Watermaster shall give the licensed permanent trees their minimum requirements as a first priority according to the "Water Ordinance", and then shall decrease the amounts requested for other crops by a certain fixed percentage.

6. The final quantities of water applied for are entered into the Main Canal Form, and each Watermaster shall telephone the head of the operation section in the main office at 11:00 a.m. every day giving him the total quantities of water requested in his section for the next day. If the total quantity of water requested by the three sections is more than the quantity of water expected to be available from the Yarmouk River and the Authority shares in the side streams, the head of the operation section shall decrease the amounts requested by each section by different percentages, depending on the areas of licensed permanent trees in each section which shall be given their minimum requirements at any time according to the "Water Ordinance". After doing this, the head of the operation section shall telephone each of the Watermasters not later than 12:00 noon giving him the final quantities of water that will be given to his section.

7. The Side Streams Supervisor shall submit a daily report to the head of the operation section prior to 10:00 a.m. every day, stating the amount of water expected from each side stream the next day and indicating the stations of diverting this water into the Main Canal.

8. The final quantities of water scheduled, plus 10-20% excess for losses, are entered into the Main Canal Form which is then signed by the head of the operation section.

Issuing the Irrigation Schedule (Irrigation Order)

1. The completed and signed Main Canal Form is given to the Main Canal Inspector.

2. The Main Canal Inspector opens the tunnel gates the proper opening and regulates the openings of the check gates along the Main Canal and checks the openings of the lateral turnouts. The lateral turnout disc discharges are entered into the Main Canal Form under the heading of "actual water quantities".

3. The completed form signed by the Inspector is returned to the head of the operation section.

4. The Main Canal Inspector shall supervise and check the work of the gate tenders and make sure that the level of water in the Main Canal is kept always up to the free-board limit and that there is no major fluctuation in this level.

5. Whenever any of the wasteways are opened, the time of opening and closing, size of opening and head upstream of the wasteways gate shall be recorded on the form provided for this purpose.

6. During normal operation, only the last wasteway will be used for releasing any excess water. The tunnel sluiceway and Wadi Qarn sluiceway (if there is bed-load at these sites) shall also be used. This arrangement does not apply in times of emergency.

7. Whenever a wasteway is opened, care must be taken that the level of water in the Main Canal is not lowered quickly. When the Main Canal is being emptied, it is allowed to lower the water level in it by 30 cm. each day. Lowering the water one meter every 24 hours is allowed only in critical cases and when the soil behind the lining is not saturated with water. In these cases the Director of the Division or the Maintenance Engineer shall be consulted.

8. When the Main Canal is being filled, it is allowed to raise the water level in it one meter every 24 hours.

Water Measurement at the Lateral Turnouts

1. The Ditchrider is responsible for the opening of the lateral turnout to discharge the quantities of water provided in the Irrigation Schedule for this lateral.

2. The Ditchriders' Advisor will check lateral turnout discharge measurements daily, and submit reports to the Watermaster.

3. The Main Canal Inspector will also check lateral turnout discharge measurements.

4. The responsible Ditchrider will be reprimanded if the above lateral discharge measurements as checked in 2 and 3 above are different from what is directed in the Irrigation Schedule.

Measurement of Water Delivered to Sublaterals of a Lateral System

1. The Ditchrider responsible for a lateral system will open the gate of the sublateral and measure the water needed for the farm units on this sublateral according to the instructions in the Irrigation Schedule.

2. The Ditchriders' Advisor will check these measurements.

Measurement of Water Delivered to Farm Units

1. The Ditchrider will open the gate of the delivery box for the farm unit and measure the water delivered.

2. Only the farm units listed in the Irrigation Schedule shall be delivered water and in the amounts instructed in the Irrigation Schedule.

3. The flow of water in the lateral shall be checked downstream of an opened and operating delivery box up to a point lower than the berm by 5-8 cm.

4. When the Ditchrider delivers water to a farm unit, he shall immediately record the time and size of the opening and the operating head directly on the Daily Field Report Form that he has. These forms are serially numbered, and erasing, scratching or writing in pencil on these is strictly forbidden. Destruction of any report is forbidden and writing the official report on scratch paper is forbidden. Any corrections in these forms shall be signed. The Ditchrider shall also write on this report the following :

"According to Irrigation Schedule No..... dated....." and fill in the number and date.

These reports are subject to unscheduled checks by the Ditchriders' Advisor, the Watermaster, the Director of the Division or the Assistant to the Director.

5. The Ditchrider shall inspect the water in the lateral within his beat to insure that the gates are not tampered with by unauthorized persons, and to insure that only the farm units mentioned in the Irrigation Schedule receive the water.

6. The Ditchrider shall check the measurements of water delivered to farms within his beat

at least twice during the irrigation period.

7. The Ditchrider shall clean the delivery boxes and remove any debris before delivering water so that the measurement of water is correctly made.

8. When closing the delivery box the Ditchrider shall record the exact time of closing and shall close both the front and rear gates.

9. Some gates have been damaged by misuse, such as forcing the closing of a gate with stones or debris beneath it. Any Ditchrider who misuses or damages a gate or leaves one of the two gates open will be punished.

Control and Checking of Measurements of Water to Farm Units

1. The Ditchriders' Advisors and the Watermasters and their assistants shall check the water measurements to farm units by unscheduled checks. The person doing the checking shall make sure that the water is measured and recorded properly.

2. The Ditchrider will be punished if the water delivered to the farm units for which he is responsible is not equal to what is listed on the Irrigation Schedule, or who in his Daily Field Report enters different quantities from the quantity actually delivered.

3. The Director of the Division, the Assistant to the Director or the head of the operation section will carry out unscheduled (surprise) checks, to check measurements through lateral turnouts, main canal gates and farm delivery boxes.

4. A Ditchrider will be punished if he delivers water to farm units not mentioned in the Irrigation Schedule, or if he does not give or stops the water of a farm unit that is mentioned in the Irrigation Schedule unless this is done as a protective maintenance measure in the case of an emergency such as when the water endangers canals, structures or property.

5. The Ditchriders' Advisor shall check the calculations in the completed Daily Field Report and deliver these reports to the Watermaster not later than 24 hours after completion of an irrigation. The Watermaster reviews these and transfers them to the Accounting Clerk who shall also check them again and register the amounts of water delivered. The final amounts of water delivered are given to the Water Charges Clerk who enters the amounts and charges into the special registers.

Issuing the Water Charges Bills

1. The water charges bills shall be prepared by the Accounting Section and checked by the Auditing Clerk and the Accountant not later than the tenth day of the month for the water delivered during the preceding month.

2. The signed water charges bills will be given to the Ditchriders to distribute to the farmers. The Ditchriders shall distribute them within a week of their receipt and request the farmer to sign that he has received the bill.

3. Water will not be given to the farmer if he does not pay his bill within 30 days from the time he receives the bill (the time of action is calculated as 30 days after the week allowed for distribution of bills).

Record Keeping

1. The Accounting Section shall keep its records according to accounting regulations of the East Ghor Canal Authority and the Government.

2. The water records clerk shall receive the reports of the quantities of water delivered to farm units on each lateral daily from the accounting clerks in the section. He shall compare these to the quantities delivered to laterals through the lateral turnouts and shall keep a record as shown below:

Lateral No.....

Date water delivered to lateral	Water used on farm unit from lateral	Efficiency %

3. The Water Records Clerk shall keep a record as shown below :

Date	Water from Yarmouk	Water from side streams	Total water in main canal	Release from waste-ways	Diversion to lateral turnouts	Main Canal efficiency	Total water used on farms	Overall efficiency

4. The Water Records Clerk shall also keep a third record as shown below :

Date 12.....

Diversion from Yarmouk
Remaining in Yarmouk
Total in Yarmouk
Percentage of diversion
Diverted from side streams
Total water in Main Canal
Water scheduled for 1st. section
Water scheduled for 2nd. section
Water scheduled for 3rd. section
Total water scheduled
Water consumed in 1st. section
Water consumed in 2nd. section
Water consumed in 3rd. section
Total water consumed
Water released through wasteways
Water losses
Percentage of consumed to scheduled
Percentage of consumed to diverted

FORM : WMD/1

WATER APPLICATION FORM

Date———————

Name of Farmer———

Farm Unit No ——— Lateral No.—

Discharge Requested (l/sec.) Period Requested (hours)

Development Area—

Area to be Irrigated———————Total Quantity of Water———————

Crop : Bananas——Dun.; Citrus——Dun.; Vegetables———Dun.; Cereals——Dun.

Date of Irrigation———————————

I will follow the rules, regulations and instructions of the East Ghor Canal Project and I will pay the water charges upon notification.

Signature of Applicant

FORM : WMD/2

Irrigation Schedule for lateral no. _____ Development Area _____

To : _____ Date_____

You are instructed to deliver water according to the schedule shown below, and to report your daily work and measurements on Form WMD/3

Farm	Delivery Box No.	Name of Owner	Total Quantity M^3	Discharge l/Seo.	Irrigation Period		Notes
					From	To	

Name of Clerk_____ Signature of Water Master

Signature _____ _____

FORM : WMD/3

OPERATION & MAINTENANCE DIVISION

Date _____ Development Area _____

Ditchrider _____ Lateral _____

Daily Field Report of Water Deliveries

Farm/ Unit no.	From hour	Opening cm.	Head cm.	To hour	Dis-chargs l/sec.	Time charge open sec.	Water deli-vered M^3	Total water deli-vered M^3	Signa-ture of Farmer	Signature of Ditchrider

FORM : WMD/27

OPERATION AND MAINTENANCE DIVISION

No. ————————

Date ————————

Notice issued by the Operation and Maintenance Division of the Natural Resources Authority.

Subject : Water Charges

To Mr.————————Owner of Farm Unit No.————————
Development Area No.————————

According to Water Ordinance No. 89 for 1966, please note the following :

1. The Authority will charge you for the water delivered to your farm unit as of————at the rate of one fil per cubic meter for the first thousand and eight hundred cubic meters per dunum per year, and at the rate of two fils per cubic meter for the excess over this limit. This is collected towards covering of the annual costs of operation and maintenance.

2. The Authority reserves the right to change these rates from time to time in the light of project development to insure the best possible service to water users and to insure the proper use of water.

3. The Authority has the right to deny water delivery to the lands of the owner or operator if he misuses this precious water in a way that will cause soil erosion, or water waste, or damages to adjacent lands or rights-of-way.

4. According to Article 20 of the Water Ordinance No. 89 for 1966, you have to submit an application for water to the Operation and Maintenance Division, NRA, at the office of the Section indicating the quantity of water you need and the period of irrigation you request. The Authority will do its best to give you your needs within its capabilities and the water availability.

5. Collection of water charges will be made at the end of each month and the Authority has the right to deny water delivery to your lands if you do not pay within the prescribed period.

Director
Operation and Maintenance Division

Signature of Owner

————————————————

Date ————————————

Witness ————————————

cc : Authority Main Office
: Watermaster of Section

WATER CHARGES AND THE ADMINISTRATION OF SYSTEMS BY WATER USERS

by
Kemal Ertunc*

I. Synopsis

Irrigation activities are very important where climate and soils favor the production of various crops in Turkey. The irrigated area in Turkey was about 1.5 million ha. at the beginning of 1968. About 900,000 ha. of this total are irrigated by small installations established by the public, the remaining 600,000 ha. by installations established by the state (See the map attached).

The construction of large and expensive irrigation projects necessary for the development of major water resources cannot be carried out by the public. This is one of the most important functions of the state. About one-third of the investments made by the Government of Turkey have been for the development of water resources. The General Directorate of State Hydraulic Works (DSI) is the largest organization dealing with irrigation. It was established in 1925, and is in the Ministry of Power and Natural Resources, in accordance with Law No. 6200. DSI conducts the investigation, planning, design, construction and operation of works related to the development of water resources. DSI's budget has risen from $12 million in 1954 to $240 million in 1968, a twentyfold increase in 14 years. The total investments made by DSI at the end of 1967 were $960 million, $460 million of which was for irrigation installations. DSI operates 74 irrigation projects of a total value of $420 million. The operation and maintenance costs of these projects in 1967 prefinanced by DSI were $4 million

II. Water Charges

Water charges will be considered in two parts : the yearly amount spent on operation and maintenance of the irrigation systems; and the repayment of investment costs on these installations.

(A) Operation and Maintenance Costs

The irrigation systems constructed by DSI pass through three stages: partial, initial and full operation.

* Head, Statistics Branch, Directorate General of State Hydraulic Works, Ankara, Turkey.

Partial operation starts in some completed units while the scheme is still under construction.

Initial operation occurs during the period of irrigation development and before the end of construction activities. This is about 1 to 10 years, according to Law 6200.

Full operation occurs after the irrigation development has been completed.

The operation and maintenance of DSI irrigation installations is carried out by the division of operation and maintenance. According to the organization law, operation and maintenance costs must be repaid by the users of irrigation installations in the following year.

(1) *Water Charges*

Yearly accounts of personnel and maintenance costs to operate each irrigation scheme are sent by the operation and maintenance division to the general directorate of DSI. These are tabulated at the end of the fiscal year. These costs are approximate, because the actual costs of division operations are not known exactly. A cost-price computing division is being established and should be completed in two or three years. Measures have been initiated for getting the actual costs of operation and maintenance.

In preparing to establish charge rates, the basis laid down in the organization law is used. This fixes a cost per irrigated decare. The operation and maintenance costs of the previous year are estimated on the basis of the area to be irrigated. Thus, operation and maintenance costs are computed on the basis of irrigated decares. Water is distributed on a volume basis. Operation and maintenance costs on volume basis are desirable in order to promote farm irrigation efficiency. But large volume applications cannot be accomplished due to the relatively small plots, and a scarcity of water-measuring equipment and staff who can distribute water on this basis. Although operation and maintenance charges per unit irrigated area in full irrigation are established in the organization law, water charges for operation and maintenance based on a price per cubic meter of water can be approved by the Council of Ministers for the projects which are in the partial or initial operation stages.

In the pumping installations where distribution of water is possible on a volume basis, the operation and maintenance charges are being collected on a price per cubic meter of water. In new schemes, water-measuring equipment is being installed and the water will be measured. In these schemes, distribution and the payment of charges will be on the basis of a cubic meter of water and this will be in the new organization law.

Taking into account the repayment ability of the farmers, irrigation schemes are separated into several groups. For schemes new in operation and those not developed, a low charge is applied, provided the result remains constant. Taking into consideration the yields and water demands of different crops, various rates of charges are applied. The 1968 water charges are listed in Appendix 1.

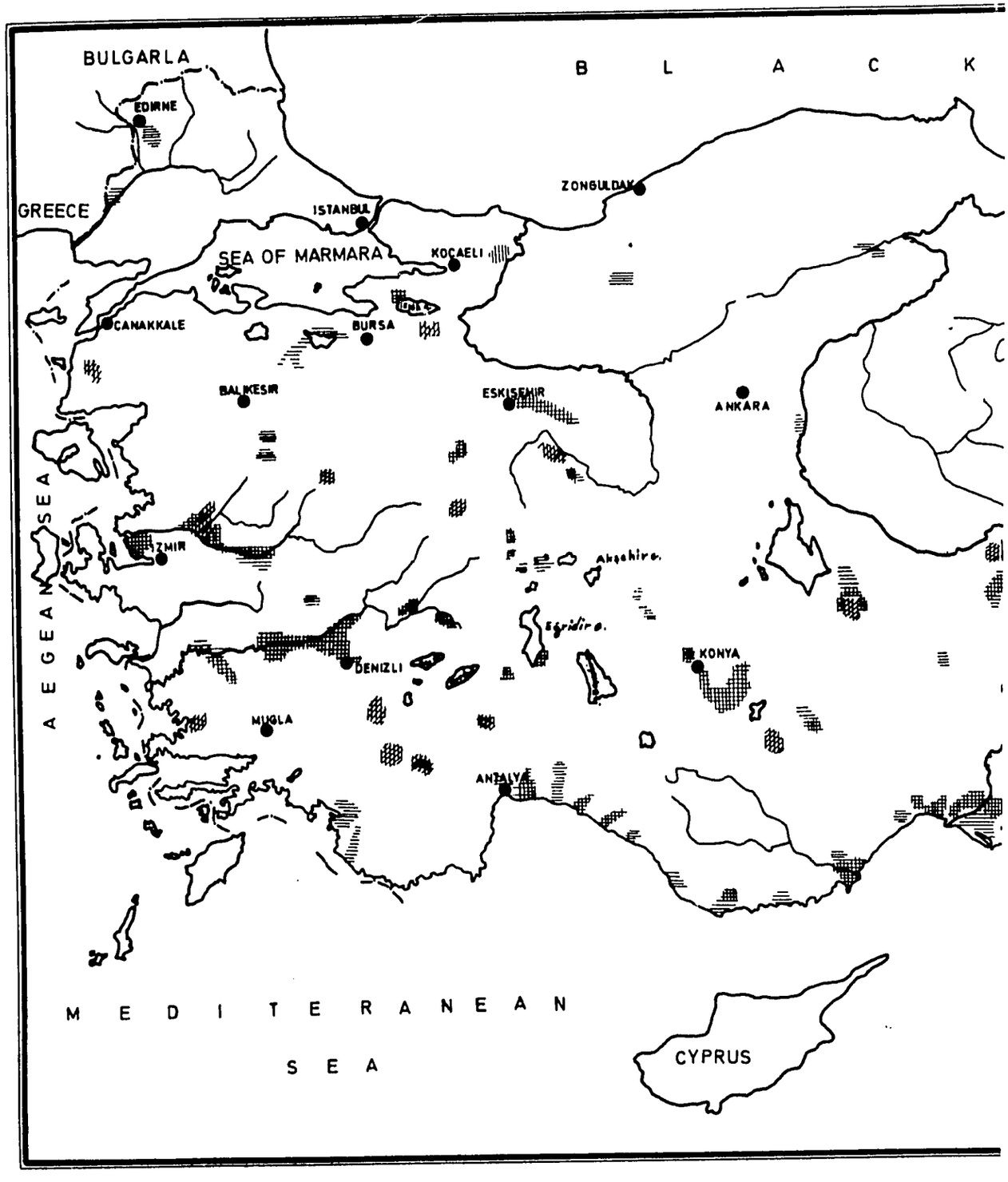
The water charges prepared by DSI are adjusted to about equal the operation and maintenance costs of the previous year. This becomes effective with the approval of the Council of Ministers, which may reduce these charges. The reduction is made by adding the reduced amount to the next year's operation and maintenance costs.

(2) *Land Survey*

The irrigated areas and plant varieties are surveyed during the irrigation season, after the village headmen have been informed in advance by the operation and maintenance division. Surveying of irrigated land is carried out on survey maps, if available. Otherwise the land plots are measured. The schedules prepared at the end of the survey are announced to the villages concerned. The farmers may request that a measurement be repeated. The payment tables are prepared by multiplying the area on the list by the water charges for different crops.

(3) *Realization of Charges and Collections*

The collection activity starts at the begin-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SEA OF MARMARA
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ESKISEHIR
ANKARA
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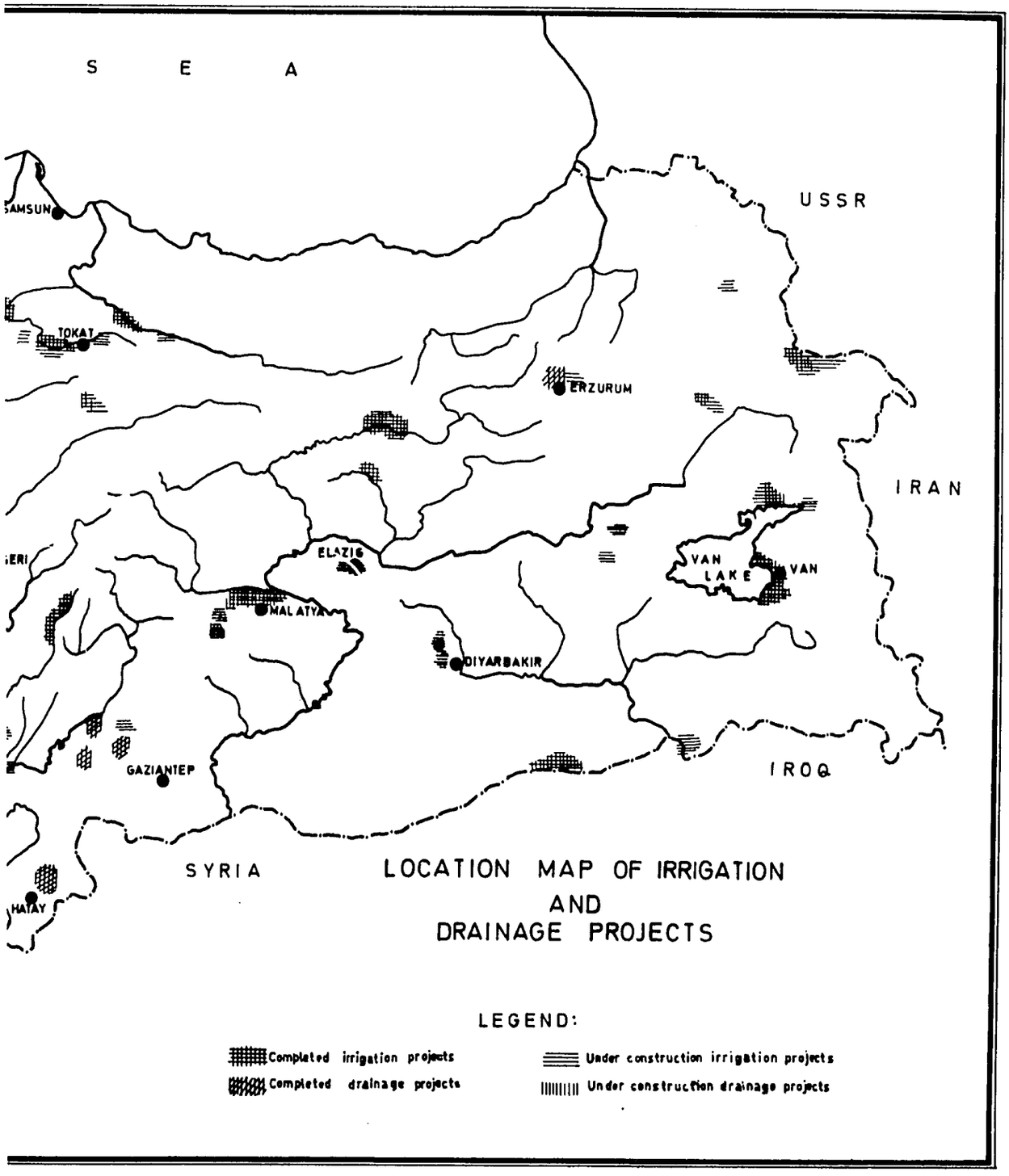

LOCATION MAP OF IRRIGATION AND DRAINAGE PROJECTS

ning of November, which is the end of the harvesting season. The first and second payments are collected in two installments during November, December, January and February. Farmers who do not make their payments within this time are required to pay a surcharge of 10 per cent. The following figures show the outstanding debt and the realization and collection, as of March 1, 1968.

Realization	..	TL. 24,800,000
Collection	..	TL. 20,300,000
Outstanding debt	..	TL. 25,400,000

The rate of collection is relatively low. The main reason for this is the delay of application of the additional debt when the debts are not paid in time. In the new organization law this will be considered.

(4) *Payment in Mass*

The yearly operation and maintenance costs of some small irrigation districts, such as irrigation dams, operated by DSI can be paid in a lump sum by the beneficiaries of these structures. This can be accomplished by a wholesale payment contract concluded between establishments of the beneficiaries and DSI. This method of payment will also be of benefit to the users. A wholesale payment contract provides that the cost of measurement of irrigated areas and the realization of charges and collection costs are not to be included in the operating cost. Therefore, operation and maintenance costs are reduced by about 25 per cent. Wholesale payment contracts have been concluded for five irrigation dams where DSI is responsible only for operation and maintenance. The distribution of water in the irrigation canals is generally carried out by the farmers. The collection of irrigation charges from the farmers is through a concluding contract.

(B) REPAYMENT OF INVESTMENTS

Repayment of investment costs by the farmers is based on the organization law of DSI, which requires farmers to make yearly payments per decare computed by dividing the irrigated area by the repayment period. Repayment of investment costs begins at the end of the initial operation period.

In irrigation schemes for which the repayment decision is established, irrigation area boundaries, repayment period, beginning date of repayment, and whether interest on capital will be accounted for, have to be made clear. DSI has proposed a solution to the Council of Ministers which will assist this matter.

The repayment of investments has started in 16 irrigation projects. In these irrigation schemes, the payment period varies between 16 and 100 years according to the repayment ability of the farmers. Due to the low repayment ability and the low rate of irrigation, interest is not added in the evaluation of investments in the year in which the construction was completed.

The investments for installations do not find place in the repayment decrees. At the end of the repayment period, remaining investment costs which are not paid during this period are covered with new repayment decrees, together with the new investments.

The yearly repayment installment is constant, and is applied to the actually irrigated plots in the irrigation area without regard to the kinds of crops grown. These installments are estimated and collected together with operation and maintenance charges.

In cases where the irrigation project is constructed by DSI and transferred to the water users, the operation and maintenance of installations are carried out by their organizations, which are then required to pay only the investment cost of the installation.

In irrigation projects which are operated by DSI, the yearly investment installments are collected separately from the beneficiaries, like the operation and maintenance charges. In the transferred installations, the yearly investment installments are estimated by dividing the construction cost into the repayment period. This is specified in the transfer contract.

In the repayment of drainage establishments

constructed by DSI, operation, maintenance and investment costs are collected by the same method as in the irrigation projects. There are six drainage installations from which operation and maintenance charges were collected in 1968. A repayment decree for drainage has also been obtained. The operation, maintenance and investment costs made for flood protection and river bed reclamation (navigation) installations are not reimbursable.

III. The Administration of Irrigation Projects by Water Users

Operation and maintenance responsibility starts after the construction of installations and continues yearly. Each project constructed by DSI results in an enlargement of the operation and maintenance department for small installations. This is difficult and expensive. As these projects are completed and the operation and maintenance responsibility of DSI increases, the transfer of this duty to water users' organizations becomes very important.

The transfer of installations constructed by DSI to water users (beneficiaries) is governed by the organization law of the general directorate. It is conducted according to the State Hydraulic Works Installations Transferring Guide, which permits transfers to village organizations, municipalities or irrigation associations.

If only a single village benefits from the constructed installation, it can be transferred to the village organization by a contract. An installation constructed within the boundaries of a municipality can be transferred to that municipality. If more than one village or municipality benefits from a project, it can be transferred to an association set up by these villages or municipalities. An irrigation project which does not have water distribution problems can be transferred to more than one village or municipality in units.

Projects in operation and those under construction schedules can also be transferred to the water users' organizations. Transfer of operating projects is more difficult because of engagements in contracts. In installations that have been completed, the users usually do not want to undertake responsibility for operation and maintenance. Small irrigation schemes can easily be transferred before programming of construction.

The installations are delivered according to a contract between DSI and the water users' organization which becomes effective after being approved by the Ministry of Power and Natural Resources. The transfer contract generally stipulates that :

(1) operation and maintenance will be carried out by the water users' organization;

(2) the property of the installations will remain in the custody of DSI;

(3) the installations will be inspected by DSI;

(4) the maintenance works found necessary by DSI will be constructed by the water users' organization;

(5) the investment costs will be repaid according to the schedule determined by the Council of Ministers.

A copy of a transferring contract containing these provisions is given in Appendix 2.

After approval of the transferring contract by the Ministry of Power and Natural Resources, the structures are transferred to the water users' organization with a protocol describing the characteristics of the irrigation structures.

With the transfer of the installation to the water users' organization, the following advantages are derived:

(1) participation of the public in operation and maintenance responsibility;

(2) proper use of irrigation installations;

(3) higher benefits from the irrigation facilities;

(4) increase of farmers' repayment ability due to the saving of operation and maintenance costs;

OPERATION- MAINTENANCE AND ANNUAL REPAYMENT CHARGES FOR

P R O J E T S	C R O P S	IRRIGATION OPERATION / GROUP 1	GROUP 2	GROUI 3
IRRIGATION OPERATION AND MAINTENANCE CHARGES	Cereal	4	4	5
GROUP 1 (Gravity): Menemen, Amasya	Bean	6	8	8
GROUP 2 (Gravity): M.Kemalpaşa,Bursa-Gebere,Gümüsler,Seyitler Selevir,Yıldırırmagı,Eleskirt,Igdır,Erkenek Kuseva,Tunceli,Van,Ercis,Ortaviran,Gözegöl, Hacikamil,Idil-Dirsekli, Pazarören,Tatlarım Akköy,Sarımsaklı, Köprücay,Bogazova,Alara	Melon	6	8	8
	Sugar beet	12	14	14
	Cotton	10	11	13
	Tobacco	9	11	11
GROUP 3(Gravity) : Karadere,Ezine,Turgutlu,Adala,Nazilli,Sarayköy,Akcay,Hamcalar,Esencay,Kumavsar, Kelekci,Irgilli,Içikli,Eskisehir,Kütahya, Cumra,Uluirmak,Ayranci,Cubuk,Silifke,Seyhan,Berdan, Anamur,Gilindires, Lamas-Kizilgecit,Lamas-Limonlu,Tokat,Erzincan, Malatya,Dogansehir,Elazığ,Nusaybin,Ürgüp, Aksi,Varsak,Ulualan	Aniseed	9	11	11
	Peanut	10	12	12
	Sun flower	7	8	8
	Poppy	6	7	7
	Garden flewer	9	10	10
	Flax	7	8	8
GROUP 4 (Pumping) : Amasya	Sesame	7	8	8
GROUP 5 (Pumping) : Kütahya,Alakova,Gilindire,Silifke,Mersin bahceleri,Vayvayli,Erbaa,Elazig,Sarimsakli, Elmali	Corn	6	7	7
	Rice and sugar cane	25	30	30
GROUP 6 : Alanya (pumping and gravity)	Plant	5	6	6
	Fig-Tree	7	8	8
DRAINAGE OPERATION AND MAINTENANCE CHARGES	Vineyard	6	7	7
GROUP 7 : Amik	Olive-tree	7	8	8
GROUP 8 : Marmaracık,Tekfuranbarı,Gavurgölü, Emen, Mizmilli	Fruit	14	16	18
	Strawberry	13	18	18
IRRIGATION ANNUAL REPAYMENT CHARGES	Citrus	20	20	20
	Banana	33	40	40
GROUP 9 : Menemeh	Vegetable	13	15	17
GROUP 10 : Seyhan	Potato	9	12	12
	Onion and garlic	7	8	8
GROUP 11 : Amasya	Feeding crop	5	5	6
GROUP 12 : Nusaybin	Poplar,eucalptus	6	8	8
	Out of season irrigation	3	3	3
GROUP 13 : Alanya	Water mill (for each mill stone)	500	500	500
	Brickkiln (for each)	350	350	350
	m^3 charge (as kurus 1 lira = 100 kurus)	1	1,2	1,5

MAINTENANCE CHARGE (TL)						DRAINAGE O.AND M. CHARGE		IRRIGATION ANNUAL REPAYMENT CHARGE TL.				
GROUP 4	GROUP 5	GROUP						GROUP 9	GROUP 10	GROUP 11	GROUP 12	GROUP 13
		Gravity	Pumping Step I.	Pumping Step II.	Pumping Step III.	GROUP 7	GROUP 8					
6	8	4	11	19	27	4	6	7	10	11	5	13
9	12	7	15	25	35	4	6	7	10	11	5	13
9	12	7	15	25	35	4	6	7	10	11	5	13
18	21	15	29	39	51	4	6	7	10	11	5	13
15	20	15	27	35	45	4	6	7	10	11	5	13
14	17	12	23	31	39	4	6	7	10	11	5	13
14	17	12	23	31	39	4	6	7	10	11	5	13
15	18	15	31	39	55	4	6	7	10	11	5	13
10	12	15	27	35	45	4	6	7	10	11	5	13
9	11	12	23	31	39	4	6	7	10	11	5	13
14	15	15	27	35	45	4	6	7	10	11	5	13
10	12	10	21	29	37	4	6	7	10	11	5	13
10	12	5	12	23	31	4	6	7	10	11	5	13
9	11	7	15	25	35	4	6	7	10	11	5	13
36	45	37	61	85	115	4	6	7	10	11	5	13
8	9	12	23	31	39	4	6	7	10	11	5	13
10	12	7	15	25	35	4	6	7	10	11	5	13
9	11	5	13	23	31	4	6	7	10	11	5	13
10	12	5	13	23	31	4	6	7	10	11	5	13
21	27	20	35	55	75	4	6	7	10	11	5	13
20	27	29	51	65	85	4	6	7	10	11	5	13
30	30	50	70	160	280	4	6	7	10	11	5	13
35	60	60	90	215	335	4	6	7	10	11	5	13
20	26	35	60	110	140	4	6	7	10	11	5	13
14	18	22	35	51	65	4	6	7	10	11	5	13
10	12	13	35	35	45	4	6	7	10	11	5	13
7	9	5	13	23	29	4	6	7	10	11	5	13
9	12	13	25	37	49	4	6	7	10	11	5	13
5	5	3	11	25	35	4	6	7	10	11	5	13
-	-	500	-	-	-	-	-	-	-	-	-	-
-	400	350	-	-	-	-	-	-	-	-	-	-
4,0	4,0	2,0	4,0	7,0	10,0	-	-	-	-	-	-	-

(5) assuring useful cooperation between the farmers and their organization.

Flood control structures built by DSI can also be transferred to the users. Investments in flood control structures are not reimbursable. The transfer contracts for these structures are different from the others, especially the small flood control structures serving a village or town, which are transferred to the relevant village or municipality. An example of this type of transfer contract is presented in Appendix 3.

As of March 1, 1968, 43 irrigation, 1 drainage and 72 flood control installations have been transferred to the organizations of beneficiaries.

IV. Irrigation Groups

The number of irrigation schemes increases every year. The setting up of associations by users and the transfer of irrigation projects to these associations is not practical for all irrigation schemes. In large projects, the equipment resources and the technical and budgetary strength of the farmers' organizations are not adequate to conduct the required operation and maintenance. The development of improved irrigation practice requires time. Therefore it is necessary for DSI to operate these projects at the beginning of the operation stage.

In the irrigation projects operated by DSI, attempts have been made to transfer the operation of secondary and tertiary canal systems to groups of farmers. Each group elects a representative from among its members, and this representative requests water from DSI operation personnel on behalf of his group and distributes water to their plots. In like manner, he transmits the demands of farmers in his group to the interested personnel of DSI. These irrigation groups are assisting DSI to an important extent, and a saving from the standpoint of operation personnel is realized.

In cases where water distribution is carried out by irrigation groups, the irrigation charges are reduced by 15 per cent below the normal rate, as the secondary and tertiary canal operation costs are about 15 per cent of the total cost.

At present only operating responsibility is given to irrigation groups. The delivery of water from the turnout of secondary and tertiary canals by the irrigation groups results in the possibility of controlled irrigation application.

In all irrigation schemes, especially in canalet systems, these groups are very important and necessary. Group works have been carried out for about three years A total of about 150 irrigation groups have been established in 10 irrigation projects.

Appendix 2

TRANSFER CONTRACT FOR THE ESTABLISHMENTS BUILT BY THE STATE HYDRAULIC WORKS IN THE . . . DISTRICT OF THE PROVINCE OF . . .

Article I : Contract.

The conditions of transfer contract which has been agreed by SHW. . . . . .Regional Director, in the name of the General Directorate of State Hydraulic Works, referred to as the "administration" in the contract, and the . . . . . referred to in the same contract as the "beneficiary".

Article II : Subject of the Contract.

The beneficiary will take over from the administration the . . . . . establishment, built by the administration, by means of a protocol, and operate it.

Article III : Maintenance and Repair.

The beneficiary is held responsible for providing all the services and the necessary expenses with regard to the maintenance and repair of the establishment. The administration has the right to audit all these activities whenever it is . . . . . necessary. When the beneficiary does not fulfill the . . . . . .of the administration, the latter is entitled to provide the above activities and to collect the resulting expenses, without being required to get also a decision from any responsible authority from the beneficiary.

Article IV : Repair and Extension of the Establishment.

The beneficiary will not make any alterations or enlarge the plant without written permission from the administration. If such changes are made without written permission and if the administration decides that the plant should be put back in its original state, the expenses of bringing the plant to its original state will be charged to the beneficiary automatically.

Article V : Operation of the Establishment.

The establishment will be operated in accordance with the transfer protocol by the beneficiary. During the operation, the beneficiary will give all the information demanded by the administration regularly and fully.

The beneficiary during the operation has to correct any faults and shortcomings observed by the administration.

The beneficiary will provide profit only from those plants located on such parts of the land as outlined and shown on the land classification maps.

Article VI : Repayment.

Law No. 6200 requires that the beneficiary has to repay. . . . . .TL. and this amount should be repaid to the administration without any interest charge each year, starting in . . . . not later than the first of December in one payment. However, all these matters become definite only by a decision of the Cabinet.

Article VII : Giving Information.

The beneficiary gives the administration any information it demands at the proper time and without withholding anything.

Article VIII : Transfer to a Third Person.

The beneficiary is not allowed to transfer the rights obtained by this contract to any real or juridical person.

The beneficiary is not allowed to profit those who are not members of the unit represented by the beneficiary from the establishments.

Article IX : Dissolution (Cancellation) of the Contract.

The administration has the right to dissolve the contract if the beneficiary does not observe the requirements of the contract in spite of a written warning. In such a case, the beneficiary will have no right to sue the administration for damages, losses or indemnities, and hands over the establishments to the administration immediately and in full accord with Law No. 6200. The beneficiaries from establishments which require repayment will be made to pay the normal operating and amortization costs that the law demands.

Article X : Water Charges.

The beneficiary implements the water charges concerning the operation, maintenance, repair and amortization costs that it will take from March, after having them approved by the administration. The administration has the authority to make adjustments in these water charges.

Article XI : Contract Expenses.

All the expenditure related to this contract must be paid by the beneficiary.

Article XII : Solution of Disagreements.

The court of . . . . . .has the authority to decide any disagreements that arise from this contract.

Article XIII : To Put into Effect.

This contract is put into effect after it is signed by both parties and approved by the Ministry.

SHW Regional Director.

Note : Both parties accept and undertake to make adjustments in accordance with any laws that might be put into effect in the future as regards water rights and the usage of water rights.

Appendix 3

TRANSFER CONTRACT FOR THE FLOOD CONTROL ESTABLISHMENT BUILT BY THE STATE HYDRAULIC WORKS IN THE . . . . . .DISTRICT OF THE PROVINCE OF. . . . . .

Article I.

The conditions of the transfer contract which are given below have been agreed upon by SHW . . . . . .Regional Director, in the name of the General Directorate of SHW, referred to as the "beneficiary" in the same contract.

Article II.

The beneficiary takes over the . . . . . flood control establishment built by the administration, by means of a protocol, and takes care of its maintenance, repair and protection.

Article III.

The establishment will always be in the possession of the administration.

Article IV.

After the establishment has been transferred to the beneficiary in good condition, the beneficiary will be responsible for its maintenance, repair and protection, and will pay all the expenses for the above.

Article V.

The beneficiary will not make any alterations or enlarge the establishment without permission from the administration. If such changes are made without written permission from the administration, and if the administration wants the plant put back to its original state, the expenses will be charged to the beneficiary automatically.

Article VI.

The beneficiary will give the administration any and all information it demands at the proper time and without withholding anything.

Article VII.

The administration after an annual check up of the establishment will give the beneficiary a written statement of what is required for maintenance and repair. The beneficiary will have to provide these repairs and pay all the expenses, except technical assistance, which will be given by the administration.

Article VIII.

The losses suffered because of negligence of the beneficiary in providing the required maintenance, repair and protection, as was made known by the administration in a written statement, will be paid by the beneficiary.

Article IX.

All the expenditure related to this contract will be paid by the beneficiary.

Article X.

The court of . . . . . will have the authority to adjudicate any disagreements that may arise from this contract.

SHW Regional Director — Beneficiary

WATER CHARGES IN RELATION TO BENEFITS DERIVED

by
M. S. Minhas

Introduction

The area of Pakistan is 365,529 square miles comprising two wings, West Pakistan and East Pakistan. The total land area is about 234 million acres, of which 198.6 million acres lie in West Pakistan and 35.9 million acres in East Pakistan. Agriculture is the mainstay of the economy, considering that 75 per cent of the total labor force is engaged in it and the nation derives three-fifths of its income from this sector. Twenty-five million acres in West Pakistan are under irrigation, which constitutes the largest input of the agricultural sector in this province. Therefore a study of the water charges structure in West Pakistan assumes great importance.

There was a growing disparity between the growing population and agricultural output in Pakistan. There has been a large import of food grains over the years to meet the needs of the growing population. At the same time, intensive use of land and water resources has been planned over the last ten years. Generally, new irrigation projects have been executed in difficult terrain and at much higher costs as compared with projects built from half a century to a century ago. To meet the contingencies of financing the capital and maintenance costs of irrigation projects, water charges have to be realized from the beneficiaries. The higher the capital cost the greater is the stress on beneficiaries from high water rates, which become necessary to balance the burden of increasing capital and maintenance costs. At the same time, the beneficiaries who are still suffering under the legacy of backward agriculture, are bound to react adversely to increased water charges. The purpose of this paper is to bring out the salient features of the problems involved and to propose a rational basis for water charges in relation to benefits derived.

Early History of Financing Irrigation Projects

The capitalist system of financing irrigation projects in the Indian subcontinent began under British rule. Private enterprise and companies formed for financing irrigation projects did not meet with success in British India. The government of those days had the foresight to decide that irrigation projects to be successful should be financed from the public exchequer, and the history

of irrigation development has proved that they were right. The financial results of irrigation projects were tested:

(1) by considering the capital cost of any work to be simply the sum actually spent on its construction ;

(2) by debiting the revenue account yearly with (*a*) the simple interest on the capital cost of the works at the commencement of the year; (*b*) the working expenses of the year;

(3) by crediting the revenue account yearly with (*a*) direct receipts (*b*) indirect receipts, called revenue receipts. The direct receipts consisted of occupiers' rates (water charges) on lands irrigated, the sale of water to towns and forest plantations, navigation and water mill rents, etc., charged under the Canal Act.

The difference between (2) and (3) would show the profit or loss for any year.

It was generally admitted at that time that irrigation works could not be expected to pay in less than 10 years from the opening of the canal for irrigation, and this period was therefore fixed for testing the financial results of any project. The actual test was the ability of the project to pay a certain minimum return, after the deduction of all working expenses, on the capital cost of

TABLE I

Comparison of Water Rates for Main Crops on Major Canals

Crop	Upper Bari Doab Canal	Lower Bari Doab and Lower Chenab Canals		Lower Jhelum Canal		Pakpattan Canal (Perennial) S.V.P.
		Schedule A	Schedule B	Schedule A	Schedule B	
			1937-38			
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Wheat	4 4 7	4 4 0	3 8 0	4 4 0	3 12 0	4 4 0
Rice	6 8 10	6 8 0	6 8 0	6 8 0	4 4 0	6 8 0
Sugarcane	11 1 6	11 0 0	11 0 0	11 0 0	8 8 0	11 0 0
Oil Seeds	4 4 7	4 4 0	3 8 0	4 4 0	3 8 0	4 4 0
Cotton	4 8 7	5 4 0	4 8 0	5 4 0	4 8 0	5 4 0
Fodder	2 8 4	2 8 0	2 8 0	2 8 0	2 8 0	2 8 0
			1965			
		Ordinary	Special	Ordinary	Special	
Sugarcane (Perennial)	Rs. 24.45	24.00	24.00	24.00		24.00
				22.40*		22.40*
Wheat	Rs. 7.34			7.20	6.40	7.20
Rice	Rs. 12.22	7.20	6.40	11.20	11.20	10.40
Oil Seeds	Rs. 8.86	8.80	8.80	8.80	8.80	8.80
Cotton	Rs. 11.61	10.40	10.40	12.00	12.00	12.00
Fodder	Rs. 4.80	4.80	4.80	4.80	4.80	4.80

*Kharif

construction, plus the arrears of simple interest up to the tenth year of operation.

Until 1921, all loans for the construction of productive irrigation works in the subcontinent were raised by the British Government in the London money market. These were treated as advances made to the provincial governments from the central revenues at rates of interest fixed by the central government. From 1921 till independence, the provincial governments raised loans on their own credit.

Water rates charged for various crops per acre at present are practically uniform throughout West Pakistan. Table 1 compares the water rates charged for the main crops in 1937-38 and 1965 on the major Punjab canals. Table 2 gives the progressive increase in water rates (average) over the years. Charges did not vary with distance from the source of supply, the value of the land or the cost of delivering water up to the head of the cultivator's watercourses. The revenues earned from direct receipts would make an irrigation project productive or non-productive.

At the time of the integration of the provinces into West Pakistan in 1955, there were two separate systems of taxation on agricultural land. In the southern zone, there was a composite tax which included water rate (*abiana*) and land revenue; while in the northern zone (including the old N.W.F.P., Punjab and Bahawalpur) water rate (*abiana*) and land revenue were assessed separately. The land revenue in the northern zone was based on land capability; in the southern zone it was based on crop produce returns. In order to unify and rationalize the system, land taxation in the southern zone was bifurcated into water rate and land revenue as in the northern zone, with effect from *kharif* 1959, and water rates were fixed on more or less the same basis. So far as land revenue was concerned it was not possible to adopt any uniformity, as there were two different systems prevalent in the two zones at that time.

After the bifurcation of these rates, the government set up committees from time to time to remove the disparity in land taxation in the two zones. The following reliefs were given to the southern zone:

(1) Development cess (25 per cent of the land revenue which was being levied all over the province) was abolished.

(2) Land revenue rates were reduced by 25 per cent with effect from *kharif* 1961.

(3) Block system of assessment was abolished from *kharif* 1963 and assessment made only on area cultivated.

(4) *Malkana*, charged at the rate of Rs. 150 per acre for extra supply of water for the gardens, was abolished.

TABLE 2

Progressive Increase in Water Rates

	Rs.
1900-01	3.00 per acre
1907-10	3.60 per acre
1910-16	3.70 per acre
1916-24	3.95 per acre
1924-26	3.95 per acre
1926-32	4.50 to 3.85 per acre
1932-34	4.29 per acre
1937-38	5.75 per acre
1959	9.46 per acre
1965	11.30 per acre

Wheat, rice, sugarcane, oil seeds, cotton and fodder crops are the main crops on the Lower Jhelum canal.

	1937-38 Rs.	1959 Rs.	1965 Rs.
Wheat	4.25	6.00	7.20
Rice	6.50	10.00	11.20
Sugarcane	11.00	20.00	24.00
Oil Seeds	4.25	7.25	8.80
Cotton	5.25	10.00	12.00
Fodder	2.50	3.50	4.80
Average rate	5.75	9.46	11.30

The water rates have since been raised, and further study of the water rates levied in the two zones as applicable from *kharif* 1965 shows that these water rates were charged per crop and separately for each canal in both zones.

The following picture emerges of average water rates for perennial and non-perennial canal systems in both zones, irrespective of the cropping pattern.

YEAR	SOUTHERN ZONE		NORTHERN ZONE	
	PERENNIAL	NON-PERENNIAL	PERENNIAL	NON-PERENNIAL
	Rs.	Rs.	Rs.	Rs.
1962-63	6.91	6.97	7.35	4.82
1963-64	7.48	8.37	7.84	5.59
1964-65	7.63	8.25	7.53	5.44
AVERAGE	7.34	7.76	7.57	5.28

Most of the non-perennial canals in the southern zone grow rice, those in the northern zone dry *kharif* crops. The main differences in water rates are due to different cropping patterns and intensity of irrigation

Basis of Charging Water Rates

Water rates, unlike land revenue, never had any scientific basis of assessment. They had been determined by rule-of-thumb, by what seemed possible and expedient to men of common sense. The value of the crop to maturity served as a rough guide. To start with, these rates were deliberately fixed very much below the commercial value of irrigation water, which at that time should have approximated what it costs a cultivator to water his land from a well with bullocks or other means.

It was suggested that the method of charging on the crop-acre basis leads to wastage of water, and that a better method would be to charge for water actually taken on a volumetric basis. Objections to the latter method were that it involved an appreciable investment in meters and a large additional staff to measure and record the water taken by cultivators, thus increasing the working cost. The method was open to misuse. The volume of water sold would vary considerably from year to year owing to climatic variations, and would cause a still greater fluctuation of revenue.

From the cultivator's point of view, the values of different crops might not be in proportion to the amount of water required for them to mature. The volumetric sale of water would also necessitate big changes in the design of the canal system.

Cost and Returns on Irrigation Projects

The annual expenditure on an irrigation project comprises (1) interest on the capital cost and arrears of interest for the construction period; (2) cost of administration; and (3) cost of annual repairs and maintenance.

The total of interest and working expenses is the actual cost to the state of supplying irrigation water to each acre. When the water rate for any crop is less than this amount, irrigation may be considered as subsidized by the state. Table 3 gives the financial results of West Pakistan's canals. For the sake of brevity, non-productive works are excluded.

Recovery of Water Charges in Relation to Irrigation Development

The prerequisites for introducing an irrigation supply to farm land are land leveling and the construction of watercourses. Expenses in West Pakistan on this preliminary work vary from Rs. 30 to Rs. 70 per acre for watercourses and Rs. 150 to Rs. 200 per acre for land leveling. These must be kept in view before burdening farmers with total water charges. To minimize this burden there may be a water-tax holiday for two to three years after the commencement of irrigation, or the water charges could be raised progressively, suggesting a total or partial subsidy in the early years of irrigation development. Also, to overcome the difficulties of land acquisition and cost, particularly in proprietary areas, a law should exist permitting free and compulsory acquisition of land by the government for the watercourses.

TABLE 3

Financial Results of West Pakistan Canals (Major Productive Works)

Year	Direct and Indirect Capital Outlay to End of Year	1964-65			
		Gross Revenue	Working Expenses	Net Revenue	Percentage on Capital Outlay
		(Million Rupees)			
1956-57	1252.12	127.61	52.22	75.39	6.20
1957-58	1377.17	129.64	58.40	71.24	5.20
1958-59	1511.25	143.02	66.48	76.54	5.06
1959-60	1638.80	171.61	59.43	112.18	6.85
1960-61	1803.01	203.76	74.81	128.95	7.20
1961-62	1894.79	326.19	85.30	240.89	12.71
1962-63	1975.80	163.72	88.46	75.26	3.80
1963-64	2053.02	213.26	115.81	97.45	4.75
1964-65	2247.59	252.64	119.88	132.76	6.00

Note : Working expenses for unproductive works for 1967-68 were Rs. 10.39 million.

Kanwar Sain reported, on the basis of farm accounts for 1934-35, that the water rates charged to the farmer were 30 per cent of his net income. Farm management studies carried out by the Government of West Pakistan's Department of Agriculture (Report F.M. III, Oct. 1966) show that water rate and land revenue were 5.7 to 6.8 per cent of net farm income. This is because farm produce prices and income have registered a greater rise than water charges. But the net income and water charges relationship should be viewed both from the subsistence level of the farming community as well as the financial returns from the farming industry. In a study carried out by CENTO (Seminar, May-June, 1963) for major agricultural products in Turkey, Iran and Pakistan, the return on sugarcane alone in the Peshawar area was 3.7 per cent, whereas on wheat it was 2 per cent for Lahore and 1.4 per cent for Peshawar. Rice gave a return of 1.6 per cent for Lahore. The Board of Economic Inquiry, West Pakistan, (Publication 1387, 1966), conducted similar studies which suggest that at the present level of production, irrigation crops would not stand the pressure of increased water rates. But increased water charges may pressure the farmer into using improved agricultural methods and other inputs, so as not only to pay the higher water charges but also increase his net income and therefore his financial returns.

The increase of average water rates and land tax per acre on major crops between 1955-58 and 1959-63 was 96 per cent for sugarcane, 62 per cent for oil seeds, 44 per cent for tobacco, 35 per cent for rice, 30 per cent for cotton and 27 per cent for wheat. The economic return on these crops during this period showed a maximum rise (1955-56 price index: 100) of 67 for sugarcane, 48 for oil seeds, 66 for tobacco, 36 for paddy, 21 for cotton and 26 for wheat (Report S. S. V, Ministry of Agriculture, Government of Pakistan, 1955-56 and 1962-63). This suggests that price stability and price rise of farm produce are necessary to justify increased water charges and land tax.

Economic Returns from Irrigation Projects in Relation to Water Charges

(A) The criterion of being productive, set for irrigation projects in West Pakistan, needs a

fresh appraisal, because the existing canal system is now burdened with the capital cost of the Indus basin replacement works, which are necessary to keep the old irrigation projects in operation and to bring additional areas under cultivation. Six new barrages and 8 link canals have been constructed, and the existing link canals and the Balloki headworks have been remodeled. The total cost of these projects is given as Rs. 1,106 million. New allocations of water supplies in each canal project have to be made, and the costs of the Indus basin replacement works and of the irrigation and power supplied from the Mangla dam must be distributed. On most of the existing canals the original capital costs have been liquidated, so that each canal project's share of the capital cost of the replacement works would be the new capital cost.

A fresh analysis of the returns from water rates and their reassessment for financial justification is needed therefore. An overall appraisal of the Indus basin canal water distribution system is also necessary, keeping in view the new surface and ground water supplies developed. Should the water rate returns in each canal system be analyzed independently because the water allowances, irrigation intensity and soil characteristics vary from one canal system to another? Some areas of West Pakistan, such as the foothills of Dera Ghazi Khan, Dera Ismail Khan, the Potwar plateau, etc. are still backward, and irrigation facilities are scant. Outside the Indus basin boundary, Quetta and Kalat are underdeveloped areas, where canal irrigation is new and the farmers are not fully initiated in the system and the benefits to be derived. The water charges for these areas should not aim at defraying the interest, amortization and operational costs of the facilities provided. Rather, areas where irrigation has developed fully should attract increased water rates to make the projects in the underdeveloped zones financially and economically viable.

(B) Salinity and water-logging once threatened the life of the existing canal system, but reclamation and drainage works have since been constructed in the areas known as SCARP-I, II, III, etc. An additional water rate and a reclamation fee were proposed for these areas, where intensity of irrigation has been increased and lands reclaimed from water-logging and salinity, thereby increasing crop yields. But the beneficiaries were not in a mood to repay the government for the reclamation services provided to save their lands. The fixed annual charges for interest and amortization (4 % interest, a 40-year amortization period, and a sinking fund for a tubewell life of 20 years), as well as the annual operation and maintenance costs on 2,043 tubewells in SCARP-I (capital cost Rs. 103 million), indicate the following water charges per acre :

Intensity (per acre)	110	120	130	140	150
Area irrigated (million acres)	1.25	1.37	1.48	1.6	1.71
			(RUPEES)		
Annual field cost	6.50	5.80	5.50	5.10	4.75
Annual operation and maintenance	14.90	15.20	15.50	15.70	16.00
Pre-project recovery	5.50	5.00	4.70	4.30	4.00
Total	26.90	26.00	25.70	25.10	24.75

But it has not been possible to effect recoveries at these rates.

A committee has recently been appointed to go into identical problems pertaining to water rates and irrigation. Its terms of reference, as reported in the press, are :

(1) To revise and recommend barrage allocations, reservoir release patterns and drawdown levels, and examine other major issues of water policy, such as

the use of ground water in relation to surface water deliveries.

(2) To estimate the costs, capital and maintenance, of the overall water development in West Pakistan from 1960 to 1975 (including storage, flow and ground water).

(3) To estimate the cost of supplying water to each system.

(4) To determine the rate of water recovery, specifying how best to recover the cost, and to suggest a desirable rate of return.

(C) The need for raising the water rates has been felt since the early days of World War II. The cost of operation and maintenance of the canal system has been rising steadily. The shortage of food grains during World War II and thereafter had a direct impact on food grain prices, which have shown a continuous rise until the maximum price of Rs. 17 per maund, fixed for 1967-68, has been reached. In the legislative assembly there has always been opposition to increasing water rates, regardless of the fact that the prices of agricultural produce have risen. The water rates were revised in 1959 and again in 1965. The actual overall cost of each canal project as well as of the entire irrigation system should be appraised, taking interest, amortization, and operation and maintenance costs into account, and a new schedule of water rates, either for the whole of the Indus basin or for each canal system, should be evolved, which would give realistic budgetary support to the development of West Pakistan.

(D) The construction costs of irrigation and other engineering projects have considerably increased and development areas have diminished. Almost all the perennial supplies have already been utilized, and any further development must depend on the conservation of flood flows or the exploitation of the ground water potential. Projects in the latter categories have a limited life, and a provision to recover costs within the life expectancy of the project would be an added burden on the beneficiaries. The projects now being planned provide for intensive irrigation and a full water supply for the consumptive use of crops, and also for leaching to control, and in most cases to reverse, salinity. Greater emphasis on surface and subsurface drainage is an essential feature of every new irrigation project, and is an element of additional cost not always considered necessary in old projects.

(E) These are a few of the considerations which indicate that the "financial productivity test" is no longer valid as the sole basis for judging projects. The time has come when economic feasibility should also be considered, and the cost of each project weighed against the overall increase in the national income expected to result from it. Financial justification would deal with the repayment and the annual expenses, and would be in line with the repayment capacity of the direct and indirect beneficiaries.

For economic feasibility, the most commonly used criterion is the benefit-cost ratio. The indirect and fringe benefits ought to be assessed and the monetary gains arising from them should be accounted for. Even if monetary gains are not accounted for they should be given due recognition, because in many cases these benefits, especially of a socio-political character, may outweigh all other considerations.

For financial justification, the net revenue from a project is of prime importance and the annual charges to be recovered from the beneficiaries need careful consideration. For run-of-the-river irrigation projects, the annual charges consist of:

(1) maintenance and operation costs ;

(2) betterment tax (levied only for a specific period and at specific rates);

(3) interest at 6½ per cent on capital cost (sum at charge is defined as the direct capital cost of construction, plus the accumulated arrears of simple interest up to the 10th year after the commissioning of a project).

For storage and lift irrigation projects,

amortization or repayment of capital cost over the useful life of the project is an added expenditure now being included in our analysis, although no policy regarding this has yet been definitely laid down. The levy of amortization costs in addition to interest charges is open to serious question. The complications arising out of the fixing of new water rates in SCARP-I have not yet been solved.

Out of the annual costs, interest on capital is a very heavy and substantial item which also warrants close scrutiny. In many countries of the world, the interest on capital expenditure on irrigation projects is not levied. The beneficiaries are required to pay only the operation and maintenance charges, plus repayment of the cost of the project over a specified period. In the U.S.A this period is at present 40 years, but quite a few projects have been sanctioned for a longer period through specific legislation, and extension of this period to 100 years is being seriously considered. An irrigation project, especially in an agricultural economy like that of Pakistan, provides perhaps the most important base for development which benefits other sections of the population besides the farmers. It is therefore logical that the burden of payment should also be shared by those who benefit indirectly from the project. Increases in land revenue and other taxes, such as water advantage rate (*khush haisiyati*), result directly from the irrigation project but are excluded from financial appraisal studies. Government receipts from other sources also increase as a result of more production, and can therefore rightly be counted towards the payment of interest on the capital invested in an irrigation project.

(F) It is generally accepted that the present irrigation supplies in West Pakistan, with better farm management practices, could yield substantial increases in farm production. Perhaps the low water rate levied on a per-irrigated-acre basis is one of the factors responsible for low production: it does not compel the farmers to get the maximum from their lands.

Conclusion

What value of farm produce should be taken into account when fixing the water rates as a percentage of the average value of produce? Should it be the gross value or the net profits of the cultivator ? In the report of the Abiana Committee in 1934, the value of crops on each canal was taken separately and the results totaled up. The season and crops report issued by the director of land records gives actual average yields and prices of principal crops prevailing at harvest time for each civil district. From these sources, weighted average figures of yields and prices are determined, taking into account the areas under different crops irrigated in each district. The total estimated value of crops in the areas served by canals is then worked out and the gross value of crops per acre arrived at. The system of calculating revenue on a sliding scale is different from calculating water rates on a sliding scale. For land revenue there is an assessment circle or estate, which is a *tehsil* or part of a *tehsil*, and a standard of one-quarter of net assets is prescribed to determine the pitch of land revenue rates.

The point for consideration is: what ratio of water rate to value of crops would be a fair charge on the water user? And having determined the average water rate per acre assessed, should it be applied as a flat rate per acre or should it be split up into different rates according to the class of crops grown ? And what would be the final effect of a sliding scale in case it was possible to evolve one ? Fixed water rates would oblige the farmer to change the cropping pattern according to the market prices ruling in favor of certain crops. As for his capacity to pay water rates, we may assess the farmer's income and his capacity to pay with the rise or fall of crop prices. This suggests fixing water rates on a sliding scale. Sliding water rates may keep the farmer tied to an unprogressive crop pattern, as he would have to pay only a fixed ratio of the crop market value earned by him. If water rates were treated purely as payment for value received, then all sales of water should be on a volumetric basis. But to change from our present system of water deliveries and water rate assessment to water delivery by volume, would involve such changes of the canal system as might cause an upheaval we can ill afford at this period of agricultural develop-

ment. Of course, recent increases in food grain prices have changed the outlook of farmers, and we find intensified agricultural operation and irrigation. A realistic composite water rate, levied on the project acre basis instead of irrigated acreage, would go a long way in providing the necessary incentive, and would also indirectly meet the recommendations of the Food and Agricultural Commission to promote the sale of water by volume as against crop matured.

There are many other factors which need to be considered in this context. These include the repayment ability or paying capacity of the beneficiaries, the relationship between the size of the farm and repayment capacity, the power cost for lift irrigation and tubewell projects, and drainage and reclamation costs.

Besides adequate water supplies, improved farm practices are also very essential for increased crop production. In order to achieve the desired results from an irrigation project, it is very necessary that adequate agricultural extension services are provided to the farmers in the project area. The cost of these services should be included as an integral part of operation and maintenance costs, as is being done for projects prepared by WAPDA.

The irrigation projects of the future must, by the very nature of things, be less paying. Yet the financial experts are in favor of stiffening the test of productivity. Unless there is a change in this outlook, development of irrigation in backward areas may be seriously jeopardized. This is particularly important for irrigation projects (small or medium storage) where costs are high and areas are underdeveloped. The accumulated net profit to the government from the canals in British Punjab up to the end of 1937-38 came to Rs. 89.2 crores, after paying all operation, maintenance and interest charges, against a total capital outlay, both direct and indirect, of Rs. 34.5 crores. Thus, the government of that time could have built a reserve fund of Rs. 54.7 crores to construct canals in other less developed parts of the province. It can be argued that all these profits were utilized instead to build up beneficent departments. But the share of benefit from these departments derived by the inhabitants of the unirrigated areas has been much less than that derived by people in the irrigated areas. For the equitable distribution of the natural wealth of the province, irrigation projects should have been constructed in areas hitherto relegated to the background, irrespective of financial results. Their capital cost could have been considered as merged with the capital cost of projects already existing, and the test of productivity then applied to the canal system as a whole to arrive at the water charges.

The provincial and central governments both derive such large sums of revenue as a result of the development of irrigation, in addition to direct and indirect irrigation receipts, that there are sufficient grounds to lower the financial test for such schemes. In Germany and France, it has been estimated that 45 and 47 per cent respectively of the capital cost of navigation canal schemes is directly returned to the government in the form of taxes, duties, etc. In Germany, an estimated 31 per cent of operation costs is returned to the state in addition. In other countries, irrigation has invariably been subsidized by the state, and frequently not only the annual interest charges but also part of the capital cost are waived in fixing water rates. Each government has to adopt a national policy for water development and water charges according to the social structure of the farming community and the ruling economic forces. Developed economies as well as underdeveloped ones should take steps to maximize the use of water resources and irrigation. In certain cases agricultural development through irrigation may attain such levels, that rigid financial criteria for water charges would not act as a deterrent to the further utilization of water resources. Beneficiaries in less developed areas would be afraid of a high financial standard to recover water charges, and the development of irrigation would suffer. Alternatives to consider, therefore, are:

(1) Assess water charges in developed areas to offset the deficit from less developed areas, where charges must be light enough to encourage the farming community towards full use of the irrigation facilities. Low water charges would

mean that interest charges or amortization or both may have to be written off.

(2) On multipurpose projects, revenues from the sale of power should balance the deficit, if any, due to low water charges, which of necessity must be kept at such levels to support the farmer.

(3) If the water charges must be kept at levels designed to recover interest, amortization, and operation and maintenance charges, price supports on agricultural produce may be necessary to improve the paying capacity of the farmer. This policy would also encourage the growth of particular crops.

The percentage ratio of the average water rate to the average value of the produce per acre on the Punjab canals has varied from 6.0 per cent in 1918-19 to 15.2 per cent in 1930-31. Farm management studies carried out recently show this ratio is about 6 per cent. The variation in the case of certain areas and of particular crops may have been even greater. If the water rates are to depend on the paying capacity of the cultivator, as hitherto assumed, they should obviously bear a more or less constant ratio to his net profits from irrigation. Before World War II, the ratio of water rate to value of crop raised per acre in America varied from 16 to 20 per cent, while in Egypt it was about 14 per cent. What this ratio should be is too difficult and complex a matter to decide, but this seminar may bring out some new ideas.

Chapter VIII

IRRIGATION PRACTICES RESEARCH AND SOIL SALINITY

GROUND WATER INVESTIGATIONS

by
Saleh M. Popalzai*

Introduction

In 1958, the Ministry of Mines and Industries and the Ministry of Agriculture and Irrigation started ground water investigations in different parts of the country. The northern part of Afghanistan, a part of Kabul and a part of Khost were assigned to the Ministry of Mines and Industries.

In 1964, the Water and Soil Survey Authority (W.S.S.A.) of the Agriculture and Irrigation Ministry started ground water investigations with the help of the United Nations Special Fund. These investigations were in the southeast of Afghanistan.

* Director of Groundwater, Water and Soil Survey Authority, Ministry of Agriculture and Irrigation, Royal Government of Afghanistan.

Water Studies

In 1966, the W.S.S.A. sent a small group of hydrologists to Andkhui and Doulatabad in the northern part of the country to investigate the water conditions in that area, where there were serious difficulties in the water supply.

On the basis of the existing water analyses, the relation between ground water and surface water was studied and water samples were analyzed in the laboratory. Three borings were made in the town area in Andkhui. The details of the borings and water analyses are shown in the table which follows.

This study showed that the area investigated does not have sufficient underground water supply capacity, and that in some locations the water is not potable.

Borehole	Depth	Water Table	Drawdown	Capacity l/s
No. 1	125 m.	22.65.m.	17.35 m.	0.08
No. 2	53 m.	15.80 m.	24.20 m.	0.08
No. 3	47 m.	—	—	0.01

Borehole	Water Temp. in C°	Part in mg/l						Evap. Residue	pH	Hardness in dh	
		HCO_3	SO_4	Cl	Ca	Mg	Na+K			Total Hardness	Carbonate Hardness
No. 1	16°	536.0	940.0	610.0	60.0	109.0	848.0	2960.0	7.0	33.6	8.9
No. 2	16°	731.0	6648.0	5319.0	700.0	972.0	4209.0	18328.0	7.0	322.0	36.9
No. 3	16°	293.0	312.0	543.6	136.0	79.0	270.0	—	7.0	36.5	—

Ground Water Investigation in Southeast Afghanistan

(A) Location

Katawaz, including the upper Tarnak valley down to the Abi-Istada basin, the Nahar valley and the Ghazni valley, is located between 69° and 67°E longitude and 35.5° and 32.8°N latitude.

(B) Climate

In summer it is hot and dry, and in winter it is cold with temperatures falling below zero. Average precipitation is about 12 inches.

(C) Geology

Ages are only suggested because of the absence of fossils:

Recent: alluvium, sand and loess.

Pleistocene: terrace, gravels, sub-horizontal to tilted.

Pliopleistocene: acidic, volcanic (mainly tuffit), agglomerates and marl very gently folded.

Miopliocene: conglomerates, sandstone, silt, stone, folded.

Paleocene and Eocene: flysch and limestone deposits, highly folded and metamorphosed.

The recent deposits rest uncomfortably on the older sediments which have been uplifted and eroded. The volcanic sequences are rather more tilted than the terraced gravels, but not as well folded as the mio-pliocene deposits. The younger eocene formations are tightly folded, whereas the older formations are more highly folded, faulted and metamorphosed. Each of these units has characteristics that are identifiable on air photographs, though the tuffits and terrace gravels display many similarities that make them hard to separate.

Hydrology

The demand for ground water is for agricultural (irrigation) and domestic use. The areas with soils suitable for irrigation are shown on the land classification maps prepared by the Water and Soil Survey Authority.

The Tarnak basin is within the Chaman fault zone, which passes in a northeasterly direction through Chaman and Mukur into the Ghazni area. The whole basin varies in width from about 28 to 50 kilometers, whereas the main valley is between 12 and 20 kilometers wide. The structural valley continues northward where it is occupied by the Ghazni river. The Ghazni river, instead of continuing southwest to enter the Tarnak valley, flows into the Katawaz area and

ends at Abi-Istada, a salt lake east of the Tarnak basin.

The western side of the watershed is the fringe of an extensive mountain range. The southeastern limit is a ridge of mountains, whereas to the northeast the watershed extends beyond a continuation of this ridge and forms a broad divide with the Ghazni watershed in an area of quaternary alluvium.

Water Quality Studies

There are many wells, springs and *karezes* in the area, which were plotted on 1:50,000 scale maps. Water samples were collected for chemical analysis as part of the inventory program. A preliminary isocon map of the Tarnak valley was prepared on a 1:100,000 scale.

A total of 1,300 water samples have been collected to date. Of these, 1,212 samples have been analyzed.

Most of the water had a specific conductance of between 400 and 800 micromhos, but water from wells in an area near the Tarnak river, southeast of Mukur, had a specific conductance of between 1,200 and 1,600 micromhos. The water from these wells also had a relatively high boron content of between 1 and 6.5 parts per million. This area of relatively high dissolved solids, with an area of low resistivity, is outlined in the section on geophysics.

Generally, the water is of bicarbonate type with a dissolved solid content of less than 500 ppm.

Most of the information has been plotted on triangular coordinate graphs to see if any difference occurs in the ground water from different sub-watersheds. The samples analyzed so far are similar in composition, but the water from piedmont deposits in the sub-watersheds north of Mukur has slightly more magnesium than similar deposits found in the sub-watershed south of this area.

Water quality is generally good for drinking and agriculture.

Drilling

For ground water investigation in this project, three 60 RL percussion rigs and one rotary rig to drill exploratory boreholes are in use. A summary of the data for wells drilled from September 1, 1966 to August 1, 1968 is listed in Table 1. Johnson and "OBO" screens, made of plasticized wood and slotted pipe, were used in these wells. The valley fill materials intersected were sands, silts and conglomerates, all of which were very poorly sorted. Mechanical analyses were run on many samples.

Test Pumping

A bailer test was carried out prior to test pumping on BH 4/67, with results as follows:

(Static Water Level) (Below Ground Level)
S.W.L. 31. 2 m. B.G.L.
Removed 560 U.S. gallons approximately in 1 hour.
D.W.L. to 44.6 m. B.G.L.
Water level recovered to 40.1 m. in 2 hours.

The 10-inch casing was jacked free and withdrawn, the 12-inch casing pulled up to 33 m. B.G.L. and the borehole backfilled to a depth of 35 m. and cemented to 34 m. B.G.L.

A cavity in the region of 35 m. depth consumed a large quantity of backfill material. A testing string, comprised of a 15-foot length of 100-slot Johnson screen, 8-inch diameter, was run in the borehole to 32.9 m. B.G.L. with plain casing to the surface. The annulus was gravel-packed simultaneously, with the 12-inch casing being pulled up to 28.25 m. B.G.L. A large cavity was present in this region which again consumed a considerable quantity of gravel.

Bailing inside the testing string continued for a full day, followed by a bailer test. Results were as follows:

S.W.L. 20.42 m. B.G.L.
Removed 500 gallons in 1 hour.
Water level remained constant at 20.42 m.

A 21-stage "flo-way" 6-inch spindle-driven pump was inserted in the borehole, suction at 28.21 m. B.G.L., powered by a Ford diesel engine,

TABLE I

Borehole No.	Nominal Diameter Casing (inches)	Depth Drilled (meters)	Station Water Level (meters)	Aquifer	Discharge
1-66	12	69.62	29.50	Alluvial gravel	
1A-66	5		29.11	Alluvial gravel	ob
1B-66	3		29.20	Alluvial gravel	ob
2-66	8	98.0	53.04	Colluvium	
2A-66	3	70.0	50.31	Terrace fan	ob
3-66	8	30.0	9.28	All gravel	250 GPM
4-66	3	60.0	22.89	Fanhead gravel	ob
1-67	—	233.0	24.0	Variant alluvium	
2-67	10	392.0	22.59	Terrace	200 GPM
3-67	8	237.0	10.16	Alluvium & tuffite	876 GPH
3A-67	6	70.0		Gravel	ob
4-67	16	118.0	26.07	Gravel	95 GPM
5-67	8		21.40	Alluvium gravel	ob
1-68	12	84.0	3.60	Alluvium gravel	ob
2-68	1			Terrace gravel	ob
3-68	12	48.0	22.59	Fanhead gravel	ob
4-68	16	60.8	12.27	Terrace gravel	228 GPM
5-68	8	55.0	46.63	Head fan (colluvial)	ob
6-68	—	Incomplete			ob
7-68	16	31.0		No water	

ob—observation well

model 300. A 68-hour continuous step-test was conducted. The yield was 95 U.S. g.p.m. for a drawdown of 6.15 m. The pump and the Johnson screen were withdrawn. An experimental testing string of 8-inch diameter casing was positioned in the borehole, and bottomed at 32.15 m. B.G.L. and gravel-packed. All of the 12-inch casing was withdrawn. The spindle-driven pump was re-installed, suction at 29 m. B.G.L., and a 20-hour test carried out. The yield was 95 U.S. g.p.m. for a drawdown of 6 m. A recorder was placed over the borehole for observation of the recovery water level.

Permeability

On the basis of observations and measurements of test pumping of BH 4/67, the coefficient of permeability was estimated. The value of the coefficient of permeability for an aquifer composed of sand and gravel, with the lower section partly cemented, changes from 0.30×10^{-1} cm/s to 0.21×10^{-1} cm/s. The lowering of permeability in the period of increasing drawdown is probably caused by certain sizes of grains clogging the Johnson screen or by the lower permeability of the lower section of the aquifer.

Test Pumping BH 2/67 in Charikar

The same pump which was used in borehole 4/67 was inserted in the borehole to test the section from 40.50 to 100 m. B.G.L., suction at 91.09 m. A 44-hour step-test was conducted, followed by a continuous test of 75½ hours' duration, during which a yield of 200 U.S. g.p.m. was established, drawing the water level down from 22.4 to 44.5 m. B.G.L.

A stone house was built over the borehole and a water level recorder installed.

Recharge

Most of the run-off, and presumably ground water recharge, in the Tarnak valley appear to come from the mountains to the west, although some subsurface flow may enter from the lower Ghazni valley to the east.

In order to facilitate recharge studies the watershed has been subdivided. Along the western or right side of the valley, the subdivisions correspond to sub-watersheds, whereas on the eastern or left side, for obvious reasons, tentative subdivisions are physiographic units, such as the area east of the mountain ridge and the piedmont slope west of the ridge between Abi-Istada and Mukur.

The largest of the sub-watersheds occupied by the Alghzar river has been selected initially for recharge studies. The sub-watershed has an area of approximately 500 square kilometers, the drainage from which must enter the main Tarnak valley about 15 kilometers west of Mukur. It is planned to drill observation wells in an alluvial fan at this location to determine how much of this water infiltrates into the ground.

The water level in all the boreholes drilled by the project was generally measured weekly, whereas the flow from a number of observation springs and *karezes* in the Tarnak valley was measured less frequently.

Water levels in the wells along the valley flanks responded quickly to recharge from melting snows, rain and ephemeral streams, whereas the water levels in wells nearer the valley center began to rise later and did not rise as much.

For some of the observation wells, hydrographs have been prepared.

Resistivity

Resistivity observations are made to determine the nature of the valley fill material and to give some indication of ground water quality, since coarse-grained material saturated with water of good quality will have relatively high resistivity, compared with fine sediments or sediments containing saline water. Approximately 570 resistivity stations and 900 gravity stations were occupied in this area.

Mapping

All kinds of maps, such as topographic and photographic maps of different scales, were prepared by the Cartographic Institute. Geological mapping is done by the project.

To select drilling sites in the area of Abi-Istada, near Munari and Katawaz, several field trips were made to collect more hydrological information. Using data from measurements of the depth-to-water level in selected dug wells, preliminary sketches of ground water contour maps and isolinear maps of the depth-to-water level were prepared.

A base map of the combined Nahar and Abi-Istada basins is being prepared on a scale of 1:100,000. It will include roads, major streams, drainage subdivisions, major geological features, wells, springs and *karez* head shafts. Water level elevations of inventoried points were ready to place on the map in order to prepare a water table contour map.

Surveying

Surveying consisted of leveling in conjunction with the inventory program. Leveling was completed in the Tarnak valley, including a part of the river itself (about 8 kilometers) near Mukur in the region where permanent flow begins. The road construction bench marks were used for all of this work.

A traverse of third-order accuracy, from Ghazni to Mukur via the Nahar valley and Abi-Istada, placing bench marks every 5 or 6 kilometers was completed. In the meantime, level circuits were run to wells, springs and *karezes* in the Nahar valley, Abi-Istada and Tarnak valley and Zarghun Shahr.

Conclusion

Since this investigation is not yet complete, we cannot predict the available underground water supply accurately, but generally speaking, the possibility of a water supply from this source looks favorable at present. It is hoped that this particular project will be completed by the end of 1969.

WATER REQUIREMENT OF FIELD CROPS IN EAST PAKISTAN

by
Noazesh Ahmed*

Needs and Uses of Water by Plants

Water is not an inert material. The water in plants, as in all living matter, contributes as much to the essential properties of life as do the more complex proteins, the fatty compounds, carbohydrates and minerals. Chemically, the protoplasm inside the cell wall is complex. Next to water, proteins are present in greatest abundance. The properties of protein that make them the principal building material of living matter and the substances that control most of the life process are actually properties of protein solutions in water. Water, proteins and other constituents of protoplasm compose a complex system, no part of which can be omitted without fundamentally altering the potentialities of protoplasm.

Plant growth is primarily the result of two major processes: cell division and cell elongation. Intensive investigation on sugar beet by Watson (6) at Rothamsted indicated that soil moisture deficits affect growth mainly by inhibiting cell enlargement, rather than by affecting cell division. The turgor pressure in the cell is the force that brings about cell enlargement, and its effectiveness is controlled by the action of auxin, a growth-regulating substance present in the cell. Thus, plant growth is directly related to the degree and duration of turgescence of plant tissues.

Water loss from plants by transpiration brings about a tensional stress within the plant that is counteractive to the prevalence of turgor pressures in expanding cells. This internal stress is eased by water absorbed from the soil by the roots. Of all the materials used by the plant for its growth and maintenance, that taken up in the largest amount is water. For every pound of dry matter in a plant we commonly find about 5 or 10 pounds of water, but for each pound of dry matter produced the plant must absorb several hundred pounds of water. The difference between the 5 or 10 pounds and the several hundred pounds represents water lost by transpiration (4).

Water Consumption by Field Crops

Scientists have tried various ways to determine the amount of water used by plants. One

* East Pakistan Agricultural Development Corporation.

of the earliest attempts was to remove leaves or branches from a plant and let them dry for a brief time, then weigh them to see how much water they had lost. Another method is to place plants in sealed containers and measure the moisture that accumulates in the confined air. Estimating consumptive use of water by agricultural crops from climatological and other data has been practiced by irrigation engineers for many years. C.R. Hedke developed the effective heat method for the Rio Grande valley (2). Lowery and co-workers (6 & 8) analyzed data on consumptive use from irrigated valleys and humid watersheds with wide differences in climate, latitude, elevation and type of crops. They found a straight-line relation between annual consumptive use and heat supply, expressed in terms of accumulated daily maximum temperatures above 32°F. during the growing season. Penman and Schofield at the Rothamsted experimental station (6) correlated evaporation from open water and evapotranspiration from grass with meteorological observation, and developed an index for estimating transpiration. Penman has made the most complete theoretical approach, showing that consumptive use is inseparably connected with solar energy.

Blaney and Morin (2) in 1941 developed formulas for temperature, day-hours and humidity records. Since humidity records were not readily available, Blaney in collaboration with Criddle later on simplified the above formulas by eliminating the humidity factors. The procedure with the Blaney-Criddle formula is to correlate existing consumptive use data for different crops with monthly temperature, percentage of day-time hours, precipitation, frost-free (growing) period or irrigation season. The coefficients so developed are used to transpose the consumptive use data for a given area to other areas for which only climatological data is available. Disregarding the unmeasured factors, consumptive use varies with the temperature, day-time hours and available moisture, according to the Blaney-Criddle principle.

Increasing thought has been devoted since 1946 to the problem of measuring the water use of plants under optimum conditions of soil moisture. A device has been developed and standardized by Thornthwaite and co-workers. It consists of a large soil tank, so constructed that plants can be grown in it under essentially field conditions and provided with water as they use it. A number of these evapotranspirometers are in operation in widely-scattered areas of the world, but many additional installations are needed to understand the variations of evapotranspiration from one area to another. Thornthwaite (8) mentions that the rate of evapotranspiration depends on five factors: climate, supply of soil moisture, plant cover, soil type and structure, and land management. When the soil moisture is maintained at the optimum, land management and soil type or structure have little effect on the rate of evapotranspiration. There is also considerable evidence to show, that when the root zone of the soil is well supplied with water, the amount used by the vegetation depends more on the amount of solar energy received by the surface and the resultant temperature than on the kind of vegetation growing in the area. Thornthwaite further adds that these possible sources of energy for evaporation or evapotranspiration are stored radiation heat that reaches the evaporating surface from the air, and heat that is stored in the evaporating body. (He theorized that temperature was a good index of energy in a zone of essential equilibrium.) According to Thornthwaite, different types of vegetation differ in their potential evapotranspiration because they absorb different amounts of solar radiation.

From the various methods of determining evapotranspiration, imperfect and scattered though they may be, we get an idea of how much water is transpired and evaporated under different conditions. The principal limitation of Penman's approach is the lack of sufficient weather measurement in most localities. The formula, even though quite reliable, does have practical limitations. Further, equiation coefficients were determined for a rather humid area, not far from the ocean and essentially covered with growing vegetation. Penman's formula applies better under humid conditions than in arid and low-humid areas. Thornthwaite's method also applies

quite well to humid, well-vegetated areas. The Blaney-Criddle formula, on the other hand, was developed to fit arid and semi-arid conditions, and will give estimates of seasonal water needs under these conditions.

Water Requirement for Rice

The cropping pattern in East Pakistan is adjusted to climate, soils, topography, depth and occurrence of flooding, and traditional agricultural practices. Most of the *kharif* crops in the province grow under hot, humid, tropical conditions. It has been observed that the water requirement for rice is rather high, because most of the lands are submerged for three to five months. Literature relating to the water requirement for rice in the Indo-Pakistan subcontinent is scanty. Buckley estimated that the water requirement of a paddy crop of 140-160 days' duration in Bengal was a minimum of 56 inches (1 & 7). Ellis (7) has given the requirement of the crop after transplanting as a minimum of 4 inches and a maximum of 6 inches per half month, the need being less during the last two months of the crop. Some experiments have been conducted under the Ganges Kobadak project at Amla to find out the water requirements of *aman*, *aus* and *boro* paddy. These experiments were designed in randomized blocks. Soil tanks used in the experiment were so constructed that rice plants could be grown under essentially field conditions and provided with water as they used it.

Huq (5) reports that the 5-year mean value of average daily water loss for transplanted *aman* was about 0.36 inches. (Total consumption of water for 110 days was 37.08 inches. It was calculated that the total requirement of water for successful rice growth in the area was about 74 inches, based on a 50 per cent irrigation efficiency.) This figure is very close to that of transplanted *aus*, for which the daily average water consumptive use was 0.34 inches. The consumptive use of water by transplanted *aus* and *aman* at 10-day intervals is represented graphically in Figures 1 and 2. Tables 1 and 2 list data. These findings indicate that the maximum water requirements for *aus* and *aman* are in the months of July and October respectively. Huq further shows that the average daily water loss by evaporation and transpiration in *boro* paddy was 0.34 inches in 1958-59 and 0.31 inches in 1960-61. In other parts of the subcontinent, namely, Damodar valley and Hyderabad (Deccan), water requirements of the paddy crops growing during the summer and rainy seasons have been estimated at 41.8 inches and 44.0 inches respectively (1 & 7).

TABLE 1

Consumptive Use of Water by Transplanted Aman Paddy at 10-Day Intervals (1960-61)

DATE	DAYS	WATER USED (INCHES)
July 15	0—10	0.8
July 25	11—20	1.1
August 4	21—30	1.2
August 14	31—40	2.0
August 24	41—50	2.5
September 3	51—60	3.7
September 13	61—70	4.8
September 23	71—80	5.5
October 3	81—90	6.0
October 13	91—100	5.8
October 23	101—110	4.8

TABLE 2

Consumptive Use of Water by Transplanted Aus Paddy at 10-Day Intervals (1961-62)

DATE	DAYS	WATER USED (INCHES)
May 1	0—10	1.0
May 10	11—20	1.6
May 20	21—30	1.8
May 30	31—40	1.5
June 10	41—50	3.1
June 20	51—60	4.5
June 30	61—70	4.3
July 10	71—80	5.7
July 20	81—90	5.5
July 30	91—100	5.0

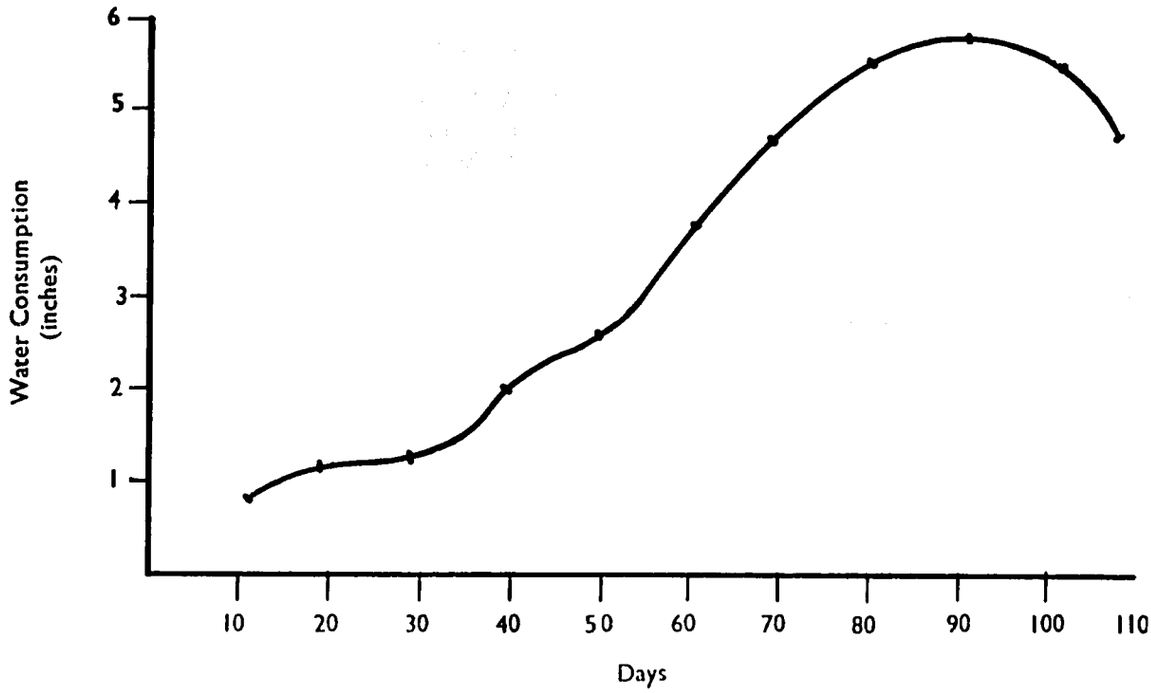

FIGURE 1 Consumptive Use of Water by Transplanted Aman at 10-Day Intervals, from July 15 to October 23, 1960.

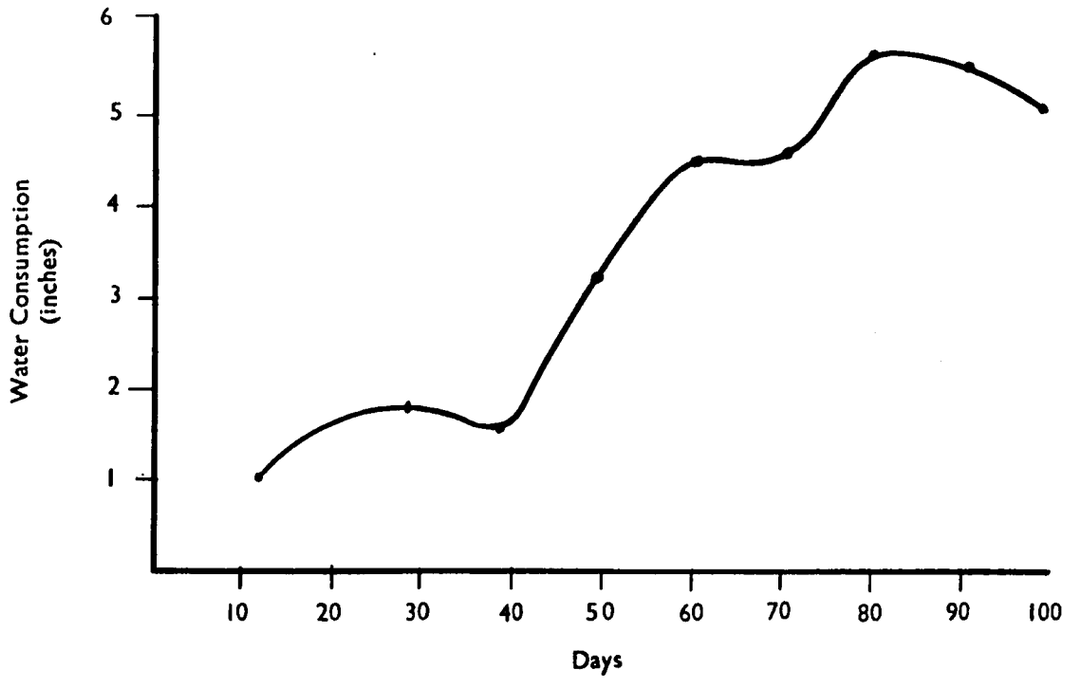

FIGURE 2 Consumptive Use of Water by Transplanted Aus at 10-Day Intervals, from May 1 to July 30, 1961.

Interaction of Water and Fertilizer

A preliminary study was made in 1967 at the Agriculture Development Corporation's Dattanagar farm to ascertain the effect of different doses of fertilizer, with two different levels of moisture, on the yield of IRRI-8 rice. The experiment was laid out in a split-plot design. Two levels of fertilizer were applied: high level —80 lbs. of N_2 in the form of urea and 40 lbs. of phosphate in the form of T.S.P.; and low level —20 lbs. of N_2 in the form of urea and 20 lbs. of phosphate in the form of T.S.P. In the experiment, two levels of moisture were maintained: one, continuous irrigation by flooding; the second, water level up to saturation point. Continuous flooding was managed by maintaining the water level 3 inches to 4 inches above the surface, and saturated soil by maintaining the water level above field moisture capacity. The four treatments and the results were as follows:

Treatment	Yield (maunds per acre)
High fertilizer + flooding	85
High fertilizer + saturated soil	70
Low fertilizer + flooding	50
Low fertilizer + saturated soil	45

Chow and Dudal (9) reported that saturated soil is as good as flooded soil for maximum yields in several varieties of rice in the Philippines and Formosa. It is anticipated that varietal response to the above treatment will be quite prominent with our local varieties of rice.

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RECENT RESEARCHES IN THE FIELD OF IRRIGATION IN INDIA

by
N. G. Dastane*

Abstract

Irrigation research has received a great impetus in recent years in India on account of the creation of large irrigation potentials and an all-out drive for increased crop production. A co-ordinated approach, with a team consisting of an agronomist, an engineer and a soil scientist, has been adopted by the Indian Council of Agricultural Research, New Delhi, to tackle the problems. Salient features of some of the important experiments are reported here.

Studies of the relationship between meteorological parameters and consumptive use of water by crop plants have been made, in which evaporation from the sunken screen pan evaporimeter and the can evaporimeter have shown better correlations than with empirical formulae. Cup evaporimeters have been found useful for micro-climatic studies in field crops. Investigations on the degree of crop canopy and consumptive use have shown that it is not necessary to have cent per cent ground cover for attaining potential rates. In other studies it was observed that crop growth does not affect potential evapotranspiration at the active growth stage and when there are no advective effects. Experiments on crop planting and wind direction have shown that frequency of irrigation can be reduced by planting shallow-rooted crops on the leeward side and deep-rooted crops on the windward side.

For rice, the drum culture technique has been developed and found useful in assessing water requirements. Cultural practices have been evaluated for areas endangered by temporary water-logging. Optimum moisture regimes have been worked out for many new high-yielding strains. Criteria in selecting land for irrigation commands for the economic and efficient utilization of water have been under consideration. Devices such as moisture meters, terylene blocks and tensiometers have been developed from indigenous materials. Rapid methods have been devised for the determination of soil moisture content. Attempts are being made to utilize research information from operating irrigation projects in the training of suitable personnel at different levels.

* Special Officer, Irrigation Research, Major River Valley Project Areas, Indian Agricultural Research Institute, New Delhi.

Report

Realizing the importance of water in increasing crop production, the Government of India has attached the topmost priority to enhancing water resources by undertaking several river valley projects in different parts of the country during the last three five year plans. Today nearly 36 million hectares are under irrigation from various sources, such as canals, wells, tanks, etc. Precise information and data are required for the economical and efficient use of water. Unfortunately, inadequate attention to water management research and developmental programs in the past resulted in inefficient irrigation practices and low crop yields. There were difficulties in obtaining adequate funds, trained personnel and suitable equipment. Basic concepts in the soil-water-plant and climate relationships were not properly understood. Identifying these shortcomings, the Indian Council of Agricultural Research, New Delhi, set up a branch under a deputy director general to deal with the problems of water management research. The Ministry of Food & Agriculture has a department of minor irrigation and water use for dealing with the problems of well and tank irrigation. Another department, called the water utilization cell, has been established to deal with the problems of canal irrigation. This paper reports only the salient features of recent research in the country.

I. Coordinated Teamwork

In recent investigations, a coordinated teamwork approach has been adopted in different research schemes. In three major river valley project areas situated in different soil and climatic regions of the country, namely, Bhakra Nangal, Hirakud and Tungabhadra, three irrigation research centers have been established with an agronomist, a soil scientist and an engineer working together. The object of the scheme is to develop water management practices consistent with the economical and efficient use of irrigation water for maximum crop production.

There is another scheme, in which agricultural universities and engineering research institutes are being strengthened to intensify teaching and research work in the field of water management at ten different centers. In a third scheme, new cropping patterns under canal conditions are being studied at twelve centers. Yet another scheme, financed by the Indian Council of Agricultural Research, is determining the water requirements of crops grown in the command area of Bhavanisagar project in Madras. Special emphasis is being given to cotton and groundnut, besides rice and other cereals. Thus, the work has been properly coordinated and provides for intensification of research and training of personnel. (Pal, 1968).

II. Climatological Research

Different types of experiments have been conducted to examine basic relationships between the climate and water use by plants. The results of different trials are furnished below:

(A) Determining Correlations of Evapotranspiration with Weather Parameters in Different Crops

Studies were conducted on wheat, berseem, oats, onion, cowpea and fodder sorghum to test the application of two widely accepted formulae, namely, those of Thornthwaite and Penman. It was observed that the Thornthwaite formula considerably underestimated evapotranspiration in all the crops and in all the seasons. The Penman formula worked well from December to February, but later there were deviations. The application of these formulae, therefore, has limited scope.

Actual and computed values of consumptive use during different growth periods are shown in Fig. 1, while the values of correlation coefficients are shown in Table 1. The correlation coefficients were high in all cases, but on the whole, data on evaporation from the U.S. open pan evaporimeter furnished a better correlation with crop water use.

Singh (1968) found at Udaipur. Rajasthan, that consumptive use of water by wheat is 0.8 times the U.S. open pan evaporimeter value.

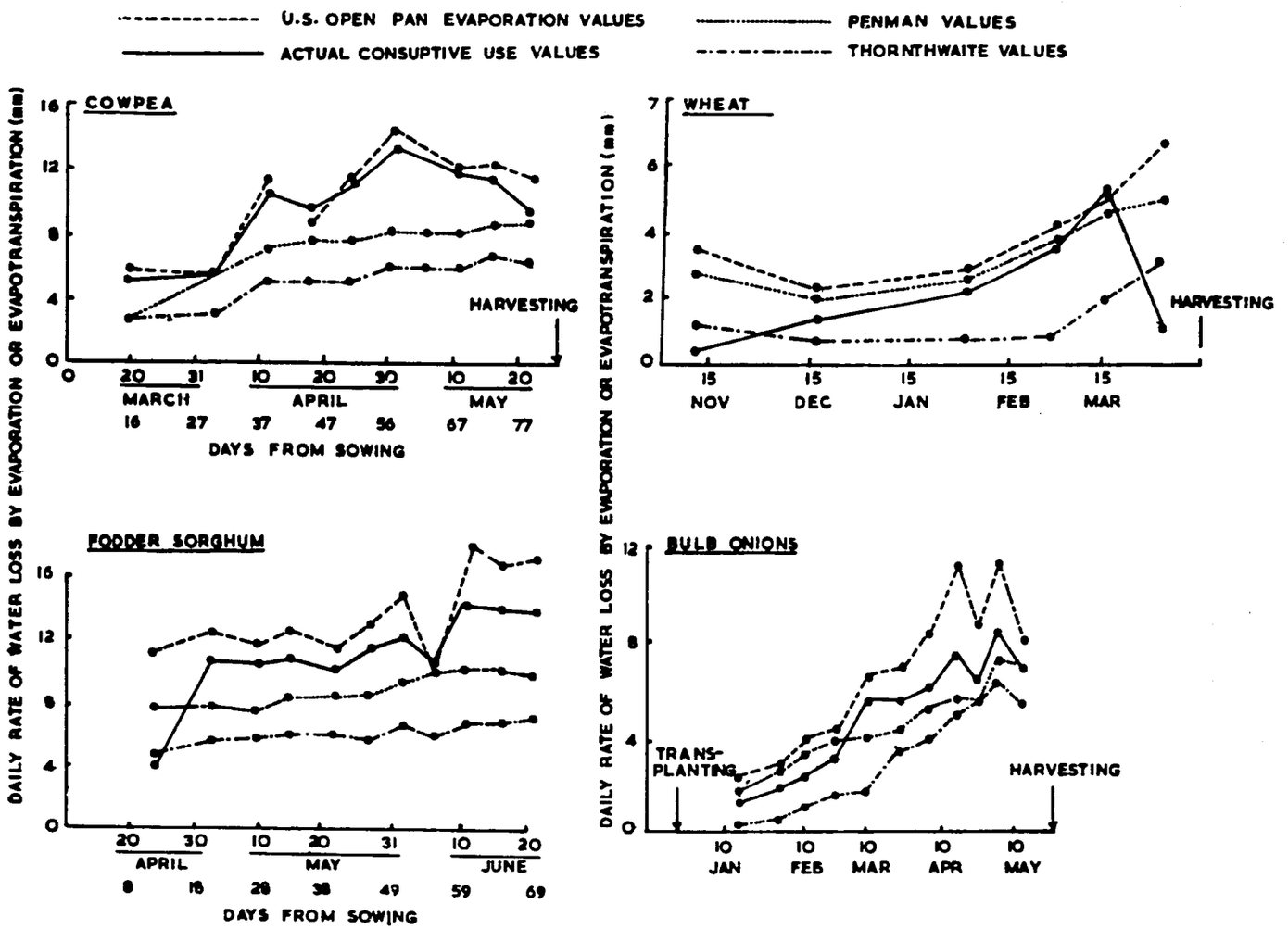


FIG. 1. DAILY RATES OF ACTUAL AND COMPUTED WATER LOSS IN DIFFERENT CROPS IN THEIR OPTIMUM MOISTURE REGIMES

TABLE I

Correlations between Values of Actual Consumptive Use and Those Computed with Different Methods in Different Field Crops Grown in Optimum Moisture Regimes

Crop	Penman Method	Thornthwaite Method	U.S. Open Pan Evaporation Method
Wheat	0.982	0.939	0.998
Cowpea	0.854	0.894	0.942
Sorghum	0.794	0.936	0.800
Berseem	0.997	0.944	0.973
Oats	0.687	0.789	0.780
Onion	0.626	0.733	0.858
MEAN	0.833	0.872	0.891

(B) EVAPOTRANSPIRATION IN RELATION TO STAGE OF GROWTH AND DEGREE OF CROP CANOPY

Whether evapotranspiration increases with crop canopy and whether it differs at different stages of growth are controversial issues. Our findings were that evapotranspiration increased in the initial stages with crop canopy, but the potential rates of evapotranspiration were attained long before the ground was completely covered with vegetation.

In oats, plant cover varying from 21 per cent to 100 per cent showed no significant difference in consumptive use of water in the optimum moisture range. In berseem, two days of growth after cutting lost the same moisture as a 45 cm.-tall crop ready for a cut. In hot-weather maize, plant covers varying from 50 per cent to 100 per cent showed no influence on consumptive use. Data in the case of oats and berseem is presented in Tables 2 and 3 respectively.

This observation increases the scope of applicability of empirical and semi-empirical formulae for estimating water use by field crops, and thus enables the water controller to prepare better schedules for water delivery.

The stage of growth does not affect evapotranspiration as long as the crop is in the active stage of growth. During the senescent stage, however, evapotranspiration decreases considerably.

(C) USE OF EVAPORIMETERS IN IRRIGATION PRACTICE

Studies were conducted on correlations of the values of consumptive use of water by field crops (berseem and wheat) and the evaporation from different types of evaporimeters, and empirical formulae. Better correlations were obtained in the case of the sunken screen open pan evaporimeter, as shown in Table 4. This evaporimeter (Figs. 2 and 3) is made of galvanized iron sheet and is 60 cm. in diameter and 45 cm. in depth; it is sunk in the soil to a depth of 35 cm. The stilling well is 15 cm. in diameter and 45 cm. in depth and is outside the evaporation pan. It has a pointer inside as an index for measurement of fall in water levels. There is a screen cover of 6/20 mesh wire-netting on the pan as well as on the stilling well. The cost is Rs. 50 ($7) as compared with Rs. 500 ($70) for the U.S. open pan evaporimeter.

The sunken screen pan evaporimeter has been further simplified for use in an individual field by developing what is known as the 'can evaporimeter' (Fig. 4). This is a simple one-kg. capacity can with a pointer inside at 1.5 cm. below the brim to facilitate recording of water levels. It is painted white and has a screen cover of 6/20 mesh. The can has given correlation coefficients of more than 0.8 with evapotranspiration when installed at the crop height. This is the simplest and most practical device a farmer can use for scheduling irrigations to his field crop under Indian conditions, where the effects of advective energy are considerable. It is as efficient as other methods, as can be seen from the data in Table 5.

Recently, Dastane and Patil (1968) have found that cup evaporimeters (Fig. 5) can be used very satisfactorily for studying micro-climate in field crops. The cups, made of plastic, are 7.5 cm. in height and 6 cm. in diameter, and are fitted with a nail in the center which serves as an index

TABLE 2

Mean Evaporation from Fallow Plot and Consumptive Use of Water by Oats (in mm.) during Seven Short Periods in 1964-65

Treatments Seed Rate (kg/ha)	11/12-22/12		11/1-28/1		Active stage						Yellowing stage			
					20/2-4/3		29/3-4/4		8/4-11/4		24/4-29/4		3/5-10/5	
	12 days		18 days		13 days		7 days		4 days		6 days		8 days	
	% cover	Moisture loss	% cover	Moisture loss	% cover	Moisture loss	% cover	Moisture loss	% cover	Moisture loss	% cover	Moisture loss	% cover	Moisture loss
Fallow	—	30.2	—	20.7	—	25.1	—	44.2	—	47.4	—	34.8	—	53.3
25	21	36.3	57	54.1	37	47.3	87	53.8	92	49.1	92	47.3	92	51.2
50	37	37.5	63	35.5	26	33.6	77	38.7	92	59.8	92	37.5	92	51.5
100	41	32.6	71	40.0	27	35.3	72	45.8	85	63.7	85	42.8	85	49.9
200	45	42.7	76	27.3	23	29.8	81	58.0	100	35.3	100	38.4	100	51.8
400	53	37.9	92	38.4	27	34.3	75	50.0	97	58.8	97	62.8	97	49.5
'F' test	—	N.S.	—	N.S.	—	N.S.	—	N.S.	—	N.S.	—	N.S.	—	N.S.
S. Em. ±	—	7.25	—	6.41	—	4.83	—	9.30	—	8.30	—	7.23	—	5.62

N.S. = Not significant

TABLE 3

Mean Consumptive Use of Water by Berseem (in mm.) during Seven Short Periods in 1965

Treatments	2/2-8/2		9/2-15/2		23/2-1/3		8/3-15/3		20/3-25/3		30/3-6/4		8/5-11/5	
	7 days		7 days		7 days		8 days		6 days		8 days		4 days	
	Days' growth	Moisture loss	Days' growth	Moisture loss	Days' growth	Moisture loss	Days' growth	Moisture loss	Days' growth	Moisture loss	Days' growth	Moisture loss	Days' growth	Moisture loss
B_1	15	37.6	7	13.7	7	24.9	7	50.0	2	38.7	7	77.6	7	61.0
B_2	22	44.8	22	70.2	14	38.3	21	47.6	17	54.6	14	72.9	15	57.1
B_3	29	50.0	29	19.0	21	32.7	28	48.5	31	56.3	29	63.3	22	40.5
B_4	35	36.7	36	12.0	35	29.3	35	49.0	38	45.6	43	75.2	28	69.9
'F' test	—	N.S.	—	N.S.	—	N.S.	—	N.S.	—	N.S.		N.S.	—	N.S.
S. Em.±	—	3.84	4.63	—	5.17	—	4.62	—	8.50	—	7.64	—	10.27	—

N.S. = Not significant

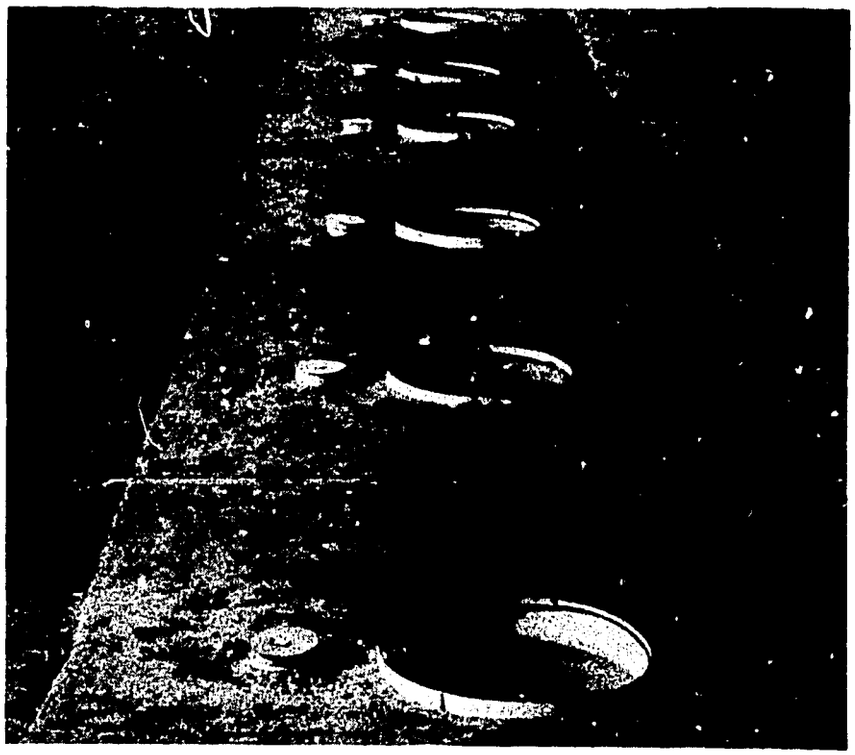


FIGURE 2. Sunken screen pan evaporimeters installed at the I.A.R.I., New Delhi

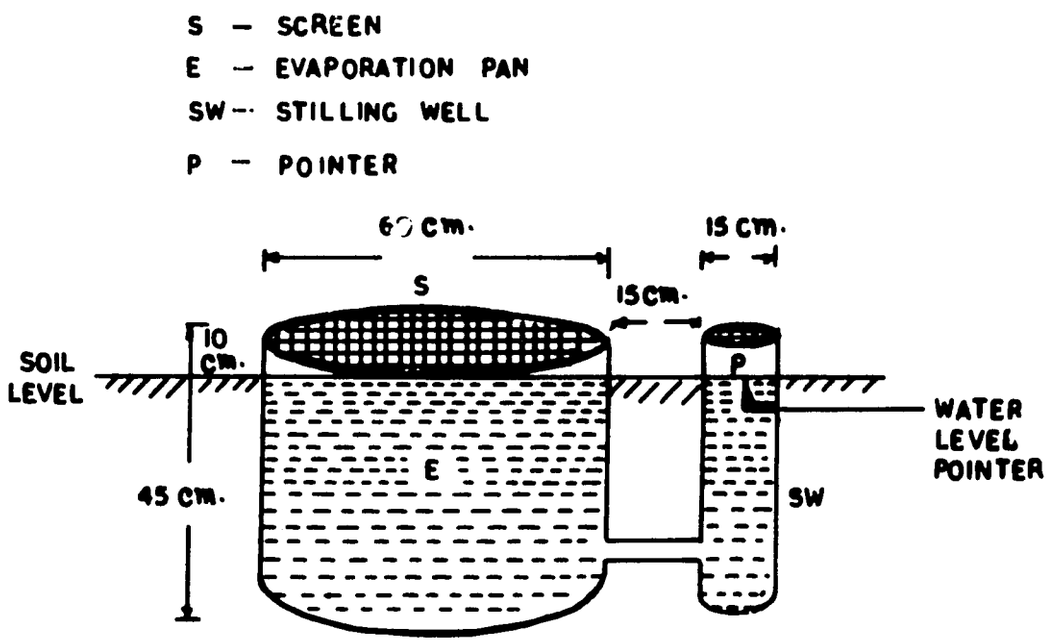


FIGURE 3. Drawing of a sunken screen pan evaporimeter

for recording water levels. On the top there is a screen cover of wire-netting of 6/20 mesh. The device is simple, cheap and reliable.

(D) Possibilities of Delaying Irrigation to Shallow-rooted Crops

Because of their shallow root systems, crops like onion, garlic, etc. need light but frequent irrigation. Such a practice may not be possible under canal conditions or may be more laborious. Investigations in this line have shown that the frequency of irrigation can be reduced without affecting yields, by planting these crops on the leeward side and some other deep-rooted crop on the windward side (Fig. 6). Alternatively, a deep-rooted species can be mixed with the shallow-rooted species. The deep-rooted species meets the evaporative needs of the climate by extracting moisture from greater depths, thereby relieving the water stress on the shallow-rooted species (Saraf, 1966).

Experiments were conducted on bulb onion, using lady's-finger as a mixed crop to the extent of 3 per cent, 5 per cent and 7 per cent on an alluvial sandy loam soil. The irrigations were delayed from 6 days to 8 days without affecting the onion yields in a 3 per cent mixed crop.

III. Crop Research

(A) Rice

Recent research on rice has been on the evaluation of techniques for assessing its water requirements, the determination of optimum water regimes and the identification of critical stages during its life.

TABLE 4

Monthly Evapotranspiration (mm) by Berseem and Wheat, and Ratio of Evaporation Worked with Other Methods to Evapotranspiration

Period	Et	S.S.O.P. Evaporimeter	U.S.O.P. Evaporimeter	PEt Penman	PEt Thornthwaite
		BERSEEM			
Dec. 63	56.0	1.00	1.20	0.93	0.91
Jan. 64	56.0	1.00	1.25	0.97	0.89
Feb. 64	69.6	1.00	1.25	1.04	0.85
March 64	149.4	0.98	1.25	0.83	0.74
April 64	226.6	0.99	1.42	0.74	0.74
May 64	252.4	1.00	1.41	0.87	0.79
TOTAL	810.2	—	—	—	—
MEAN	—	0.99	1.24	0.83	0.79
		WHEAT			
Dec. 63	55.4	1.01	1.22	0.94	0.92
Jan. '64	56.8	0.98	1.23	0.95	0.87
Feb. 64	72.7	0.96	1.20	1.00	0.81
March 64	145.4	1.01	1.27	0.25	0.79
TOTAL	330.3	—	—	—	—
MEAN	—	0.99	1.24	0.92	0.81

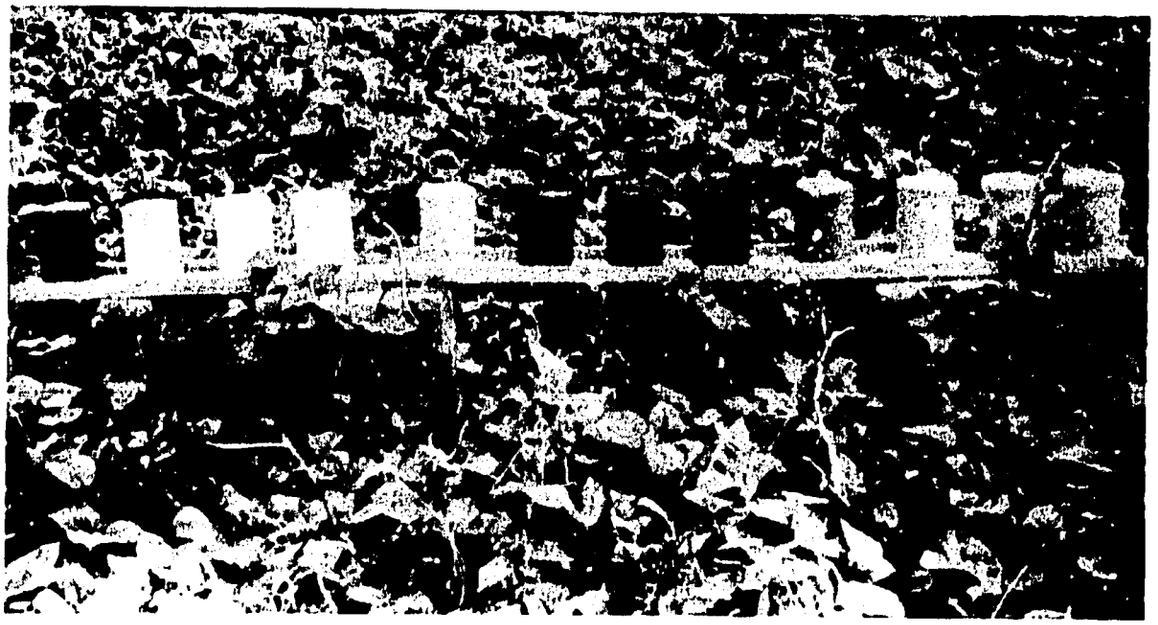


FIGURE 4. Can evaporimeters of different colors in a cowpea patch

TABLE 5

Values of Actual Evapotranspiration (Et) and Those Predicted with Different Methods

	Period	Actual Et (mm)	Predicted Et (mm)			
			Can Evaporimeter		U.S.W.B. Class A Pan	Thornthwaite Method
			Aluminum	White		
Wheat (1967)	23/1- 3/2	23.95	27.73	27.10	29.18	21.24
	4/2-10/2	19.51	22.55	22.69	23.82	24.77
	14/2-28/2	36.43	34.62	33.36	35.33	34.92
	3/3-12/3	34.35	33.16	34.28	34.74	37.71
	15/3-20/3	27.96	23.12	23.34	21.75	26.84
	3/4-10/4	32.84	39.85	39.66	36.22	35.56
Ratio between Et, Eo/Ecan/PEt			0.904*	0.900*	0.824*	0.289*
Percentage error in predictions			12.06	12.29	15.97	12.89

*Significant at 5 per cent level

FIGURE 5. Cup evaporimeters for micro-climatic studies

In rice, water is required for the evaporation needs of climate as well as the percolation needs of the soil. The drum culture technique has been evolved for this purpose and found very useful (Dastane, 1967). Two drums, one (A) with and the other (B) without a bottom, are installed in the rice field. Water is maintained in them to a certain height. The difference in water levels on two consecutive days in drum A furnishes the values of consumptive use, while a similar difference in drum B furnishes the values of total daily needs of water. Differences between water levels in the two drums show percolation losses. Fig. 7 shows the drum culture technique.

As regards the optimum water regime, land submergence varying from 4.0 cm. to 0.0 cm. gave the maximum yield with N. P. 130 (fine rice) as well as with Taichung Native-I (coarse rice). Land submergence greater than this was found to be positively harmful to Taichung Native-I, while it showed no advantage in the case of N.P. 130. Data is shown in Table 6.

During growth, tillering and pre-flowering were found to be the critical periods for moisture. Non-submergence during the last month did not reduce the yield in either of the above varieties. Data is presented in Table 7.

Studies on how and why land submergence is beneficial to rice are in progress at various places. Factors being assessed are: soil temperature control, weed control, nutrient availability, nitrogen fixing algae and congenial micro-climate.

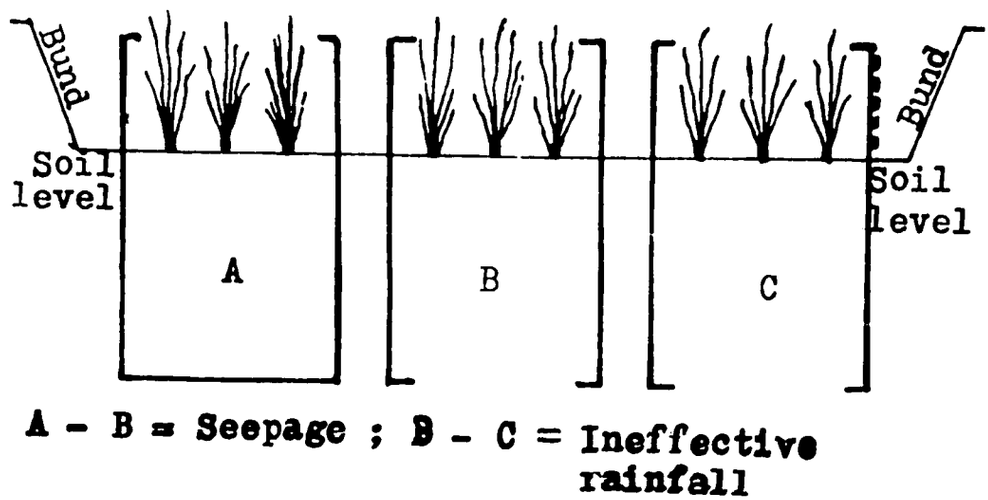
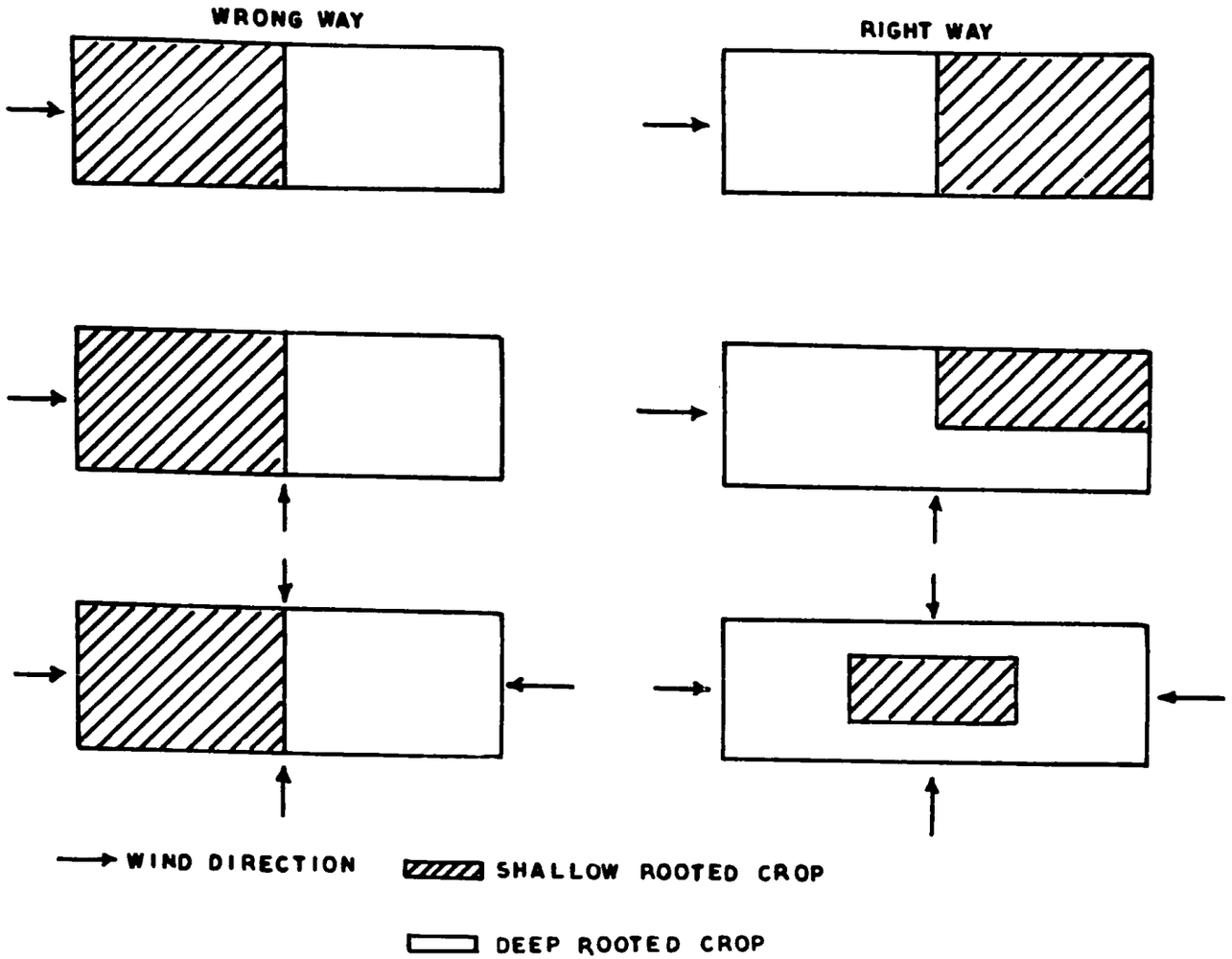


FIGURE 7. Drum culture technique for determining water requirement of rice



CROP PLANNING AND WIND DIRECTION
FIG. 6.

TABLE 6

Effect of Water Regimes on Rice Yields

Water Regimes	Yield (q/ha)	
	N.P. 130	Taichung N-1
Field capacity to 0.4 atm. tension	46.1	55.8
0-4 cm. standing water	59.0	71.9
4-9 cm. standing water	57.0	56.1
C.D. at 5%	6.56	4.66

TABLE 7

Effect of Withholding Irrigations at Various Stages of Growth on Grain Yield (q/ha) of N. P. 130 and Taichung Native-1 Paddy

Treatment	N.P. 130		Taichung N-1		Mean
	Absolute	Relative	Absolute	Relative	
A	66.9	100	70.2	100	68.5
B	49.1	73	58.9	84	53.9
C	62.6	94	67.2	96	64.9
D	52.7	79	58.9	84	55.8
E	61.8	93	63.6	91	62.7
F	67.6	101	68.1	97	67.9
G	67.5	101	69.9	100	69.9
H	66.9	100	70.8	101	70.8
Mean	61.9		65.9		63.9

	S. Em.	C. D. at 5%
Varieties	±0.40	1.17
Water treatments	±0.97	2.85
Interaction	±1.1	3.32

A: 4-0 cm. throughout
B: Withholding irrigations 0-20 days
C: Withholding irrigations 20-40 days
D: ,, ,, 40-60 ,,
E: ,, ,, 60-80 ,,
F: ,, ,, 80-100 ,,
G: One drainage
H: Two drainages

(B) Wheat

Studies have revealed that the newly-introduced Mexican dwarf varieties of wheat need one or two more irrigations during growth than the tall Indian varieties. The Mexican varieties have relatively slow growing and shallow roots, and therefore need a moist soil zone from 2 cm. to 5 cm. in depth till tillering is over. The first extra irrigation may be needed at the time

of tiller initiation, that is, at about two to three weeks, and the second during the grain developing period. Since the Mexican wheats are dwarf and do not lodge, this irrigation boosts the yield. The time of irrigation has been found to be a vital factor in affecting crop yields. At Delhi it was found that yields were highest when the four irrigations were applied at three, six, ten and fourteen weeks for the crop sown in the third week of November. These correspond to tiller initiation, boot stage, flowering and grain development respectively. The optimum moisture regime has been found to be from field capacity to 0.5 atm. tension in the top 30 cm. layer of Delhi's alluvial sandy loam (Anonymous, 1962-67).

(C) Other Crops

The optimum moisture regimes for different crops observed on a sandy loam at the I.A.R.I., New Delhi, are shown in Table 8. (Anonymous, 1962-67).

TABLE 8

Optimum Moisture Regimes for Different Crops Observed on Sandy Loam at the I.A.R.I., New Delhi.

Crop	Regime Lower Limit		Depth of Measurement in cm.
Maize	0.65	T	15
Sorghum (fodder)	75%	A	90
Cowpea (fodder)	75%	A	90
Tomato	70%	A	25
Sugarcane	0.70	T	22
Cotton	5000	O	30
Berseem	0.25	T	22
Tobacco	0.30	T	18
Potato	0.30	T	18
Onion	0.65	T	8
Radish	0.20	T	18
Turnip	0.20	T	18
Beetroot	0.20	T	18

A=availability; T=tension in atm.; O=ohms resistance

IV. Miscellaneous Research

(A) Cultural Practices for Crop Production under Soil Salinity-cum-High Water Table Conditions.

Many a time problems of a high water table and soil salinity go hand in hand. It is necessary to evolve suitable agronomic practices for crop production under these conditions. Investigations were undertaken on barley in which different agronomic practices—seed treatment with salt water, irrigation levels, layouts, etc.—were tried. The electrical conductivity of the saturation extract of the soil was 5.0 mmhos/cm. at 25°C., while the water table fluctuated from 69 cm. to 119 cm. during the life of the barley crop.

The seeds were soaked in a sodium chloride solution of 0, 2, 4 and 6 per cent concentration for four hours to observe hardening effects. There was no significant difference in the emergence or growth of seedlings. The irrigation frequency of 0, 2 and 4 caused no differential response in the yield of grain or straw. Higher seed rates than normal, however, were found to be beneficial and gave more yield. Ridge-and-furrow layout with furrow planting was found superior to the flat layout, as can be seen from Table 9.

(B) Evaluation of Land for Irrigability

At present, any type of land that falls under command area is brought under irrigation indiscriminately. A new system, therefore, has been proposed for judging irrigability of soils, taking into account five important properties, A, B, C, D and E, for sound and permanent irrigated farming. Marks are allotted for various properties, as shown in Table 10, and multiplied to obtain the grand score, on the basis of which the land is further classified for its suitability, as in Table 11. The method is more realistic than any other previous methods. In case of rice, percolation forms as high as 62-70 per cent of total water requirement. For rice, therefore, land should be selected on the mean daily percolation values during the crop growing season, as shown in Table 12.

TABLE 10

Limits and Rating of Different Characters in Evaluation of Land for Irrigation Commands

Description	A Available water holding capacity (mm) of top one-meter layer		B Minimum permeability of water in root profile (mm/hour)		C Potentiality of water rise after introduction of irrigation. Depth to water table in meters		D Maximum soluble salt content % in root profile		E Maximum exchangeable sodium % in root profile	
	Limits	Marks	Limits	Marks	Limits	Marks	Limits	Marks	Limits	Marks
Excellent	>175	3	15-25	3	always below 3	3	<0.20	3	<5	3
Good	100-175	2	10-15 or 25-50	2	always below 2	2	0.20-0.30	2	5-10	2
Fair	25-100	1	5-10 or 50-125	1	below 1	1	0.30-0.50	1	10-15	1
Poor	<25	0	<5 or>125	0	within 1	0	>0.50	0	>15	0

Grand score = AxBxCxDxE

TABLE 9

Effect of Different Treatments on Grain Yield of Barley

Layout*	Yield (q/ha)	Seed Rate* (q/ha)	Yield (q/ha)	Irrigation Frequency**	Yield (q/ha)
F_0—flat	18.96	S_1—60	17.20	M_0—0	19.19
F_1—Ridge & furrow	19.74	S_2—75	19.50	M_1—2	19.21
F_2—	Sig	S_3—90	21.36	M_2—4	19.25
S. Em. ±	0.24		0.30		0.30
C.D. at 5%	0.67		0.85		—

*Significant

**Not Significant

TABLE 11

Classification of Land

Irrigability Class	Description	Score
I	Excellent	Above 80
II	Good	50-80
III	Fair	16-49
IV	Poor	2-15
V	Unsuitable	0-1

TABLE 12

Land Evaluation for Rice Culture

Class	Percolation (mm/day)
Excellent	1.0-2.5
Good	2.5-5.0
Marginal	5.0-7.5
Unsuitable	>7.5

(C) MOISTURE DETERMINATION

Hukkeri and Dastane (1968) have recently calibrated a rapid field method for moisture determination by using spirits. Moisture is removed by adding spirits and igniting the mixture. It has given good correlations with the oven-drying method.

Prihar and Sandhu (1967) have recently developed a method for determining soil moisture content by a flask method, on the principle that a variable increase in the known volume of a liquid with the addition of a moist soil sample is proportional to the varying moisture content of the soil. The flask is suitably calibrated to read direct soil moisture percentages.

Mohsin and Ghildyal (1968) have fabricated nylon and terylene blocks, using indigenous materials costing about Re. 1 ($ 0.15). Abrol (1968) has recently developed a method for determining the bulk density of soil by using a rubber solution diluted with benzene. A soil clod is immersed in the solution and its volume is found by the displacement method. A thin layer of rubber-benzene makes the clod waterproof.

(D) CROP PRODUCTION IN TEMPORARILY WATER-LOGGED AREAS

Temporary water-logging is a serious problem during *kharif* in north India, causing enormous crop damage. A wet farming system was therefore evolved by selecting excess-water tolerant species, and adjusting seed rates, sowing time and field layouts (Joshi and Dastane, 1965-1966). Investigations revealed that the higher plant population through increased seed rate maintained the yield by compensating for the loss due to poor growth. Growing crops on ridges, as compared with the flat layout, reduced the damage considerably. Sorghum was more tolerant of

excess water than pearl millet, which was more tolerant than maize. In maize, the seedling and flowering stages were found to be extremely sensitive. In legumes, the species in decreasing order of tolerance were: cowpea, cluster bean, black gram, green gram and kidney bean. Data is shown in Table 13.

(E) MANAGEMENT OF BLACK SOIL FOR IRRIGATION

Inadequate aeration becomes a limiting factor in growth when crops on black soils are irrigated. The setback received after each irrigation on a plain field is serious; therefore

TABLE 13

Effect of Layout on Relative Toierance of Pulses to Excess Water Conditions and on Grain Yield in q/ha

Crop	Unflooded control (flat)		Flooding at 3 weeks for 4 days and at 9 weeks for 7 days (flat)		(ridge)	
	Actual	Relative	Actual	Relative	Actual	Relative
Cowpea	26.7	100	19.6	73	29.9	112
Cluster bean	16.3	100	12.9	79	23.2	142
Black gram	11.2	100	6.7	58	9.7	84
Green gram	3.3	100	1.5	45	3.3	100
Kidney bean	0.3	100	0.1	33	0.5	166

these soils should be irrigated in such a way that part of the land surface remains dry. This is achieved by opening ridges and furrows and irrigating alternate furrows, or by growing the crop in flat beds but applying irrigation only through peripheral channels. Lateral movement of water wets the subsurface root zone satisfactorily. High yields of cotton have been achieved with water economy by this method on the black soils of Surat (Joshi, 1968).

Irrigation management needed for soil types prevalent in India, namely, alluvial, red, laterite and black, has been recently discussed by Dastane, *et. al.* (1968), and for black soils by Motiramani (1968).

(F) IMPLEMENTS RESEARCH

Michael, *et. al.* (1964) have recently designed and tested a number of bullock-drawn implements for irrigated farming. These are a buck scraper and float for leveling, an A-frame ridger for bunding and a V-ditcher for opening channels. They have also suggested designs, suited to Indian conditions, of diversion boxes, checks, turnouts, canvas and metal dams, chutes etc. These are simple, cheap and fairly efficient implements within the reach of Indian cultivators.

Summary

It can be seen from the above report that problem-oriented work on various aspects in the field of water use has been planned and conducted. Climatological research, especially on the use of the evaporimeter, will enable canal authorities to assess the water requirement of crops rapidly, and to plan command areas and irrigation schedules more realistically. Crop research will guide the application of desired quantities of water at the right time, consistent with the moisture-holding properties of the soil. The work on miscellaneous items will help to solve special problems in different areas. Development of new implements and water control structures will lead to better preparation of fields and higher irrigation efficiency. All the new techniques evolved and the devices invented, as reported in this paper, are simple and cheap with high practical utility

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WEED AND RODENT CONTROL PROBLEMS IN THE MANAGEMENT OF IRRIGATION SYSTEMS IN TURKEY

by
Fikret Celenligil*

WEED CONTROL

Abstract

The primary objective in conducting experimental trials and analysis of this data was to develop a formula for comparing different chemicals, to find the most economical for control of emergent and submerged aquatic weeds. While studying the use of these methods of aquatic weed control, an effort was made to measure the effect of well-known chemicals.

Five years of observations of vegetation control indicate that herbicide formulation of aminotriazol was most effective for brush control. Dalapon is excellent for control of phragmithes and typha under experimental conditions. Gramaxone was effective on most of the submerged aquatic weeds.

The long-lasting effect of these products should be observable by repeated inspections of these trials during 1968 and 1969.

* Director, Agricultural Section, Operation and Maintenance Division, Directorate General of State Hydraulic Works, Ankara, Turkey.

Introduction

Man is almost entirely dependent for his food supply on the products of land and water, and the plant and animal species of the earth. We must seek more efficient and complete use of these resources. Practices that reduce resource productivity or cause wastage should be eliminated. The four ways in which increased crop yields are universally obtained are by :

application of fertilizer;
use of irrigation or soil moisture-conserving practices;
use of improved adapted plant varieties;
control of pests and diseases.

Irrigation without fertilization, or vice versa, or without pest control will not result in maximum yields, nor is it likely to yield the most economic returns. Often the combined effect of two or more factors is far greater than the sum of their separate effects, and may be more economical. Adequate delivery of irrigation water to millions of decares of irrigated farmlands depends on the timely control or removal of submerged weeds in the irrigation systems. Dense stands

of water weeds seriously impede the flow of water in irrigation channels. The impeded water flow raises the water level in the canal and thereby causes increased seepage and evaporation. In severe cases canal banks have been broken.

When man became interested in managing his environment he became concerned with the control of undesirable plants. Research in weed control has stimulated the proper use of tools to apply chemicals. The effectiveness of these chemicals can be improved through a knowledge of their characteristics and the techniques of application. By applying the principles already established to the science of weed control, the opportunities for increasing effectiveness are available. The word "principles" is used deliberately because there are established practices available to accompany these principles, and they usually relate to the areas where the principles have been developed. There are hazards in transferring practices too freely from one area to another. Broad principles can be applied but their limitations in new areas must be determined by field trials and investigation. The particular conditions of a local area (climate, type of weeds, etc.) will require specific studies. For example, in Turkey crops are planted up to the edge of the ditch. The spray must be accurately applied in a narrow band without any spray drift.

Irrigation or drainage canals and ditches must be cleared out periodically, as they become progressively blocked by a dense vegetation which reduces the water flow. Chemical control of aquatic weeds will become an important business in Turkey. This will occur as soon as dependable chemicals can be marketed and provided. These kill a high percentage of weeds in canals, ditches, ponds and lakes, and permit an economical control of reinfestations.

The weed maintenance staff is primarily concerned with emerged aquatic and semi-aquatic species, rooted in the soil and growing luxuriantly above water and along the bank. The prevailing species are : carex spp, juncus spp, nupher luteum, phragmithes communis, ranunculus aquatilis, scirpus lacustris, scirpus maritimus, typha angustifolia, typha latifolia. The most troublesome submerged weeds are: potamogeton pectihatus, potamogeton natans, potamogeton nedosus, ceratophyllum demersum, myriophyllum spicatum, chara spp. and several flamentous algae.

In 1963 field experiments were started. This report presents experience in nearly 30 different locations during five years.

The following preparations were used : aminotriazol dalapon, basfapon, elmasil, gramaxone, reglone, simazine and atrazine.

The experiments on aquatic weed control performed between 1963-1967 by the State Hydraulic Works (DSI) can be grouped into two periods.

During the first period, attempts were made to control emergent water plants. Satisfactory effects were obtained on most emergent species by applying a formulation of basfapon and aminotriazol, and a combination of basfapon plus gramaxone.

In the second period, emphasis was directed to control of submerged species. Attention was given mainly to paraquat and diquat. It proved to be very effective on a large number of submerged and floating plants. Most ditches are characterized by frequent change in dominance between these two species. Intermingling of different species occurs more commonly than pure species.

Summary

The most effective means of weed control have been chosen for presentation. It is possible to discuss only selected projects among a total of 30 experimental trials. .These are fairly indicative of the efficiency of our chemicals and trials.

A total of seven herbicides are being evaluated to determine their ability to control aquatic vegetation. These were applied to replicated 100 square-meter areas at two different rates.

The results of preliminary evaluation of seven compounds are given. This includes chemicals known to possess good herbicidal properties

and new compounds. Two of those tested were considered suitable for controlling submerged aquatic weeds in irrigation systems. These experiments indicated that systemic and contact herbicide treatments significantly reduced the number and size of rooted aquatic weeds. Species were treated under conditions both of flowing and standing water in order to evalua e herbicidal response under different conditions. Plants grown in static water showed more injury than those treated in flowing water. A series of tests was conducted at three different locations and under different climatic conditions to determine the effects of temperature on herbicidal action.

Data from this study will provide useful information to the operation staff on the use of herbicides to prevent or destroy excessive growths of aquatic weeds. This has proven to be the most economical and effective method of controlling these plants in irrigation systems. Only a general comparison of herbicides is included in this report. The following section briefly describes the different experiment trials conducted.

Main Project

(A) Control of Emerged Aquatic Weeds

Trials for control of emerged aquatic weeds were conducted from 1963-1967 in June and July at three locations: Bursa, West Anatolia; Samsun, North Anatolia; Adana, South Anatolia. Herbicides were tried under different ecological conditions. After approximately three months, assessment was made by means of observations.

Most of the trials were located in drainage canals and ditches. Partial clogging of canals and ditches results in raising the ground water level, which concerns the growers. They have always been concerned with the infestation of the water system by aquatic weeds in the ditch bottom and on the lower part of the bank. The prevailing species listed in order of decreasing density are: phragmithes communis, typha latifolia, typha angustifolia, sparganium erectum, butomus umbellatus, juncus, carex, scirpus maritimus.

On the bank and adjacent areas are: rubus idaeus, rubus fruticosus, tamarix, rumex, equisetum palustre, circium arvense, sinapis arvensis, carduus draba.

(B) Products Used

(1) The following active ingredients and products were applied:

Soil Herbicides:

Simazine	10-15 kg/ha.
Atrazine	10-15 kg/ha.

Leaf Herbicides:

Aminotriazol	30-40 kg/ha.	per 1000 lit. of water
Elmasil	70 kg/ha.	"
Dalapon	25-30 kg/ha.	"
Gramaxone	11-25 kg/ha.	"

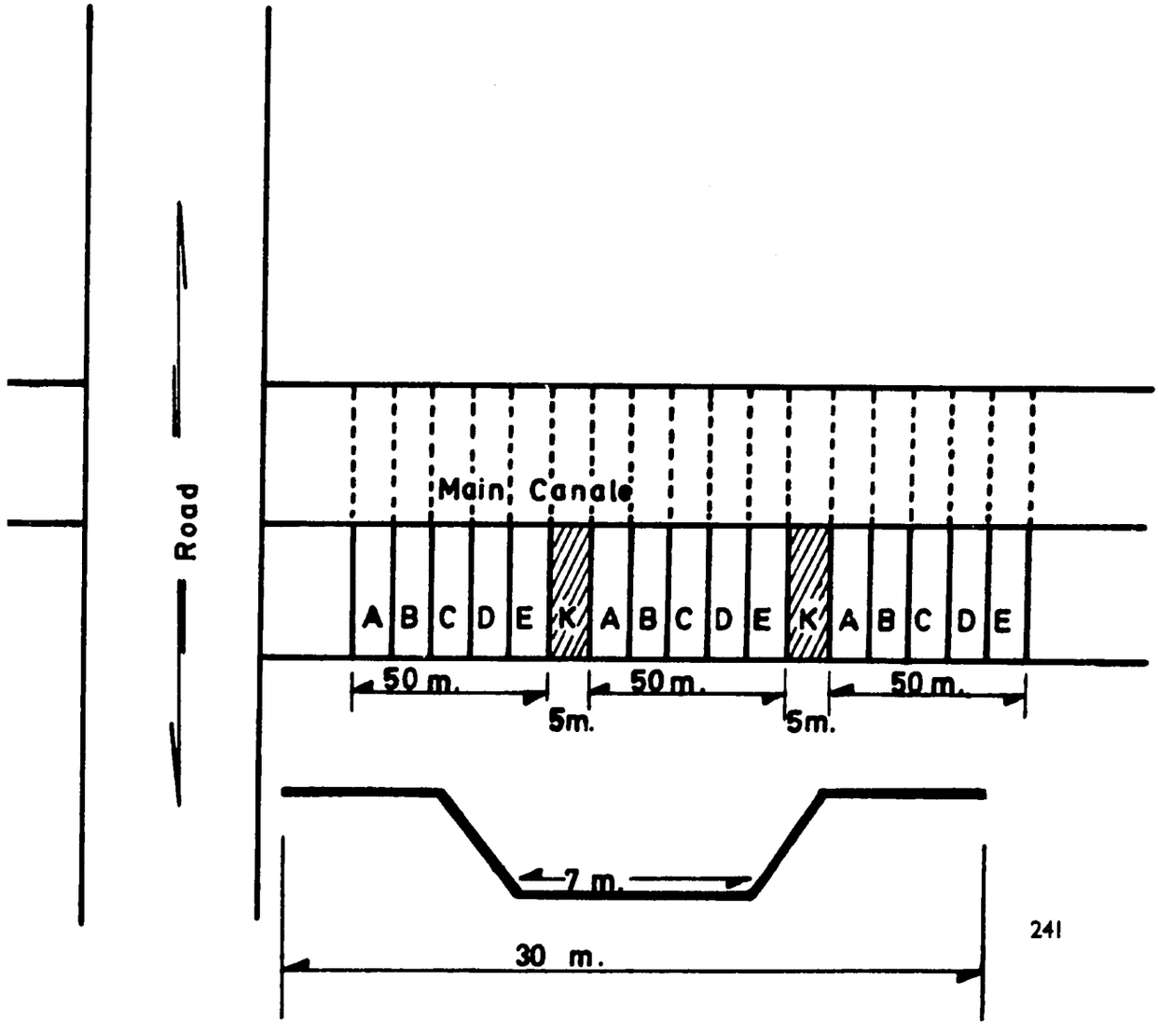
Trials and the cross sectional area of the canal are shown on the following page.

(2) These applications were made during July and August on fully grown weeds. This is always done with dalapon. These chemicals were most effective when the plants were at optimal growth and had already developed a density of leaves. An important factor in this technique is to treat phragmithes communis and typha spp. at about the flower-head stage of growth.

After one season, it was concluded that dry-off could be obtained on these weeds by application of dalapon or aminotriazol at 3 per cent in 1,000 liters of water per hectare. This was the least troublesome application for maintenance staff.

Phragmithes spp. has a capacious rhizome, and retreatments of regrowth with dalapon or aminotriazol may be necessary. Only spot spraying is needed the second year, regardless of the prevailing species. Both chemicals can be applied early with success, but overall applications will be needed the second year. Some green shoots may appear by the end of that year. Another limitation to early application is regrowth of these species at the end of summer. They may not absorb enough chemicals at application, and spot spraying may be needed in early fall.

	PLOTS	DATE	DOSES	M^2
A	AMINOTRIAZOL	29.6.1966 — 1967	30 kg.	100
B	AMINOTRIAZOL	" "	40 kg.	100
C	GRAMOXONE	" "	11 kg.	100
D	TCA + 2.4 – D + ATA	" "	70 kg.	100
E	BASFOPON	" "	20 kg.	100



Results

Analysis and comparison of seasonal results are presented in the following tables.

Discussion

(1) *Elmasil.* A good brush or woody plant killer, but with 2,4-D will have hidden hazards where irrigation is concerned, particularly where cotton, tomato, grapes and many flower and ornamental crops are grown.

(2) *Aminotriazol.* In comparison with elmasil, the efficiency against shrub-type plants is somewhat poor, and is insufficient as regards

A.—Ditch Bottom and Lower Part of Bank

Material	Overall Results after 3 Months	Overall Results at Late Fall
Aminotriazol	1-P. Mixture of dry, white leaves	1-P. Most leaves fallen away and stalks dry and brittle.
	2-T. All leaves dry	2-T. Most leaves fallen away and new shoots white.
	3. All the others burning at the top	3. All others dry at the top.
Dalapon	1-P. All leaves dry	1-P. Most leaves fallen away and stalks dry and brittle.
	2-T. All leaves dry, some fallen away	2-T. Most leaves fallen away and very few green shoots.
	3. All others dry	3. All others dry.
Gramaxone	1-P. All leaves dry, but new shoots	1-P. Most leaves fallen away but regrowth.
	2-T. All leaves dry, but new shoots	2-T. Most leaves fallen away but regrowth.
	3. All others regrowth	3. All others regrowth.
Dalapon 14 days after Gramaxone	1-P. All leaves dry	1-P. Most leaves fallen away, stalks dry and brittle, complete destruction.
	2-T. All leaves dry	2-T. All leaves dry.
	3. All others dry	3. All others dry.

P = Phragmithes
T = Typha

control of tamarix. With aminotriazol only reed-type weeds and gramineous weeds in the ditch bottom and at the border were controlled. Broad-leaf weeds, including weedy plants such as rubus fruticosus, on the bank and adjacent paths were also controlled. An application rate of 30 kg/ha. proved sufficient in all trials. After an initial treatment with aminotriazol or elmasil, only a spot treatment against recurring growth is necessary.

(3). *Dalapon.* Dalapon proved to be successful on typha and phragmithes. When applied from July through October, it has the advantage of not harming cotton or other crops susceptible to 2,4-D. This makes it necessary to apply dalapon separately. No damage was noted at any trial site.

(4) *Dalapon-Gramaxone.* Control of typha and phragmithes was achieved by an application of 15 kg. of dalapon per hectare, followed by 5 lit. per hectare of gramaxone about 14 days later. A dual treatment of dalapon followed by gramaxone is very effective for rapid control of phragmithes and typha. An important factor is to apply them at about the flower-head stage of growth. The result of the dual treatment indicates that 10 kg/ha. of dalapon is equivalent to 30 kg/ha. of dalapon applied without gramaxone.

(5) *Triazines.* Chemical weed control in irrigation systems in most cases can be achieved by simazine and atrazine. They cannot be used alone because there are too many resistant weeds, such as phragmithes sp, carex sp, sorghum halepense, etc., and other deep-rooted perennial weeds, especially typha. Under normal conditions these weeds are quite resistant to simazine and atrazine. Good results can be obtained only with high application rates. We are of the opinion that in many cases a combination of the triazine herbicides with systemic weed killers such as aminotriazol and dalapon, and hormone-type weed killers such as 2,4-D may offer some economic advantage for bank control because of its long residual effect.

B.—Bank and Adjacent Areas

Material	Overall Results after 3 Months	Overall Results at Late Fall
Aminotriazol	Best results against broad-leaved weeds	Poor results on shrubs.
Elmasil	Good results on all, but best on shrubs.	Good results on brush or woody plants, especially on tamarix.
Dalapon	Insufficient results as far as control of broad-leaved weeds, particularly shrubs, is concerned.	Very poor results on shrubs, and selectivity effects on broad-leaved weeds.
Gramaxone	All green parts dry, but regrowth.	Regrowth especially on shrubs.
Triazines	Some of broad leaves dry.	Poor results on brush, selectivity effects on most of the weeds.

Conclusion

The following recommendations are made:

(1) Elmasil is one of the best brush or woody plant killers but it should be used carefully.

(2) In practice, aminotriazol provides good control of emergent water weeds and bank weeds when the flora are mixed. Aminotriazol applied on fully-grown weeds provides good to excellent seasonal control of all species listed in the appendix at the end of this paper.

Treatments should preferably be made before flowering or during the inflorescent stage. A supplementary treatment is usually necessary the following year, when the amount of aminotriazol used can be reduced. It is better not to use the ditch or canal immediately for irrigation or watering livestock, even though the amount of aminotriazol is very small in relation to the volume of water. It is desirable to study further this aspect of the problem.

(3) Control of typha and phragmithes with dalapon is very satisfactory. It is also excellent for scirpus and juncus and has the advantage of not harming cotton or other crops.

(4) These chemicals must be used at the given rates, shown in kg. per hectare, in an average amount of 1,000 liters of water, though this may vary according to the density and height of vegetation. Application must be abundant and even until the run-off.

(5) These chemicals perform better with the addition of a wetting agent like citovet (alkylarylpolyglycoleter 100%, CgH_{17}-(OCH).

RODENT CONTROL

Abstract

The State Hydraulic Works of Turkey is interested in rodent control which is becoming increasingly important. Our efforts have been devoted to the protective treatment of irrigation systems.

Introduction

Most people have seen only a few of the more than 100,000 species that make up the mammal population of the world. Mammals are so secretive in their habits that many of us go through life without knowing that twenty to fifty kinds of wild mammals may live in our neighborhood. Most of these mammals are small folk, such as mice, rats, moles, shrews and ground squirrels. Field rodents living on farm lands are man's competitors and affect his business, pleasure and health.

Interest in rodent control has increased greatly in recent years, due to the damage caused by these creatures to the canal banks and levees. Little study has been devoted to mole-rats. These rodents dig a network of burrows which may extend over a 3000 square-meter area. Piling up subsoil in a mound, a single animal may dig 200-300 m. of passages, all leading to a nest-chamber located anywhere from half a meter to 1.5 m. below the ground. These galleries make open channels. Excavation of this magnitude requires the bringing up of soil from below to the surface at a rate of 2 to 3 cubic meters per animal per year. It is no wonder that each animal can do a lot of damage in breaking canal and ditch banks, causing breaks through the earthwork which allow water to flood adjacent lands.

Summary

From an economic viewpoint a great many rodents are harmful and destructive. The most serious pests to irrigation operation are mole-rats, which cause damage to irrigation ditches and interfere with the operation system.

With the advance of knowledge in rodent control, it has become necessary for us to separate the study of these animals into smaller categories, so that individuals can follow a certain line of study much further. As a first step, special attention has been given the mole-rat. Later we will also study other rodents like ground squirrels, rats, etc.

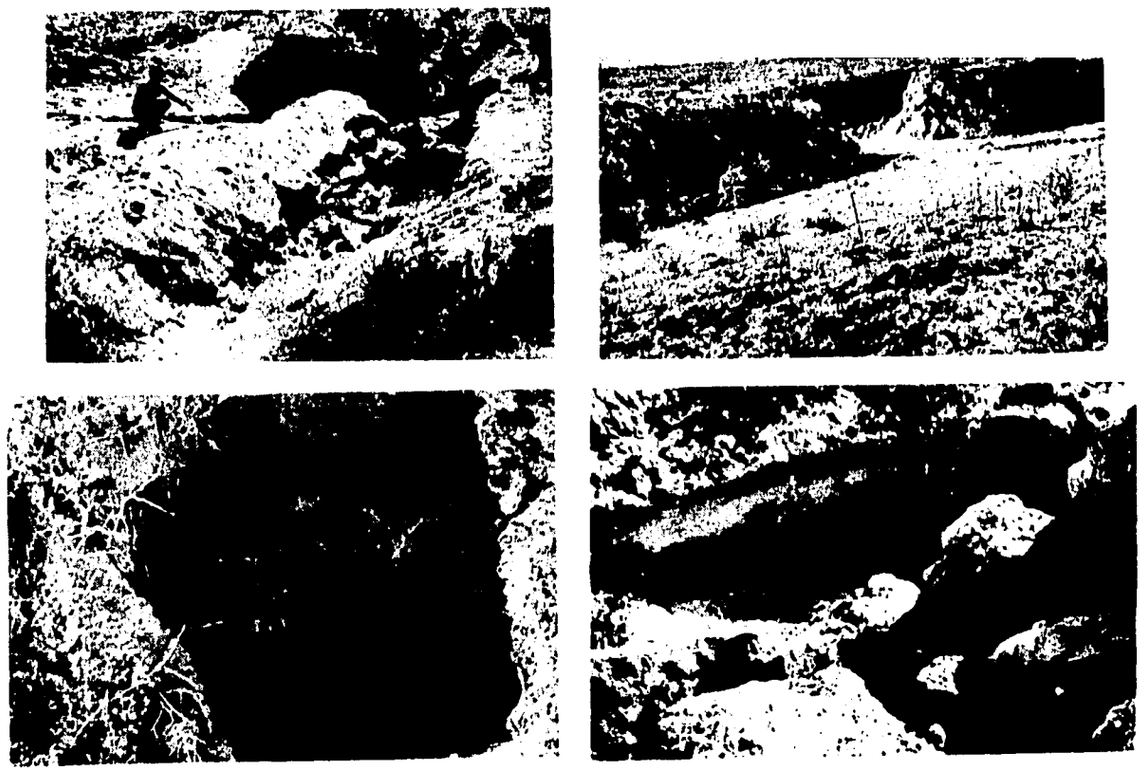
It is one thing to obtain knowledge about mole-rats and quite another to get field experience. These animals are among the most perfectly

adapted to a particular environment, and the difficulty in developing control methods is that they often differ from one another in habits and characteristics. Sometimes differences are the result of seasonal or other cyclical influences, sometimes of the physical environment itself. Occasionally they are inexplicable. Often mole-rats in one place will differ markedly from those of another place nearby, even when apparently similar conditions prevail. Each animal exhibits a number of measurable characteristics and various complex relationships with its environment. Therefore, an effective control technique that meets all requirements under all conditions has not been devised. Not all animals even within the same species react alike to bait or traps. In three years we have used various baits and several kinds of poison.

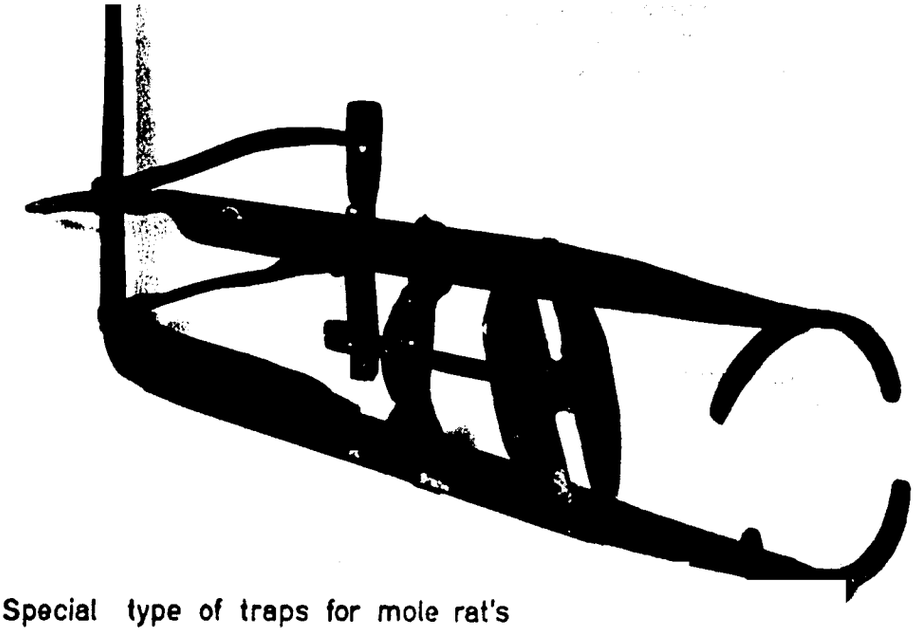
Main Project

(A) Mole-rats (Spalax leucodon; Spalax menticola)

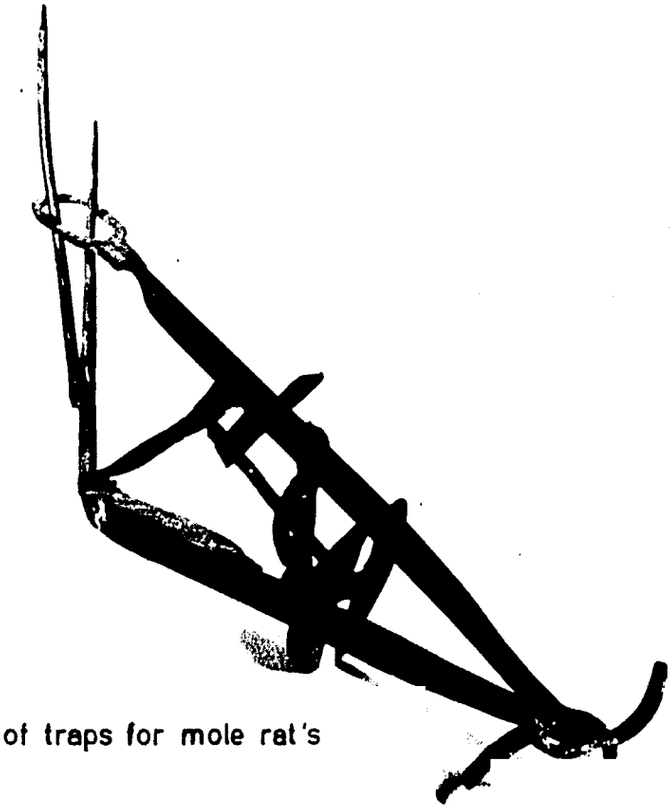
These strange subterranean rodents, known as Russian mole-rats, have no eyes and are covered with a dense, ash-brown fur. They live in burrows of their own construction and never come out of the ground. They dig clean-cut, cylindrical tunnels 8 cm. to 10 cm. in diameter and parallel with the soil surface, using their highly-developed fore-claws to burrow and their incisors to cut away soil or dislodge small stones. These teeth, in addition to their size and strength, are self-sharpening and grow constantly. The animals are herbivorous, feeding mostly on tubers which they find by digging in loose soil. They appear to be able to get along with little or no water, surviving almost entirely



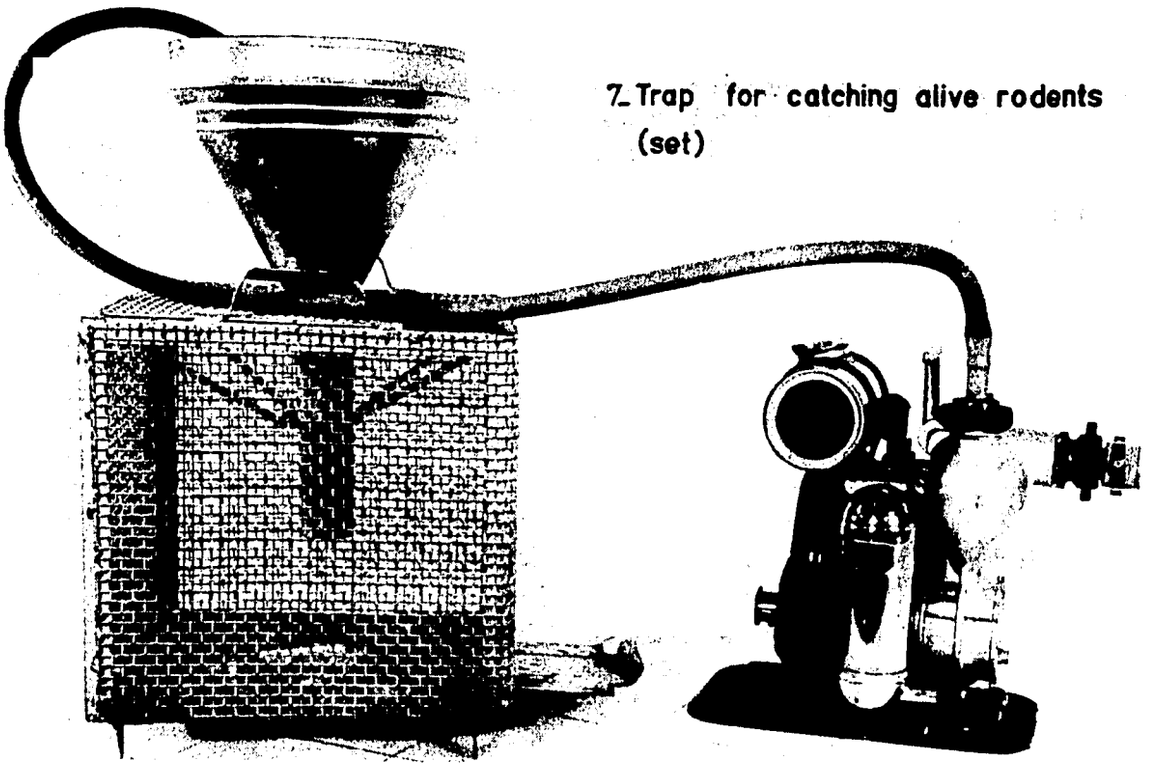
Irrigation canals damaged by mole-rats



1_ Special type of traps for mole rat's (set)

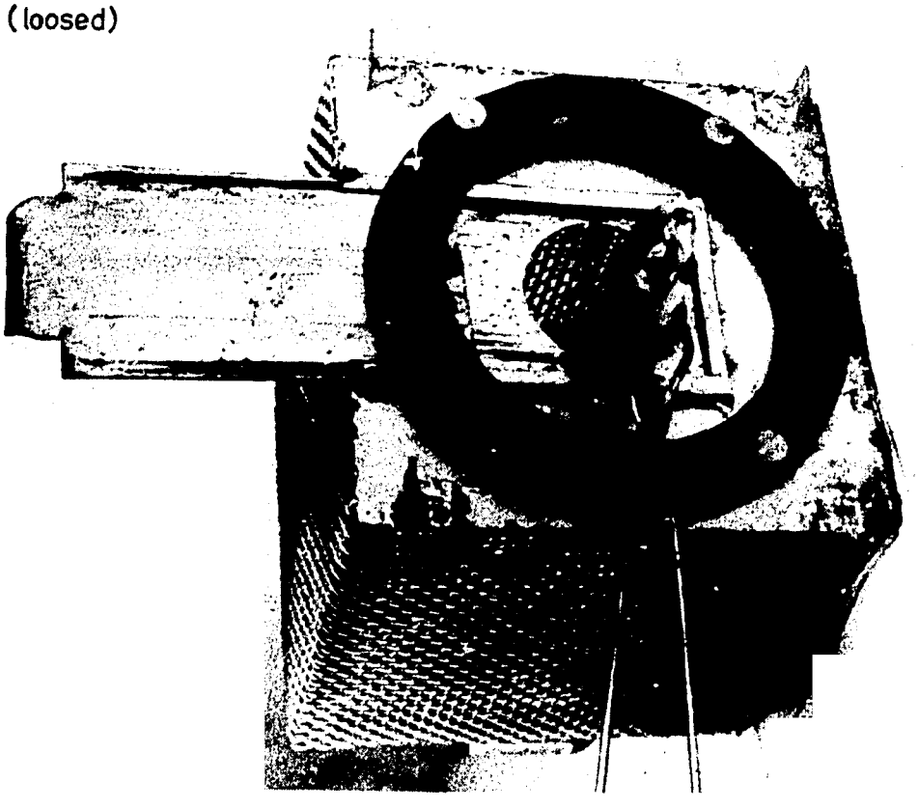


2_ Special type of traps for mole rat's (loosed)



7_Trap for catching alive rodents (set)

8_Trap for catching alive rodents (loosed)



on plant juices. They plug their burrows at various points, either for security or to maintain humidity. The male keeps a separate burrow all the year round. Mole-rats are found in Eastern Europe, the Balkan countries, Transcaucasia, Asia Minor, Central Asia and North Africa.

(B) EXPERIMENT

This detailed information about mole-rats has been given because it must be kept in mind when control measures are considered. We have conducted an intensive three-year study in all parts of Turkey, collecting spalax specimens and information on their living and feeding habits Control measures we have tried include trapping, poisoning and gassing.

Trapping may be effective in small-scale operations. But for several kilometers of canals and adjacent areas the cost of labor makes this method prohibitive.

Among *poisons* used in mole-rat runways were: potatoes, onions and carrots with strychnine; carrots, turnips, beets and onions spread with calcium arsenate; phostoxine (aluminum phosphide) tablets introduced in damp places where they slowly produced phosphine (pH_3), a poisonous gas; dust and strychnine mixed with ground glass; tomorin dust [3-(α-acetonyl-p-chlorobenzyl)-4-hydroxyco-umarin] blown into runways; and cotton soaked in aldrine.

The exhaust *gas* from a motorized knapsack containing carbon monoxide was piped into runways; through rubber hoses.

Discussion and Conclusion

Among rodents the mole-rat is one of the most difficult to control with common rodenticides. Control measures by means of traps are of little help. Fumigations are generally useless because these animals close their runways to any danger. Apparently good results have been obtained with baits spread with calcium arsenate or strychnine. But we have not had sufficient test experience in this area of application to make any recommendation.

We have also developed a trap for catching ground squirrels alive, under a patent issued in the name of Fikret Celenligil.

Appendix

Salix, Morus sp, Ficus sp.
Cirsium
Chenopodium
Centaurea
Urtica
Conicum maculatum
Polygonum sp.
Equisetum pulustre
Equisetum arvense
Xanthium
Typha latifolia
Typha angustifolia
Phragmithes communis
Carex
Acorus colamus
Phalaris
Glyceria

IRRIGATION — SOIL — SALINITY AND PLANT INTERACTIONS IN WEST PAKISTAN

by
Muhammad Hussain*

Important factors in the evaluation of the agricultural potential of any country are: soil, availability of water, climate and people. In West Pakistan despite favorable conditions agriculture was not a profitable concern. The yields of irrigated crops were among the lowest in the world. Among causes contributing to low yield and low cropping intensities were the problems of water for irrigation, soil, the water table, salinity and alkalinity hazards, and their interaction. Investigation of some of the problems imposing severe restraints on irrigated agriculture were undertaken as early as 1925. The results achieved so far are briefly discussed in this paper.

Quality of Irrigation Water from Rivers

The major sources of good quality water for irrigation are the river diversions, which form the largest continuous system of irrigation in the world. (The analysis results of water are given in Appendix I). The salt content of river water varies from 100-250 ppm. The percentage of calcium and magnesium is usually 2 to 3 times that of sodium and potassium. Bicarbonates are higher than sulphates and chlorides.

* Director, Land Reclamation, West Pakistan, Lahore.

Diversions of the river flow five years ago averaged about 85 m.a.f.—52 m.a.f. in high-flow season and 31 m.a.f. in low-flow season—irrigating an area of about 25 million acres. The existing canals are unlined. As a consequence, the conveyance losses amount to about 35 per cent from the headworks to the farm outlets. Actual farm deliveries are therefore of the order of 54 m.a.f. After taking into consideration further surface and percolation losses in the farm watercourses, the net water supply is 41 m.a.f. Farm deliveries of surface water in the northern zone are roughly 2.2 acre-feet per acre of cropped area during summer (April through September), and 1.6 acre-feet per acre during winter (October through March), compared with the optimum requirements of 2.7 and 2.4 acre-feet in the respective seasons. The Indus plain lands are therefore generally under irrigated.

The high conveyance losses in the channels created drainage problems. The inception of canal irrigation is invariably followed by a period of rising ground water levels, until recharge from the irrigation system is balanced by loss due to evaporation. The influence of evapotranspiration on the water table can well be gauged from a study of the rate of rise and stabilization in the

canal irrigated areas of the Indus plain. It is summarized below:

Depth of Water Table	Annual Rate of Rise
30 feet and below	1.0 to 1.7 feet
15 to 30 feet	0.3 to 0.7 feet
5 to 10 feet	0.1 feet

When the water table is within 10 feet from the ground surface the influence of evaporation is conspicuously marked, evaporation losses being of the order of 2 feet per year. Such conditions aggravate salinity problems and in extreme cases lead to water-logging of irrigated land.

Nature of Soil

The vast plains of alluvial deposits in the Indus basin have been formed by transported silt loads which filled up the sea. The receding sea left saline residues both in the soil profile and in the aquifer. Such alluvium and aeoline deposits of quaternary age extend throughout the Punjab and Sind plains. The uniform distribution of salts within permissible limits in the soil profile, essentially in the root zone, indicates a favorable salt balance. But the quantitative accumulation of the same salt as a zone in the upper horizon points up the unfavorable salt balance for crop production. The prolonged ascending movement of solutions, even of low concentration, and the evaporation of water from the soil in amounts higher than the rainfall or irrigation application lead to salinization. This points up the fact that even if salt is not added to the soil, the existing salts in the soil profile will redistribute themselves in different soil horizons and thus upset the salt balance.

Soil profile studies in the northern zone of the Indus plain show that under the present cropland use, inadequate irrigation applications, even with good quality water, result in the accumulation of salt in patches in a period of 8 to 10 years, under conditions where the water table is well below the influence of evaporation.

In a study carried out in the northern region of the Indus plain, about 70 per cent of the samples contained Ca + Mg concentrations well below 5 meq/l., 22 per cent contained Ca+Mg concentrations even less than 2 meq/l. and only 8 per cent were found to contain Ca+Mg above 15 meq/l. In exceptional conditions, as high as 35 per cent of the area may have concentrations of Ca+Mg greater than 15 meq/l. These are very limited and rare localities, however.

When the range of Ca+Mg is less than 2 meq/l. the soil tends to form saline-alkali to alkali conditions, even when leached with canal water of good quality, as the water does not provide sufficient divalent ions at any one time for replacing all the exchangeable sodium of severe saline-alkali soils. This points up the necessity of amendments for amelioration and reclamation.

The physico-chemical characteristics of the soil determine the magnitude of soil and water reactions. The physico-chemical properties of the soil are the resultant reaction of the mechanical composition of the soil, the nature and quantity of ions present, climatic conditions,. depth and quality of ground water table, and the quality and quantity of water used for irrigation. Irrigation practices have a pronounced influence on the physico-chemical properties of the soil. In a compact soil with minimum porosity, the roots can use only a part of the soil to extract the moisture and nutrients required and the natural drainage of the soil is impeded.

A permanent high water table reduces the effective depth of the soil in the same way as compaction. Under fluctuating water table conditions the plants have to adjust their root system periodically, using energy which is then not available for vegetative growth and seed production.

The nature of the salts and their quantity in different soil sections indicate the stage of deterioration. The soil profile of the Indus plain is characterized generally by the predominance of sodium salts and sulphates, chlorides and carbonates. With time, the soil exchange complex adsorbs a high amount of sodium ions, creating a high degree of dispersion and alkalinity. The soils in this state are called saline-alkali or alkali

soils. Under such conditions the soils become less stable with regard to the action of water and carbon dioxide. Due to the presence of hydroxyl ions and later of sodium carbonate, the soil acquires an alkaline reaction.

$$H_2O + CO_2 = H_2CO_3$$

$$Na_2 \text{ clay} + H_2CO_3 = H_2 \text{ clay} + Na_2CO_3$$

As long as excess salts are present, the appearance and physical properties of these soils are generally similar to those of saline soils. When the concentration of salts is lowered by leaching, the pH of the soil immediately rises above 8.5, the soil colloids are dispersed and the soil develops unfavorable structure, restricting water and air penetration. The management of these soils remains a problem until the excess salts and exchangeable sodium are removed from the root zone of the soil profile.

In alkali soils, the colloidal matter is in a highly deflocculated condition and the penetration of air and water is very much restricted. The leaching of salts in such soils permits a certain degree of hydrolysis of exchangeable sodium, which generally leads to the formation of sodium carbonate. Organic matter is highly dispersed and distributed among the soil particles, darkening the color of the soil. The physical and chemical properties of these soils are largely determined by the exchangeable sodium present.

It is generally accepted that saline-alkali soils are as a rule potentially fertile, and once the excess saline alkali has been removed large yields of crops can be realized. But without their removal crop growth is either impossible or severely restricted.

The soils of the northern region are generally light textured. A survey carried out in Rechna and Thal Doabs covering an area of 2.89 million acres reveals that heavy soils constitute only 5.6 per cent, coarse textured soils 57 per cent and medium textured soils 34 per cent of the land. The Hunting Technical Report on Drainage estimates that in the Lower Indus (deltaic region) heavy soils are 40 to 55 per cent, medium soils 20 to 30 per cent, and light soils only 10 to 12 per cent of the total, as shown in the table below :

Regionwise Textural Soil Classification

Zone	Light	Medium	Heavy
Upper Indus Plain (Punjab)	57.0	34	6
Central Region (Sukkur Barrage)	17.0	50	33
Deltaic Region (Ghulam Mohammad Barrage)	10-12	20-30	40-55

Heavy soils with a high cation exchange capacity in the presence of high sodium salts create problems of restricted infiltration and circulation of air. The textural aspect thus plays an important role in dealing with saline-alkali soils and the use of irrigation water of different qualities. A quality of water only marginally fit for one type of soil may be quite suitable for another type of soil for the same crop. The SAR value of irrigation water for various textural soils may be quite different with the changing value of the cation exchange capacity of the soil. Keeping 3-4 meq/100 gm. of exchangeable sodium in the soil as the upper limit, the SAR of irrigation water for soils of different CEC should be somewhat as shown in the table which follows.

This indicates that water with a SAR of 20 will be quite suitable for soil with a CEC of 5, but will create a serious alkalinity hazard when used on soils with a CEC of 20. The presence of RSC will have additional independent effects as indicated in the experiments discussed later.

Salt Balance Status

With an average salt content of about 250 ppm. in river water, 2 acre-feet annual irrigation applications will contribute 0.6 tons of salts per acre. The amount of salt finally retained in the soil profile, however, can be depicted from the salt balance studies. When the salt balance is adverse, the input of salts exceeds the output. In deep water table areas without capillary influence, the dis-

SAR Limits of Irrigation Water for Soils of Different CEC

CEC meq/100 gm. of soil	Ex. sodium meq/100 gm. of soil	SAR limits of irrigation water	Ex. sodium meq/100 gm. of soil	SAR limits of irrigation water
5	3	15.0	4	20.0
6	"	12.5	"	16.7
7	"	10.7	"	14.3
8	"	9.4	"	12.5
9	"	8.3	"	11.1
10	"	7.5	"	10.0
11	"	6.8	"	9.1
12	"	6.3	"	8.3
13	"	5.8	"	7.7
14	"	5.4	"	7.1
15	"	5.0	"	6.7
16	"	4.7	"	6.2
17	"	4.4	"	5.9
18	"	4.2	"	5.6
19	"	4.0	"	5.3
20	"	3.8	"	5.0

tribution of the salts in the soil profile is under a set pattern, in accordance with the meteorological conditions and physico-chemical characteristics of the soil. With the introduction of the irrigation regime and the efficiency of farming and watering methods, either a salinization or desalinization type of salt balance is established. The salts in the upper parts of the soil profile which retard plant growth are derived from three sources : (1) salt existing in the soil before the irrigation period; (2) salt added to the soil by low and inadequate irrigation applications, which do not properly fulfill the irrigation and leaching requirements of the soil; and (3) salt residues from the evaporation of ground water in areas where the water table is near the ground surface.

Salt balance studies in the Indus plain show that the annual addition of salt in the northern region from irrigation applications is of the order of 0.6 tons per acre, and from ground water sources under the influence of evaporation, of the order of 1.7 tons per acre. Thus, the total addition of salt is of the order of 2.3 tons per acre.

The output of salt in the northern region is almost equal to the input of salt from irrigation water. In addition, 0.6 tons of salts per acre are removed by way of leaching from surface irrigation, 0.6 tons through effective precipitation and 0.1 tons by vegetation, thus making a total of 1.9 tons. The net addition, therefore, is of the order of 0.4 tons per acre.

In the southern region the position is somewhat worse. The addition of salt is of the order of 4.4 tons (3.3 tons per acre from ground water sources plus 1.1 tons per acre from irrigation water). Removal of salt is 0.1 tons by the crops, 1.1 tons by leaching through precipitation, 1.1 tons by flushing through surface irrigation application and 1.1 tons by underground drainage flow. Thus, the net annual addition is still of the order of about 1.0 ton per acre. Under such conditions only high delta crops can be grown economically. This warrants an efficient field drainage system and copious surface irrigation application to keep the salt balance favorable. Heavy flushing to reduce the total annual input of salt in the soil

profile is a continuous process on cultivated land in this part of the country, posing the question of which type of drainage system to adopt to keep the salt balance favorable. These studies recommend tubewell drainage, where the pumped ground water can be suitably made use of for irrigation. In zones where the ground water is saline and water cannot be used for irrigation, preference should be given to open drainage and covered drainage systems to permanently get rid of saline water. The permanent removal of salt water and the development of fresh water by the open drainage system have been demonstrated at Chakanwali reclamation farm, with the results given below:

Quality of Drain Water in H/I Plot in Different Periods under Open Drainage System at Chakanwali Reclamation Farm

Drain no.	1930 Dissolved salts ppm.	1931 Dissolved salts ppm.	1964 Dissolved salts ppm.	1966 Dissolved salts ppm.	1967 Dissolved salts ppm.
1	661.8	536.7			214.7
2	787.5	536.7	236.1		250.4
3	787.5	626.1	329.0	429	250.4
4	893.4	679.7	270.0	286	264.6
5	894.4	643.9	336.2	572	372.2
6	823.1	590.3	282.2	315	279.0
7	1180.6	572.4	222.0	336	250.4
8	679.7	572.4	279.0	286	322.0
9	1287.9	679.7		251	250.4
10	708.3	751.3	250.5	322	336.2
11	629.5	572.4		358	164.6
12	1538.4	787.5	286.0	458	271.8
13	966.0	572.4		294	171.7
14	1609.9	858.6		358	178.9
15	1788.7	643.9		429	250.4
16	522.3	590.5		336	243.2
17	608.2	966.0		332	
18	571.3	608.2	350.6	394	236.1
19	679.7	554.6		774	207.4
20	701.1	590.3	271.8		243.2

Effects of Irrigation from Ground Water

(A) Salinity Hazards

The interaction of good quality irrigation water has been described earlier. Recent experience and studies indicate that the effects of ground water when used for irrigation are more severe where the quality of water is marginal or poor. The White House Department of Interior Panel on Water-logging and Salinity in West Pakistan in 1964 reported the availability of 2,000 million acre-feet of water to a depth of 450 ft. in the Indus plain. This was an over-estimation, based on the assumption of a storage factor of 25 per cent instead of 12 to 14 per cent. The qualitative analysis of the data indicates that about 48 per cent of the 29.36 million acres in West Pakistan has a salt concentration of less than 1,000 ppm. of ground water at a depth of 100 to 400 feet. In roughly 12 per cent of the area the salt concentration varies from 1,000 to 2,000 ppm.

About 4 per cent of the area has a salt concentration of 2,000 to 3,000 ppm. and 36 per cent has a salt concentration of about 3,000 ppm. Regionwise data is presented in the table below:

Area Underlain by Ground Water of Various Salinities at a Depth of 100-400 ft. (million acres)

Region	Salinity in ppm.				Total
	1000	1000-2000	2000-3000	3000	
Punjab and Bahawalpur	11.83 (60%)	2.94 (15%)	1.06 (5%)	3.87 (20%)	19.70 (100%)
Peshawar	0.58 (85%)	0.07 (10%)	0.03 (5%)	—	0.68 (100%)
Sind	1.81 (20%)	0.45 (5%)	—	6.72 (75%)	8.98 (100%)
West Pakistan	14.22 (48%)	3.46 (12%)	1.09 (4%)	10.50 (36%)	29.36 (100%)

With irrigation water from river sources containing a 250 ppm. concentration of salt, about 2 to 9 per cent of water over and above consumptive use is presently required for salinity control, depending upon the salt tolerance of crops. If irrigation water has 1,000 ppm. of salt, the required amount for leaching is 11 to 67 per cent greater than consumptive use. From this it is evident that the quantity of irrigation water will increase with the increasing salt content of water, and may involve a change in cropping pattern to those crops that can tolerate a relatively high concentration in the root zone. This is necessary to keep the quantity of irrigation water required to a minimum.

(B) ALKALI HAZARD

The use of ground water is also posing a serious problem of alkali. In the northern zone the majority of salt affected areas are saline-alkali and alkali soils. For instance, the areas under non-saline alkali soils in Rechna, Chaj and Lower Thal Doabs are 14, 9 and 7 per cent respectively. If one takes the saline-alkali and non-saline alkali soils together, the percentages for Rechna, Chaj and Lower Thal Doabs work out to 58, 34 and 44 respectively. In fact, the saline areas free of alkali in these projects are small and of the order of 5, 8 and 6 per cent respectively.

Since West Pakistan is faced with an insufficient supply of canal irrigation water, the underground water sources have been exploited in special SCARPs as well as in the private sector to supplement the surface supplies. This additional water now being pumped or lifted through tubewells and open wells amounts to about 10.5 m.a.f. More tubewell schemes are planned for the future. Some of these underground supplies, being consistently of poor quality and characterized by the presence of sodium, carbonate and bicarbonate ions in appreciable amounts, will with the present farm management practices increase the alkali hazards in West Pakistan's irrigated soils.

Faced with this problem, our scientists instituted several field and laboratory studies to determine the effect of these poor quality waters on crops and soils. The studies in SCARP-I, where additional water has been provided through the installation of 2,150 tubewells, indicate that the use of varying qualities of water has affected

the soil to varying degrees, as seen in the data given below:

Effects of Tubewell Water on Observation Plots in SCARP-I Area

Serial No.	Water Quality	Normal Plots			Percentage of Plots Showing Increase	
			Salinity	SAR	Salinity	SAR
1	EC 750 or less	No change	10	8		
	SAR 2.0-6·3	Decrease	31	30	Nil	7.3
	RSC 0-2.6	Increase	—	3		
2	EC 750-1500	No change	15	30		
	SAR 2.7-10.0	Decrease	50	32	9.7	14.0
	RSC 0.7-5.6	Increase	7	10		
3	EC 1501-2250	No change	4	2		
	SAR 6.3-15.0	Decrease	10	5	6.7	53.0
	RSC 0-7.3	Increase	1	8		
4	EC 2251-3000	No change	—	1		
	SAR 13-19	Decrease	4	2	43.0	57.0
	RSC 0-11.9	Increase	3	4		
5	EC above 3000	No change	3	—		
	SAR 14-30	Decrease	4	1	12.5	87.5
	RSC 0-17.2	Increase	1	7		

The soil SAR has increased in almost all cases, the effect being more pronounced on soils irrigated with waters of relatively high SAR and RSC values.

In order to control the alkali hazard, it is necessary to adopt good management practices involving adequate leaching to maintain a low level of the bicarbonate ions in the soil solution, and the application of gypsum or any other source of soluble calcium to maintain a favorable calcium: sodium ratio in the soil solution.

Recent laboratory studies of the effects of different qualities of water when passed through columns of soil have confirmed previous observations. The results, summarized on the next page, are detailed in Appendices II and III

From this it is inferred that the SAR and RSC of water influence the alkalinity of soil independently, and the combined effect of the two is more marked. So the evaluation of the quality of water for alkalinity hazards cannot solely depend on SAR; RSC has its own importance and should be given independent consideration. Experiments to isolate the extent of effects of SAR and RSC are in progress. A special experiment was conducted to find out the amount of Ca ions added from the irrigation water and liberated from the soil during leaching, with or without the rice crop. The soil contained about

Water and Extract Analysis of Soil Before and After Treatment with 50 and 70 Inches of Irrigation Water

	Milliequivalents per liter							D.S. (by evap)	ECx 10^6 at 25°C.	pH	ESP (Calc)	Res. Co_3 me/l	SAR
	Ca+Mg	Na	Co_3	HCO_3	Cl	SO_4	Total cations anions						
Water quality No. I (canal water).	2.2	0.8	—	0.7	0.3	0.2	3.0	160	250	8.1	4.25	Nil	.76
Water quality No. II (T/well 374 Zafarwal).	4.6	8.4	—	3.7	2.5	6.8	13.0	777	1230	8.3	20.52	—	5.46
Water quality No. III (T/well 122 Sangla/Hill).	2.6	6.1	0.7	3.8	1.2	3.0	8.7	493	770	8.3	19.18	1.9	5.3
Water quality No. IV (T/well 51 Hafizabad).	2.0	8.9	0.7	5.5	1.2	3.5	10.9	640	1000	8.6	32.47	4.2	9.07
Original soil	6.25	9.25		6.32	5.9	3.28	15.5		1550	8.1	1.9	.07	5.25
After treatment with 50 inches irrigation													
Water quality No.I	3.37	3.17		3.37	1.31	1.86	6.55		650		9.12	.5	2.49
" " II	4.0	5.62		3.25	3.06	3.31	9.62		960		15.36	.12	4.02
" " III	2.87	7.12		5.00	3.37	1.62	10.00		1000		22.05	2.12	5.87
" " IV	2.5	7.87		3.87	2.87	3.62	10.37		1000		23.78	1.37	7.36
After treatment with 70 inches irrigation													
Water quality No.I	2.69	3.01		2.75	1.5	1.45	5.7		570		8.76	Nil	2.59
" " II	4.87	9.62		4.12	4.75	5.62	14.5		1450		23.79	Nil	6.15
" " III	2.62	8.32		4.0	2.5	4.45	10.82		1080		24.62	1.37	7.21
" " IV	2.25	10.12		5.0	2.5	4.87	12.37		1240		32.59	2.75	9.51

17 per cent $CaCo_3$. The analysis results of soil and water used in the experiment are given in the first table which follows.

The quantity of $Ca(HCO_3)_2$ added through irrigation water and collected in the leachate is shown in the table below it.

Analysis Results of Water and Soil Before and After Treatment

	SP	Ca	Mg	Na	HCO_3	Cl	SO_4	Cond. $ECx10^3$	pH	$CaCO_3$
Irrigation Water	—	1.56	.94	.85	1.49	.26	1.60	.30	8.2	—
Original Soil	34	9.33	2.22	2.12	4.11	3.17	6.39	1.36	8.3	17.0
Soil Extract Analysis After Harvesting the Crop										
Cropped		2.8	2.20	.80	3.50	1.0	1.30	.58	8.3	16.3
Cropped		2.9	1.95	1.15	3.65	1.4	1.95	.60	8.3	16.7
Uncropped		3.0	1.95	.80	3.60	1.0	1.15	.575	8.3	17.0
Uncropped		3.0	1.95	1.05	3.60	1.5	0.90	.60	8.3	16.5

Exactly 127.6 liters of irrigation water, corresponding to 213 inches, were used.

Amount of Water Added, Leachate Collected and $Ca(HCO_3)_2$ Contents

Container no.		Irrigation water added (liters)	Leachate collected (liters)	$Ca(HCO_3)_2$ added with irrigation water (gms.)	$Ca(HCO_3)_2$ removed in leachate (gms.)	$Ca(HCO_3)_2$ liberated during leaching and crop growth (gms.)
1.	Cropped	127.6	57.1	15.4	39.63	24.23
2.	Cropped	127.6	55.5	15.4	37.65	22.25
3.	Uncropped	127.6	84.4	15.4	33.52	18.12
4.	Uncropped	127.6	84.7	15.4	33.54	18.14

From the data it is inferred that the liberation of Ca ions from $CaCo_3$ is very slow and almost the same, whether the soil is leached with or without a rice growth. The notion that roots of growing crops produce enough CO_2 to liberate Ca ions from $CaCO_3$ in the soil is not experimentally proved. Neither Ca from irrigation water nor the liberated Ca ion from $CaCO_3$ can offset the effect of high SAR and RSC of irrigation water.

Crops and Cropping Pattern

In the choice of crops or cropping patterns, the cultivators are guided by three conditions influencing crop growth: availability of water during the growing period; soil and water table conditions; and farm labor availability.

The area and gross production value of

different crops is given in the table below.

Taking both acreage and gross production value (GPV) into account, the dominant crops in West Pakistan are wheat, fodder, cotton, rice and sugarcane, which together contributed more than 70 per cent of GPV for 1964-65. Gross production value for wheat, cotton, sugar and rice was of the order of 30.4 per cent, 16.4 per cent, 13.4 per cent, and 11.0 per cent respectively.

Area and GPV of Crops (1964-65)

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

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

In respect of net return per acre to farm land and labor, the position of farm crops in 1966-67 is shown below:

Net Return per Acre to Farm Land and Labor 1966-67

Crop	Net return per acre
	Rs.
Sugarcane	550
Vegetable and Orchards	550
Cotton	72
Rice (indigenous variety, Basmati)	330
Rice (Irri-Pak)	606
Maize (indigenous variety)	46
Hybrid maize	172
Wheat (indigenous variety)	198
Wheat (Mexi-Pak)	660

From the point of view of GPV and net return per acre to farm land and labor, more area should be brought under sugarcane. But there is a limitation on increasing the area, because sugarcane requires a perennial water supply and more labor for its cultivation.

Cotton has about half the irrigation requirements of rice and sugarcane. It is not possible to shift to cotton due to high water table conditions, soil conditions and the quality of water used for irrigation. A recent instance in SCARP-I can be quoted where a major change in the cropping pattern has taken place. Cotton has decreased by 2.5 per cent and rice has been increased by 3.5 per cent in spite of favorable water table conditions created for cotton cultivation.

On account of the rising water table, the area under cotton in the former Punjab has decreased from 56 per cent to 33 per cent of *kharif* acreage. In areas where the water table is within 5 feet, cotton is only 3 per cent of *kharif* acreage. Where the water table is 10 to 15 feet, the acreage is about 5 per cent less than in the 15-foot zone. On the Dadu canal in Sind, cotton formed 44 per cent of *kharif* acreage in 1937-38; today it comprises only 2 per cent.

The position of rice under rising water table conditions is the other way around. Where the water table is less than 5 feet, rice is 60 per cent of *kharif* acreage; from 5 to 10 feet it drops to 24 per cent; from 10 to 15 feet it drops to 14 per cent; below 15 feet it drops to 11 per cent.

Under prevailing conditions, therefore, it would be advisable to introduce high-yielding varieties of rice and maize to increase the GPV and net return per acre to farm land and labor. The net crop return of Rs. 188 on indigenous wheat varieties can be increased to Rs. 600 by introducing high-yielding varieties. Mexican dwarf wheat yields 3,226 to 3,411 kg. per hectare, compared with 922 to 1,106 kg. per hectare for native varieties.

With the introduction of high-yielding varieties of rice and the limitation of high water table conditions, the future of cotton is not bright. On account of its low yield and low price, the net income per acre for cotton is much less than for dwarf Irri-Pak rice. Another advantage of growing rice is that after harvest wheat can be sown the next winter. Efforts have therefore been made to find methods to increase the yield of indigenous varieties of cotton now grown in different parts of the Indus basin. The experiments carried out by the Directorate of Land Reclamation in this connection have met with great success. The method evolved is to eliminate inhibiting factors by the application of different plant nutrients. In these tests, 110 lbs. of superphosphate, 200 lbs. of ammonium sulphate and 660 lbs. of calcium sulphate were added. Half the quantity was applied to the root zone at the time of the first irrigation, and the other half at the time of the second irrigation after sowing the crop. The increase in yield over the control plots was 100 per cent in Rahimyar Khan district and 25 per cent at the experimental reclamation station, Bhallewala, in Sahiwal district.

It is necessary to have a clear understanding of the salt tolerance of crops grown under our conditions and agricultural practices. Cotton and sorghum should be grown on better lands, with a salt content of less than 0.2 per cent and pH less than 8.5. Sugarcane, maize and rice can be grown even with salt range of 0.2 to 0.35 per cent,

because the irrigation application is made more frequently and the soil is kept at a higher moisture level.

Need for Good Water Management and Proper Agricultural Practice

For sustained crop production, the two factors of irrigation application to be kept in view are : better water management and other agricultural inputs. Whenever proper irrigation applications remove the moisture ceiling on crop yield, other management practices such as improved varieties, fertilization, insect and disease control, become more essential.

The size of the plots in relation to the size of stream of water used for irrigation plays an important part in increasing irrigation efficiency. In our conditions the size of watercourse is generally 1 to 1.5 cusecs. In case of cotton, a one-eighth acre plot gave 70 per cent irrigation efficiency, which is 15 per cent higher than for a one-acre plot. The yield also increased by 43 to 68 per cent. In case of wheat, irrigation efficiency on a one-eighth acre plot was 69 per cent as compared with 54 per cent for a one-acre plot. The increase in yield of wheat in the one-eighth acre plot was of the order of 26 to 56 per cent over the one-acre plot.

The idea of expanded acreage for irrigation without additional water is unsound. We committed this mistake in the Grow More Food campaign of 1953, when government waste lands were allotted without arrangements for irrigation supplies. The campaign was a failure.

Our country has made tremendous progress in scientific land and water use for increased crop production and salinity control. Small and big storage dams have been constructed and ground water resources have been exploited to meet the shortage of surface supplies. About 10.4 m.a.f. of water has been added from ground water sources and through improved management of surface water resources. The surface supply utilized in 1966-67 was 95.77 m.a.f., against 83 m.a.f. in 1963-64. The larger water allotment per acre of land created conditions for desalinization. Salinity statistics from 1961-62 to 1965-66 are given below.

If this tempo of soil improvement can be maintained, it is hoped not only that deterioration and the further spread of salinity can be arrested but also that sizable areas can be restored to productive condition.

Changes in Salinity in West Pakistan

Year	Total area surveyed	Saline area (visual observations)	Percentage of saline to total area	Difference in percentage
1961-62	34,692,736	5,268,164	15.1	
1962-63	37,691,573	5,616,554	14.9	(−) 0.2
1963-64	37,018,051	5,630,443	15.2	(+) 0.3
1964-65	36,977,648	5,442,027	14.7	(−) 0.5
1965-66	37,061,855	5,444,102	14.6	(−) 0.1
			Difference	(−) 0.5

APPENDIX I

Comparison of River Water Samples Taken in Spring and Autumn, 1952

No.	Source	Date	Discharge (cft.)	ECx 10^6	Total solids (ppm)	Boron (ppm)	SiO_2 (ppm)	Milliequivalent per liter									% Sodium		Required acre-ft.	
								Ca	Mg	Na	K	CO_3 HCO_3	SO_4	Cl	F	NO_3	Found	Possible	Drainage (%)	Gypsum (lbs)
22032	Sutlej (Suleimanki)	Mar. 20	4,769	284	181	.26	8	1.52	.75	.75	.13	2.05	.43	.60	.01	.01	25	77	2.9	145
22139	Sutlej (Suleimanki)	Aug. 24	259,455	324	207	.07	14	2.45	.63	.48	.18	2.40	.36	.15	.01	.04	13	41	.9	19
22033	Ravi (Boat Bridge)	May 12	4,041	201	128	.02	11	1.35	.55	.19	.10	1.65	.36	.15	.01	.00	9	43	1.3	77
22144	Ravi (Shahdara)	Aug. 2	9,153	207	132	.05	14	1.28	.61	.28	.16	1.83	.07	.15	.01	.02	13	82	1.2	136
22034	Chenab (Marala)	Mar. 11	11,380	226	144	.02	6	1.38	.74	.21	.08	1.75	.48	.10	.01	.02	9	36	1.4	47
22142	Chenab (Marala)	July 29	70,844	179	114	.09	6	1.42	.25	.12	.08	1.60	.21	.10	.01	.01	7	63	1.0	94
22141	Jhelum (Mangla)	Aug. 7	59,640	231	148	.03	12	1.98	.34	.15	.08	2.20	.20	.15	.01	Tr.	6	56	1.0	105
22143	Indus (Kalabagh)	Aug. 2	242,500	301	193	.05	7	2.69	.25	.22	.10	3.10	.02	.14	Tr.	.01	7	100	1.3	178
22036	Indus (Sukkur)	Jan. 30	31,000	370	237	.19	8	2.12	.86	.88	.14	3.00	.25	.69	.01	.00	23	100	3.3	213
22035	Indus (Karachi)	Feb. 27	2,751	418	268	.30	11	2.08	.97	1.04	.18	2.85	.81	.62	.01	.00	25	84	3.6	180
22140	Panjnad	Aug. 22	200,598	253	162	.07	9	1.71	.56	.42	.10	2.15	.33	.20	.02	.02	16	78	1.7	138
																	Average		1.8	121

1. Samples collected under supervision of Mr. R.F.T. Farrent, Director, Irrigation Research Institute, Public Works Department, Lahore. Analyses by U.S Salinity Research Laboratory, Riverside, California.

2. Organic matter accounts for lack of balance between cations and anions and for high dissolved solids value.

3. Estimated 95 per cent return flow.

4. The required drainage percentages in terms of acre-feet of applied irrigation water for crops such as barley, sorghum and cotton are irrespective of rainfall. The gypsum requirement values assume a rotation of grain, beans and cotton; the required amounts are those per acre-foot of water (irrigation plus rain). These drainage and gypsum values are maintenance values. They cannot be applied to requirements for reclamation. Calcium for plants is taken as 0.50 meq/per acre-foot of water applied.

APPENDIX II

Effect of Different Qualities of Irrigation Water with 50 Inches Delta on Soil

	Milliequivalents per liter												
	Ca+Mg	Na	CO_3	HCO_3	Cl	SO_4	Total cations anions	D.S. (by evap.)	EC × 10^6 at 25°C	pH	ESP (Calc)	Res CO_3 me/l	SAR
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					QUALITY I								
	2.2	0.8		0.7	0.3	0.2	3.0	160	250		4.25	Nil	0.76
					ORIGINAL SOIL				EC × 10^3				
	6.25	9.25		6.32	5.9	3.28	15.5		1.55	8.1	1.9	0.07	5.25
					TREATED SOIL								
Column 0 - 4"	5.0	3.5		3.0	1.5	4.0	8.5		0.85	7.85	8.53	—	2.2
4 - 8"	2.5	4.0		3.0	1.0	2.5	6.5		0.65	7.95	12.03	0.5	3.56
8 -12"	3.0	2.0		3.0	1.5	0.5	5.0		0.5	7.9	5.83	—	1.62
12 -16"	3.0	3.2		4.5	1.25	0.45	6.2		0.62	8.0	10.1	1.5	2.59
Average	3.37	3.17		3.37	1.31	1.86	6.55		0.65		9.12	0.5	2.49
					QUALITY II				EC × 10^6				
	4.6	8.4		3.7	2.5	6.8	13.0	777	1230		20.52	Nil	5.46

						TREATED SOIL				EC × 10^3				
Column	0 - 4"	6.5	7.0		3.0	6.0	4.5	13.5		1.35	7.85	14.75	—	3.85
	4 - 8"	3.0	5.5		3.5	1.75	3.25	8.5		0.85	8.0	15.75	0.5	4.45
	8 -12"	3.5	5.0		3.5	2.5	2.5	8.5		0.85	7.95	13.95	—	3.75
	12 -16"	3.0	5.0		3.0	2.0	3.0	8.0		0.8	8.0	17.01	—	4.05
	Average	4.0	5.62		3.25	3.06	3.31	9.62		0.96		15.36	0.12	4.02
						QUALITY III				EC × 10^6				
		2.6	6.1	0.7	3.8	1.2	3.0	8.7	493	770		19.18	1.9	5.3
						TREATED SOIL				EC × 10^3				
Column	0 - 4"	3.0	11.5		6.0	4.5	4.0	14.5		1.45	8.0	35.0	3.0	9.31
	4 - 8"	3.0	7.0		5.5	3.5	1.0	10.0		1.0	8.1	21.99	2.5	5.67
	8 -12"	3.0	5.0		4.5	3.0	0.5	8.0		0.8	7.9	15.39	1.5	4.05
	12 -16"	2.5	5.0		4.0	2.5	1.0	7.5		0.75	8.1	15.84	1.5	4.45
	Average	2.87	7.12		5.0	3.37	1.62	10.0		1.0		22.05	2.12	5.87
						QUALITY IV				EC × 10^6				
		2.0	8.9	0.7	5.5	1.2	3.5	10.9	640	1000		32.47	4.2	9.07
						TREATED SOIL				EC × 10^3				
Column	0 - 4"	2.5	13.0		4.0	4.0	7.5	15.5		1.55	8.0	37.02	1.5	11.57
	4 - 8"	3.0	5.0		4.0	2.25	1.75	8.0		0.8	8.1	14.98	1.0	4.05
	8 -12"	1.5	8.5		3.5	2.75	3.75	10.0		1.0	8.0	28.13	2.0	9.77
	12 -16"	3.0	5.0		4.0	2.5	1.5	8.0		0.8	8.0	14.98	1.0	4.05
	Average	2.5	7.87		3.87	2.87	3.62	10.37		1.04		23.78	1.37	7.36

APPENDIX III

Effect of Different Qualities of Irrigation Water with 70 Inches Delta on Soil

	Milliequivalents per liter												
	Ca+Mg	Na	CO_3	HCO_3	Cl	SO_4	Total cations anions	D.S. (by evap.)	EC × 10^6 at 25°C	pH	ESP (Calc)	Res CO_3 me/l	SAR
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					QUALITY I								
	2.2	0.8		0.7	0.3	2.0	3.0	160	250		4.25	Nil	0.76
					ORIGINAL SOIL				EC × 10^3				
	6.25	9.25		6.32	5.9	3.28	15.5		1.55	8.1	1.9	0.07	5.25
					TREATED SOIL								
Column 0 - 4"	2.5	3.5		2.5	1.5	2.0	6.0		0.6	7.95	10.07	Nil	3.11
4 - 8"	2.5	2.5		2.5	1.5	1.0	5.0		0.5	7.9	7.32	Nil	2.22
8 -12"	2.75	3.05		3.0	1.5	1.3	5.8		0.58	7.8	9.01	0.25	2.59
12 -16"	3.0	3.0		3.0	1.5	1.5	6.0		0.6	7.9	8.65	Nil	2.43
Average	2.69	3.01		2.75	1.5	1.45	5.7		0.57	7.89	8.76	Nil	2.59
					QUALITY II				EC × 10^6				
	4.6	8.4	Traces	3.7	2.5	6.8	13.0	777	1230		20.52	Nil	5.46

						TREATED SOIL				EC × 10^3				
Column	0 - 4"	4.5	13.5		4.5	5.5	8.0	18.0		1.8	8.1	33.14	Nil	8.91
	4 - 8"	4.5	7.5		4.0	4.5	3.5	12.0		1.2	8.05	19.0	Nil	4.95
	8 -12"	5.0	8.0		4.0	4.5	4.5	13.0		1.3	7.9	19.65	Nil	5.04
	12 -16"	5.5	9.5		4.0	4.5	6.5	15.0		1.5	7.6	23.37	Nil	5.7
	Average	4.87	9.62		4.12	4.75	5.62	14.5		1.45		23.79	Nil	6.15
						QUALITY III				EC × 10^6				
		2.6	6.1	0.7	3.8	1.2	3.0	8.7	493	770		19.18	1.9	5.3
						TREATED SOIL				EC × 10^3				
Column	0 - 4"	2.75	12.75		4.0	2.5	9.0	15.5		1.55	8.1	35.52	1.25	10.83
	4 - 8"	2.75	7.05		4.0	2.5	3.3	9.8		0.98	8.2	21.20	1.25	5.99
	8 -12"	2.50	6.5		4.0	2.5	2.5	9.0		0.90	7.9	20.23	1.50	5.78
	12 -16"	2.50	7.0		4.0	2.5	3.0	9.5		0.95	8.0	21.55	1.50	6.23
	Average	2.62	8.32		4.0	2.5	4.45	10.82		1.08		24.62	1.37	7.21
						QUALITY IV (containing high residual carbonate)				EC × 10^6				
		2.0	8.9	0.7	5.5	1.2	3.5	10.9	640	1000		32.47	4.2	9.07
						TREATED SOIL				EC × 10^3				
Column	0 - 4"	2.25	13.75		5.0	2.5	8.5	16.0		1.6	8.1	42.60	2.75	12.91
	4 - 8"	2.25	8.25		5.0	2.5	3.0	10.5		1.05	7.9	27.28	2.75	7.75
	8 -12"	2.25	9.25		5.0	2.5	4.0	11.5		1.15	7.8	30.24	2.75	8.69
	12 -16"	2.25	9.25		5.0	2.5	4.0	11.5		1.15	7.95	30.24	2.75	8.69
	Average	2.25	10.12		5.0	2.5	4.87	12.37		1.24		32.59	2.75	9.51

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SOIL SALINITY IN RELATION TO GROWTH, YIELD AND DISEASES OF CROPS, AND DEVELOPMENT OF SALT-TOLERANT VARIETIES

by

Riaz A. Khan, S. D. Shah, M. Aslam and A. G. Kausar*

Abstract

The germination, growth, yield and quality of cultivated crops are adversely affected on saline soils. The intensity of this effect varies with the variety or species of crop, which may be classified as highly sensitive, moderately tolerant or highly tolerant, depending upon its ability to withstand a specific salt concentration. These unfavorable effects on crop growth associated with salinity result from an increase in the osmotic pressure in the soil, a specific ion effect, or the indirect effect of ions, especially sodium, on the soil structure. The hazards of salinity can be minimized by adequate drainage, use of appropriate planting practices, judicious irrigation and growing of tolerant crops.

Citrus withertip and the premature opening of bolls in cotton are serious problems in the saline soils of West Pakistan. Citrus withertip develops in soils with a high content of bicarbonates and chlorides of sodium. The premature opening of bolls in cotton develops where abnormal amounts of soluble chlorides, sulphates and bicarbonates of sodium occur in the soil, or where sodium clay in the subsoil depresses the growth and disturbs the osmotic relations of the cotton plant, resulting in physiological drought at the fruiting stage. This can be ameliorated by the application of frequent or heavy irrigations; or by deferred cotton sowings with close spacing.

Thirteen wheat varieties, and bulk hybrid seed from their crosses in F_2 and F_3 generations, grown in soils of different salinity levels have clearly brought out the differential responses of genotypes to different levels of salinity. Under the highest salinity level, C228, C518, AU47 and AU49 showed good performance with respect to germination, plant growth and yield. Hybrids AU47 × Dirk, AU47 × C591, C273 × AU50 and C5660 × AU49 were better than other crosses with respect to yield and spike characteristics. These significant varietal responses to salinity can be utilized in evolving varieties better suited to such adverse conditions.

* Respectively Head, Department of Agronomy; Reader, Department of Plant Breeding and Genetics; Professor and Head, Department of Plant Breeding and Genetics; and Professor and Head, Department of Plant Pathology, West Pakistan Agricultural University, Lyallpur.

Effect of Different Levels of Salinity on Growth and Yield

Growth and yield responses of crops grown on saline soils are dependent on the level of salinity and the inherent ability of an individual crop species or variety to withstand a specific salt concentration. Crop response at different salinity levels is indicated below (3).

Range of ECe*	Crop Response
0 to 2	Salinity effects mostly negligible.
2 to 4	Yields of very sensitive crops may be restricted.
4 to 8	Yields of many crops restricted.
8 to 16	Only tolerant crops yield satisfactorily.
Above 16	Only a few very tolerant crops yield satisfactorily.

*Conductivity of saturation extract (millimhos per centimeter at 25°C.).

(A) Field Crops

Germination of wheat, rice, corn, barley, gram and cotton on saline soils is adversely affected at a moisture level equivalent to 15 per cent of the water holding capacity. This effect is intensified when the sodium chloride (NaCl) concentration is above 0.2 per cent. However, high germination, even at 0.4 per cent sodium chloride (NaCl) concentration, can be obtained by increasing the moisture level up to 45 per cent of the field capacity in case of wheat, barley and maize, or 90 per cent in case of rice. Similar results can be obtained in gram and cotton with 75 per cent moisture level at 0.3 per cent sodium chloride (NaCl) concentration (16). From 50 to 100 per cent inhibition of sprouting in sugarcane at 7 atm. pressure, corresponding to an ECe of 8.6 mmhos/cm, has been reported (7).

Although full stands are often possible at low or moderate salinity levels, growth is usually restricted in wheat, rice and barley. Barley is highly tolerant during germination and following the boot stage, but seedlings cannot tolerate more than 5 or 6 mmhos/cm (ECe). Barley plants may be markedly stunted and still produce a normal yield of grain at moderate salinities. Similarly, rice is relatively more salt-tolerant during germination but young seedlings are very sensitive. A moderate salinity level of 4 to 8 mmhos/cm (ECe) may allow normal germination but will cause high mortality in the young seedlings (4). Tillering and plant size may be affected less in rice but may produce only 10-20 per cent of a normal grain yield at moderate salinity. Growth of sugarcane spindle and sheath ceased when sodium chloride (NaCl) at 2 atm. pressure, corresponding to a slainity level of approximately 2.5 mmhos/cm (ECe), was added to the cultural solution. Doubtless this complete cessation of growth at such a low salinity level was a temporary phenomenon following salination, and growth probably would have resumed after some internal plant adjustments had been effected (6). Soil with a relatively large quantity of sodium salts, sodium clay or both together at a depth of 3 feet or more, causes a physiological disorder in cotton at the fruiting stage, resulting in the premature opening of bolls. This effect is intensified with nitrogen deficiency and soil type (2).

The yield of crops with a relatively high salt-tolerance, such as wheat, cotton and barley, is much reduced in soil with a salt content of more than 0.4 to 0.5 per cent. Crops of low or intermediate salt-tolerance, such as pulses, maize, sugarcane and rice, show a marked decrease in yield when the soil salt is above 0.15 to 0.2 per cent (14). Yield of N.Co. varieties of sugarcane decreased by 10 per cent at 3 mmhos/cm (ECe) and by 25 per cent at about 5 mmhos/cm (ECe). Ratoon crop growth and yield of N.Co. 310 was reduced 50 per cent by an increase in ECe from 2.5 to 3.3 and 4.2 mmhos/cm respectively (7, 15). However, the yield of sugarcane can be almost tripled, provided other factors of production are favorable, by reducing the soil salt from 0.2 to 0.1 per cent (14).

(B) Vegetable Crops

Crops like radish, celery and green beans are highly sensitive and can stand only a low salinity level of 2 to 3 mmhos/cm (ECe); tomato, cauliflower, cabbage, potato, sweet potatoes, carrot,

onion, peas and cucumber can tolerate a salinity level of 3 to 5 mmhos/cm (ECe); garden beans, asparagus and spinach can withstand levels ranging between 5 and 8 mmhos/cm (ECe).

Because of the stunting of plants by salinity, most vegetables produced on saline soils are not of prime quality. Yields of such crops as tomatoes and peppers are reduced, partly because af fewer fruits per plant but also because of a marked decrease in fruit size. Size generally declines and the proportion of culls usually increases as stunting becomes more severe. As all parts of the plant are stunted, roots, leafy or flowering heads and other harvested plant parts all exhibit characteristic size decreases. Sweet corn is an exception in that ear size remains unaffected at moderate salinity levels, although the number of marketable ears per plant decreases appreciably (5).

By checking the growth, salinity may produce favorable effects on some vegetable crops. It may increase the sugar content of some vegetables, especially carrots; but this gain in quality is more than offset by lowered yields. Cabbages from salty fields are generally more solid than those from non-saline fields, but lowered yields offset this favorable effect. Chloride fertilizers are generally believed to make potatoes less starchy and more watery, but on saline soils high in chloride the decreased water availability counteracts this effect, so that the tubers produced are of normal starch content. Salinity speeds up the maturation of potatoes, although the tubers are smaller. In contrast, salinity delays the flowering and therefore the maturation of sweet corn. Thus, the effects of salinity on crop quality are variable, except for the characteristic size decrease (5).

(C) GRASSES AND LEGUMES

White dutch clover, meadow foxtail, alsike clover, red clover and ladino clover have a low salt-tolerance and grow well between 2 to 3 mmhos/cm (ECe). Sudan grass, orchard grass, oats, perennial ryegrass, alfalfa and white sweet clover are tolerant to a salinity level of 3 to 6 mmhos/cm(ECe). Bermuda grass, tall fescue and rhodes barley (hay) are tolerant to salinity levels ranging between 6 and 12 mmhos/cm (ECe).

The main effect of soil salinity on forage crops is to make it difficult for the roots to take up water. The saltier the soil, the less readily available is the water. In appearance, grasses and forage legumes on salty soil are very much like plants on droughty land. They are stunted and bear small leaves that generally have a dark, blue-green color rather than the bright green of plants that have an adequate, readily available moisture supply. Of course, if the soil water is too salty, the plants will eventually turn brown and die. This is usually because of extreme moisture deficiency rather than any toxic effect of salinity (3).

Special nutritional effects may also be involved. Orchard grass, for example, suffers when calcium salts predominate in saline soil. Species also differ in their tolerance of sodium. Most grasses and forage legumes appear to be tolerant enough of sodium. Poor physical condition of sodium soils is the principal reason for crop failure. Soils high in sodium generally take up water very slowly, and become hard and crusty when dry. Usually, such soils must be reclaimed before any crop can be grown successfully (3).

The reduced growth associated with salinity, then, results from :

1. An increase in osmotic pressure in the soil that seems to upset the water relation of the plant.

2. A specific ion effect, which may be by toxicity or by influence on plant nutrition, resulting in disturbed metabolism or morphological changes.

3. The indirect effect of some of the ions, especially Na, on soil structure.

Management of Saline Lands to Improve Crop Yield

Water management is the key to salinity control. Under dry land conditions the grower can do little to remedy a saline condition, except to provide for maximum penetration of rainfall by reducing run-off. Under irrigation the possi-

bilities for salinity control are much better.

Adequate drainage is essential for maintaining the salt balance. Part of the water applied to a field must pass through the root zone and be removed by natural or artificial drainage to keep salt from accumulating at progressively higher levels in the soil. The more saline the water applied and the more sensitive the crop, the greater will be the drainage or leaching requirement. For uniform water penetration the land should be carefully leveled, as salt accumulates in high spots which may ultimately fail to support crop growth.

Salt concentration in the seed row in furrow-irrigated row crops often causes a special problem during germination, because salt may be carried into the top of the bed and become concentrated in the seed row. This has often been responsible for the partial or complete failure of stands. Salt accumulation is much greater in the center of the bed than near the shoulders; therefore, double-row beds are less affected than single-row beds. In sloping seed-beds the seed row is well below the zone of salt accumulation, so that irrigation may actually remove salts from the seed row instead of bringing salt into it. Under saline conditions, modified planting and irrigation methods may make all the difference between success and failure.

Salinity is especially harmful to transplants. Because of unavoidable root pruning, transplants are already at a disadvantage in absorbing water. The limited water availability of saline soil is therefore particularly injurious. Whenever possible, avoid transplanting into saline soils, with the probable exception of rice crops.

Sometimes salinity cannot be reduced below a certain level, particularly when saline water is the only source available for irrigation. The selection of crops tolerant enough to produce well is necessary for successful operation under such conditions (5).

Salinity and Incidence of Diseases

The incidence of plant diseases as influenced by soil salinity has been studied in West Pakistan with particular reference to two diseases: citrus withertip, and *tirak* (bad opening of bolls) of cotton.

Citrus withertip, caused by *colletotrichum gloeosporioides*, has been shown to be serious in soils which have a high salt content, particularly sodium. Soils in West Pakistan where this disease is serious have a salt content over 0.24 per cent., which exceeds the limit of tolerance by citrus plants. A comparison of soils growing healthy citrus with soils growing withertip-affected plants indicates that the carbonate and sulphate content of the two soils is about the same, but the disease-infested soil has a higher content of bicarbonates and chlorides of sodium (1). Soil management practices which reduce the salt content in the root zone are expected to reduce the incidence of the disease.

Tirak (bad opening of bolls) of cotton is serious on soils with a saline subsoil and on those deficient in nitrogen. On soils with a saline subsoil, the disease is characterized by a pronounced drooping of leaves in September and October which results from the water starvation of the crop. Such leaves do not turn yellow prior to shedding, as with nitrogen starvation (8).

The soils with a saline subsoil have an abnormal amount of total soluble salts comprising soluble chlorides, sulphates and bicarbonates, along with small amounts of sodium carbonate in some cases. The soluble salts contain larger quantities of free or exchangeable sodium than calcium, and in some cases sodium replaces calcium in the clay complex (12).

The growth of all parts of the cotton plant is suppressed on saline subsoil by the injurious effects of sodium salts on the root system. The free soluble sodium salts in high concentration disturb the osmotic relations of the cotton plants, and cause a condition of physiological drought. The depressing effect of the sodium salts is more pronounced on sandy loam than on light sandy soils, and causes immaturity of the seeds (10,13).

The immaturity of seed resulting from *tirak*

is due to a deficiency of potash occurring at fruiting in *tirak*-affected plants. The deficiency of potash occurs indirectly, as a result of deficiency of nitrogen in the light sandy soils and of physiological drought on saline soils. The direct application of potash does not increase its uptake and does not promote seed maturity (9, 11).

Tirak on saline soils can be ameliorated by the application of heavy irrigations, by irrigations at shorter intervals during the flowering phase or by deferred sowings in June. Late sowings result in low yields, which can be improved by close spacing, but this method is regarded as more practicable for the solution of *tirak* on these soils (13).

Breeding of Salt-tolerant Varieties

Significant varietal differences in responses to salt tolerance can be utilized in evolving varieties more suited to such adverse conditions. In order to find a genetic basis for embarking on a program of breeding salt-tolerant varieties, extensive studies on wheat have been undertaken at Lyallpur, with interesting results.

Some thirteen wheat varieties, local as well as exotic, *viz.* 8A, C228, C273, C591, C518, 5660, Dirk, Sonora, 90NRB, Hard Federation, AU44, AU47 and AU49 were tested for salt-tolerance with respect to germination, tillering, final plant height, spike characteristics and yield. Simultaneously, seed from advanced generations of various crosses amongst some of the above varieties was tested at three salinity levels: low (6,000 ppm), medium (12,000 ppm) and high (18,000 ppm).

The results showed that under normal conditions germination in almost all the varieties commenced about 4 days after planting, and total emergence was complete in about 7 days. Under saline conditions, germination was invariably delayed, in some varieties extending up to 15 days. The germination rate varied from 60 to 64 per cent for tolerant varieties like C228, C518 and AU49 at the highest salinity level (18,000 ppm.), whereas it was very low for other varieties, which showed an 80 to 84 per cent germination rate in medium salinity. The germination of 8A, C273, Sonora, Dirk and Hard Federation varied from 40 to 80 per cent in medium salinity, and between 36 to 60 per cent at high salinity levels. The germination and emergence of the remaining varieties varied from 30 to 40 per cent in 18,000 ppm, and 60 to 80 per cent in 12,000 ppm, compared with about 100 per cent under control.

With respect to yield, a gradual reduction of 28 to 52 per cent was noticed under high and medium salinity respectively as compared with the control. The crosses of AU47 with C591 and Dirk, and crosses of C5660 with AU44 and AU49 showed the best performance, even better than their parents. Similarly, reductions of 22 and 11 per cent were observed in the number of spikes per plant under high and medium salinity respectively. Crosses of AU47 and AU49 showed the best performance. The number of kernels per spike, an important component of yield, also showed a reduction of 28 to 65 per cent with increasing salinity. Under high salinity, cross AU47 × Dirk produced the maximum number of grains, followed by AU47 × C591, C273 × AU50, C5660 × AU49. Under medium salinity, the crosses 5740 × AU44, AU47 × Dirk and C273 × AU50 were the best, while under normal conditions, crosses of AU47 produced the highest number of grains.

Thus, the differential response of varieties and crosses was manifest under different salinity levels. The high tolerance of some varieties and crosses was also clearly brought out in these studies. It was further observed that some varieties which are salt-tolerant do not transmit this characteristic to their progeny. It is obvious from these studies that breeding wheat varieties for salt tolerance through intraspecific hybridization seems to be a sound approach to the problems of increasing productivity on saline land.

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SOIL—WATER AND PLANT RELATIONSHIP

by

Mohammad Ibrahim Khan, Ahmad Mustafa Khan, Ghulam Hassan and Nazar Hussain

Introduction

In countries like ours, where agriculture plays a major role in the economy of the nation, higher production levels in crops are a burning topic. To achieve this objective, development of all the agronomic factors and their relationship is very important under our conditions, where water is a bottleneck.

"Irrigation is a necessary evil" is a scientific proverb, and asserts the vital importance of irrigation as well as its dangers as a result of improper or injudicious use of water. This is most important in West Pakistan. There are many areas where too little soil moisture in the plant root zone is the cause of low yields. On the other hand, there are areas where excess soil moisture in the plant root zone creates adverse conditions for proper plant growth. The drilling of tubewells to supply irrigation water where it is needed and the arrangements for draining off the excess soil water from the water-logged areas have been realized by now, and advances to overcome these menaces are being made rapidly.

The fertility status of the soil must be known, to maintain the levels of production in each crop under available soil moisture conditions in various geological zones. The production of fertilizer is increasing day by day, and greater use of fertilizer has to be popularized to obtain high production. The cultivators should be fully aware of the optimum doses of fertilizers under different soil moisture conditions.

In recent years, the atmosphere of optimism surrounding agricultural development is opening the way to a new look at the many opportunities available for increasing crop yields by proper soil and water management.

Some research work was started at Risalewala, Lyallpur, in the early forties and at Tandojam from 1963-66. Experiments of high practical value were carried out in respect to total water requirements of major farm crops, their consumptive use, time of application with different frequencies and the effect in combination with other agronomic factors. The results achieved are discussed in the following paragraphs.

Review of Literature

Some work on the agronomic factors in crop production, especially water requirements, has already been done at home and abroad, and some useful inferences have been drawn.

Alexander (1) notes that under Hawaii conditions about 26 per cent of soil moisture content is the best, and at this stage of soil moisture proper aeration is also possible.

Koeing (8) found a definite correlation between soil moisture and cane growth. Hill (6) also found similar results.

At Shahjehanpur, it was found that increase in yield of sugarcane was proportional to the frequency of water, rather than the quantity given at each watering.

According to Whitt and Van Bavel (13), the seasonal water requirement of soybeans ranges from 13 to 23 inches. Johnson *et al.* (7) report that a good crop of soybeans usually requires about 20 inches of water. But Carter and Hartwig (3) have given a range of 20 to 30 inches for a good crop.

According to Knowles *et al.* (9), in California, where soybeans are grown under irrigated conditions, 2 to 3 acre-feet of water are required on permeable loam type soils depending on the time of sowing. In addition to the pre-irrigation, they recommend 6 to 8 irrigations for soybeans sown in early May, and 4 to 6 for plantings made in late July. After the first irrigation, a schedule of once every 10 to 14 days has been advocated by them.

Whitt and Van Bavel (13) report that Leonard J. Erics and Niel A. Dimick, in experiments at the South Dakota agricultural experiment station, measured average daily consumptive use of 0.14 inches for soybeans from planting to harvesting—approximately the same as for corn, potatoes and sugar beets. They also refer to experiments at the Alabama agricultural experiment station, where a daily water requirement of 0.18 inches for soybeans was indicated.

Peters and Johnson (11) at Urbana, Illinois, found that from July 1 to maturity, soybeans in 102 cm. rows used 39.1 cm. of water in 1958 and 21.4 cm. in 1959 to produce yields of 2354 and 1076 kg. respectively. Matson (10) in his study of the water use by soybeans at Missouri, assumed daily water use to be 0.2 inches and applied irrigation when the water deficit at this rate reached 1.4 inches during periods of no rainfall. He states, however, that the daily evapotranspiration rate of 0.2 inches may be somewhat high for soybeans, in view of the results reported by England (5) with corn.

England (5) reported average daily evapotranspiration loss with corn to be 0.09, 0.14, 0.22, 0.16 and 0.10 for the months of May, June, July, August and September, respectively. He found that the total losses during the 158-day period of the crop amounted to 21.18 inches.

In a study carried out by Timmons *et al.* (12) in western Minnesota, average soybean yields of 28.3 and 35.8 bushels per acre were obtained with available soil moisture up to a depth of 152.4 cm. of soil profile, when total precipitation during the growing period totaled 45.32 and 65.32 cms. during the years 1964 and 1965 respectively.

Materials and Methods

The soil under these experiments was a loam type of soil closely resembling the average land in Lower Chenab Canal colony. The soil had 8.5 pH. The soil and subsoil strata were analyzed mechanically and chemically to a depth of 12 feet.

Canal water was used for irrigations. The water was lifted for measurement to an elevated tank which was divided into two halves, each 10 ft. × 10 ft. × 4½ ft., so that when one half was discharging to the experimental plots the other half was filled. A gauge was fitted to the inside of each tank, so that the depth of water required to be applied to the experimental plot could be determined. Water released from these tanks was conveyed through a masonry distribution system to each measured experimental plot.

The research work done on some of the main crops of the tract is reproduced below.

Results and Discussion

(A) DEPTH OF PENETRATION OF WATER IN THE SOIL WITH IRRIGATIONS OF DIFFERENT LEVELS

Treatment	Percentage of moisture in			
	3 ft. col.	6 ft. col.	9 ft. col.	12 ft. col.
1. (*a*) Before irrigation	10.40	6.18	6.74	3.61
(*b*) 3 days after 3 irrigation, *i.e.* when plot came into *wattar**	13.74	7.52	6.65	3.47
2. (*a*) Before irrigation	11.36	8.72	5.08	4.58
(*b*) 4 days after 4½" irrigation	15.15	9.38	6.40	3.37
3. (*a*) Before irrigation	11.70	9.34	6.37	4.88
(*b*) 4 days after 6" irrigation	16.59	11.15	7.59	4.47

Note: The plots were under sugarcane crop and the period of study was May 25 to June 12. Average values of nine determinations as tabulated above indicate that water penetrates to a depth of 6 feet in 3-inch irrigation, and 9 feet in 4½-inch and 6-inch irrigation.

*Local term for optimum moisture of soil for working and planting.

(B) COMPARATIVE SAVINGS IN WATER IN DIFFERENT PLOT SIZES AND THEIR EFFECT ON CROP YIELD (3-YEAR AVERAGE.)

Size of plot (acres)	Acre-inches of water applied	Yield in mds./acre	Percentage saving of water over ½-acre plot
1/16	12.04	27.06	12.27
1/8	12.08	26.47	12.09
1/4	12.71	25.99	7.28
1/2	13.72	26.49	—

The perusal of the above data reveals that the smaller the plot the greater is the saving in water. But taking into consideration the economy of land and water, 1/8th. acre is the most suitable plot size, as it saves about 12 per cent water which is sufficient for maturing 12 per cent more area of this crop.

(C) IMPROVED METHOD OF APPLYING *Rauni* WATER TO WHEAT (4-YEAR AVERAGE)

Treatment before *rauni*	Average *rauni* (inches)	Av. yld. in mds./acre*	
		Grain	Straw
Ploughed land	4.16	27.23	47.8
Planked land	3.16	25.96	44.17

*Difference in yield not significant

It can be seen from the above data that there is no difference in yield, but by making the soil surface smooth and packed, a saving of one inch, or 33 per cent, of *rauni* water can be made over the local practice of applying irrigation to ploughed land. Irrigation water thus saved can be used for sowing the normal area under wheat crop in time. Normally when *rauni* is done on ploughed land, sowing of 2½ acres per square holding gets late. The timely sowing of wheat results in an increase of about 12 maunds of grain per square, as the difference between timely and late sown wheat is approximately 5 mds. per acre.

(D) EFFECT OF FLAT AND FURROW IRRIGATION ON YIELD OF SUGARCANE

Treatment	Rainfall (inches)	Total water (inches)	Av. yld. of stripped cane (mds/acre)
Flat	8.9	54.00	988.58
Furrow	8.9	54.00	1059.96

Delta of water remaining constant, sowing of cane in lines 2 feet apart and earthing up the land in the beginning of July confirmed that furrow irrigation prevents lodging and brings about an increase in yield of about 7 per cent.

(E) TO STUDY THE EFFECT OF FLOODING (EXCESSIVE IRRIGATION) ON WHEAT

Treatment	*Rauni*	Subsequent Irrigation	Av. yield (mds/acre)
No flooding	4"	3 x 3" (end Nov., Jan. & Mar.)	23.89
Flooding 15"	—	Nil	18.71
Flooding 15"	—	1 x 3" (Dec.)	25.80
Flooding 15"	3"	Nil	18.56
Flooding 15"	—	2 x 3" (Dec., Feb.)	26.43

It may be seen that average yield can be obtained by flooding the land with 15 in. of water in August-September and sowing wheat at its normal time without *rauni* or any subsequent irrigation. One irrigation after sowing when applied in the middle of December gives the maximum yield.

(F) EFFECT OF APPLYING DIFFERENT DEPTHS OF *Rauni* ON THE SUBSEQUENT WATER REQUIREMENTS OF COTTON (2-YEAR AVERAGE)

Rauni (inches)	Subsequent irrigation (inches)	Frequencies	Rainfall (inches)	Total water (inches)	Av. yield of seed cotton (mds/acre)
4	17	5	9.13	30.13	10.62
6	17	5	9.13	32.13	11.62
6	15	4	9.13	30.13	11.44
8	13	4	9.13	30.13	12.41
8	17	5	9.13	34.13	11.79
8	11	3	9.13	28.13	12.47

It is clear from the above data that if heavy *rauni* is given to the cotton crop, the extra water given can be deducted from the subsequent irrigations without loss of yield.

(G) Effect of Varying Quantities of Water on Yields of Various Crops

(1) *Wheat*

Irrigation incl. *rauni* (inches)	Rainfall (inches)	Total water (inches)	Yield in mds/acre (4-year av.)		Yield per acre-inch (mds).
			Grain	Straw	
5.33	3.27	8.6	24.29	52.04	4.56
8.33	,,	11.6	27.27	56.42	3.27
11.33	,,	14.6	28.61	60.35	2.52
14.33	,,	17.6	30.42	68.11	2.12
17.33	,,	20.6	31.25	71.84	1.80
20.33	,,	23.6	30.98	70.20	1.52

The above figures reveal that the yield of both grain and straw increases with the increase of water up to 17.33 acre-inches of water. But the differences in yield of 14.33, 17.33 and 20.33 acre-inches are non-significant. This indicates that during a year of normal rainfall, three irrigations of three inches each are the optimum requirement for wheat for obtaining the maximum yield. However, during a dry season four irrigations will be required. The water use efficiency decreases with the increased number of irrigations.

(2) *Sugarcane*

Irrigation incl. *rauni* (inches)	Rainfall (inches)	Total water (inches)	Yield of stripped cane in mds/acre (4-year av.)	Yield per acre-inch (mds.)
39.87	9.43	49.43	870.39	21.81
46.62	,,	56.05	987.63	21.17
53.37	,,	62.82	1081.45	20.26
61.12	,,	70.55	1159.54	18.97
67.87	,,	77.30	1207.93	17.80
75.62	,,	85.05	1264.22	16.71

The study of the above data reveals that the efficiency of water decreases directly with the increase in irrigation water, but the yield increases with the increase in water applied.

(3) *Cotton*

Irrigation incl. *rauni* (inches)	Rainfall (inches)	Total water (inches)	Yield of seed cotton in mds/acre (5-year av.)	Yield per acre-inch (mds.)
14	8.7	22.7	13.92	0.61
17	,,	25.7	15.96	0.62
20	,,	28.7	17.88	0.62
23	,,	31.7	18.60	0.59
26	,,	34.7	20.48	0.59
29	,,	37.7	20.84	0.55

The above data indicates that 26 inches of irrigation water, *i.e.* 7 irrigations of 3 inches each after sowing, is quite sufficient to produce maximum yield, while 3 to 4 irrigations after sowing are enough to get a normal yield during a year of average rainfall.

(4) *Soybeans*

Irrigation incl. *rauni* (inches)	Rainfall (inches)	Total water (inches)	Yield in mds/acre (4-year av.)
18	5.35	23.35	13.75
21	,,	26.35	14.18
24	,,	29.35	15.78
27	,,	32.35	16.74

It is evident from the above data that yield of soybeans increases constantly with the increase in irrigation level, and 24 to 27 acre-inches of water is the optimum level to obtain maximum yield.

(H) EFFECT OF VARYING FREQUENCY AND DEPTH OF IRRIGATION ON YIELD OF VARIOUS CROPS

(1) *Wheat*

Frequency and depth of irrigation (excluding *rauni*)	Grain yield in mds/acre (4-year av.)
5 × 2″	24.2
4 × 2½″	24.0
3 × 3½″	24.3
2 × 5″	23.6

The above data indicates that it is the total quantity of water that matters for yield rather than the frequency and depth of irrigation.

(2) *Sugarcane*

Frequency and depth of irrigation	Cane yield in mds/acre (4-year av.)
50″ each { 19 × 2 12/19″	1127
50″ each { 15 × 3⅓″	1078
50″ each { 12 × 4⅙″	1074
8 × 6¼″	1063

The study of the above table shows that 19 irrigations of 2 12/19 in. each gave the highest yield.

(3) *Cotton*

Frequency and depth of irrigation	Seed cotton yield in mds/acre (5-year av.)
8 × 2½	14.0
6 × 3½	13.7
4 × 5	13.6
3 × 6⅔	13.8

It is evident from the above data that it is the total depth of water requirements of the crop that matters for yield, and not the frequency and depth of irrigation.

This finding is of great economic importance in the event of long canal closures. The farmers can easily tide over the canal closures by applying heavy irrigation before and after the closures, provided the crop is not allowed to suffer in its critical stages of growth.

Treatment	Water applied (inches)	Rainfall (inches)	Total water (inches)	Average yield of 5 years (maunds/acre)						Average
				C 591	C 518	C 591	C 518	C 591	C 518	
				Mid Oct. Planting		End Oct. Planting		Mid Nov. Planting		
No irrigation after sowing	4	2.22	6.22	15.98	15.96	21.47	19.41	21.09	17.72	18.60
1 × 3″ after one month	7	,,	9.22	23.03	24.13	25.58	25.85	25.05	23.42	24.51
1 × 3″ after two months	7	,,	9.22	22.72	24.15	26.83	24.80	26.04	23.78	24.38
1 × 3″ after three months	7	,,	9.22	24.36	22.82	25.58	24.31	24.35	22.58	24.00
1 × 3″ after four months	7	,,	9.22	18.33	18.83	22.53	21.58	22.34	19.48	20.51
2 × 3″ at normal Interval	10	,,	12.22	24.16	25.51	29.43	29.11	28.31	26.98	27.25
		Average		21.43	21.73	25.24	24.18	24.20	22.33	
				21.58		24.71		23.27		

(I) EFFECT OF SINGLE IRRIGATION ON THE YIELD OF WHEAT C 591 AND C 518 SOWN ON DIFFERENT DATES, AS COMPARED WITH NO IRRIGATION AND TWO IRRIGATIONS AT NORMAL INTERVALS AFTER SOWING.

It is clear from the above results that the application of a single irrigation, one to three months after sowing, gave about 6 maunds higher yield of grain per acre than no irrigation. But the yield increased by only 2 maunds if irrigation was applied after the fourth month. Second irrigation may improve the yield further, of course, with further increase in water cost.

(J) BEST TIME OF APPLICATION OF TWO IRRIGATIONS AFTER SOWING TO WHEAT C 591 & C 518 SOWN ON DIFFERENT DATES.

Treatment	Water applied incl. *rauni* (inches)	Rainfall (inches)	Total water (inches)	Average yield of 5 years (maunds/acre) Mid October C 591	Mid October C 518	End October C 591	End October C 518	Mid November C 591	Mid November C 518	Average
Early start early finish (1st. one month after sowing, 2nd. two months after 1st.)	10	1.55	11.55	19.50	19.91	20.83	19.99	23.37	24.49	21.18
Early start late finish (1st. one month after sowing, 2nd. three months after 1st.)	10	,,	,,	18.17	18.74	18.87	19.95	19.81	22.49	19.67
Late start early finish (1st. two months after sowing, 2nd. one month after 1st.)	10	,,	,,	19.59	18.91	19.96	19.63	21.49	20.80	20.00
Late start late finish (1st. two months after sowing, 2nd. two months after 1st.)	10	,,	,,	19.30	19.01	18.94	18.81	20.67	19.44	19.56
		Average		19.14		19.62		21.44		

A perusal of the above results indicates that if two irrigations are available, the application of the first irrigation one month after sowing and the second two months after the first gave the best result. However, if the first irrigation is not available till two months after sowing, then the second irrigation should be applied one month after the first to get good yield. Furthermore, sowing of wheat in the middle of November would be advisable.

(K) EFFECT OF VARYING TIME OF IRRIGATION BUT EQUAL QUANTITIES (3 IRRIGATIONS) ON GRAIN YIELD OF WHEAT C 591

Date of application	*Rauni* (inches)	Rainfall (inches)	Total water (inches)	Av. yield in mds./acre Grain	Straw
1940-41					
Dec. 5, Jan. 11, March 15	5	1.96	15.96	35.50	67.08
Dec. 23, Feb. 15, March 27	5	,,	,,	32.83	59.08
Jan. 21, Feb. 25, March 21	5	,,	,,	31.23	61.94
1941-42					
Dec. 15, Jan. 26, March 24	4	4.57	17.57	32.04	77.87
Feb. 3, March 21, April 2	4	,,	,,	31.10	76.65
Jan. 20, March 21, April 2	4	,,	,,	30.50	77.87

It is evident from the above data that in case of three irrigations, the first irrigation should be applied in December and the last should be completed by March, preferably the middle of March, to protect the crop from lodging due to strong winds which may blow after this.

(L) EFFECT OF APPLYING EQUAL QUANTITIES OF WATER BUT VARYING THE TIME OF APPLICATION ON YIELD OF COTTON

20" in 6 irrigations after sowing	Av. yield (mds/acre)
1. 3rd 4th. week of June—end Sept./early Oct.	20.14
2. Mid July—mid Oct.	19.19
3. Early July—end Oct./early Nov.	19.28
4. Same as first but 3 x 2½" and 3 x 4½"	19.24

Though results were not conclusive, it was indicated that an early first (about one month after sowing) and an early final (end of September or early October) irrigation to cotton would be more suitable than extending it to late season, in view of *rabi* sowings.

(M) EFFECT OF VARYING IRRIGATIONS AND IRRIGATION PERIODS ON COTTON

Irrigation (inches)	Rainfall (inches)	Av. yield of seed cotton in mds/acre (5 yrs.)		
		Mid September	Mid September	Mid October
15	9.69	10.44	11.00	9.99
21	9.69	12.74	13.52	13.29

It will be further confirmed from the above results that extending application of water beyond October or November, as generally believed by the cultivators, is not at all necessary. Best results are achieved if the available water supply is applied till the end of September, beyond which it is not of any avail. Water thus saved can be used for *rabi* sowings.

(N) EFFECT OF DIFFERENT INTENSITIES OF CULTIVATION ON THE WATER REQUIREMENTS OF WHEAT (4-YEAR AVERAGE)

The idea in the experiment was to see if the higher intensity of cultivation would increase yield and save water.

Treatment	Rainfall (inches)	One cultivation with desi plow plus		Average
		two with horse hoe	five with horse hoe	
1 x 3"	1.94	15.28	16.75	16.01
2 x 3"	1.94	15.86	18.63	17.25
3 x 3"	1.94	17.04	19.56	18.30
	Average	16.06	18.31	

It is evident from the above data that the yield increases by increasing the number of irrigations. A greater number of cultivations gave significantly higher yield. It is further indicated that high intensity of cultivation in combination with less irrigation can give similar yield to low intensity of cultivation in combination with a higher number of irrigations.

(O) IRRIGATIONAL *cum* MANURIAL *cum* CULTURAL TRIALS ON VARIOUS CROPS

The object in these experiments was two-fold: to see the effect of fertilizers on the yield, and to find whether application of fertilizer can effect any saving of irrigation water.

Irrigation (inches)	Rainfall (inches)	Av. (2 years) yld. in mds./acre			Average
		No manure	25 lbs. N in A/S	50 lbs. N in A/S	
10	1.45	23.12	24.30	26.88	25.43
13	1.45	23.96	26.95	27.26	26.06

It is evident from the above results that the application of 25 and 50 lbs. of N to wheat gave significantly higher yield than no manuring. But the difference between 25 and 50 lbs. of N is not significant. Thus, 25 lbs. of N is the optimum dose for wheat.

It is interesting to note that, within a certain limit, application of fertilizer with lower depth of irrigation gives similar yield to higher depth of irrigation without manuring. Though application of fertilizer can help to effect the saving of water to some extent, liberal irrigation is needed to get the maximum benefit of the fertilizer.

(P) EFFECT OF DIFFERENT SOWING DATES AND MANURING ON WATER REQUIREMENTS OF WHEAT (3-YEAR AVERAGE).

Irrigation (inches)	Rainfall (inches)	Yield in mds/acre					
		Mid October		Mid November		Mid December	
		N0	N1	N0	N1	N0	N1
7	1.70	19.13	19.51	17.51	16.80	10.05	9.40
10	1.70	19.45	22.85	18.95	20.20	11.85	11.35
13	1.70	19.46	23.23	19.59	21.99	12.50	13.15
	Average	19.36	21.86	18.68	19.66	11.46	11.30
		20.61		19.17		11.38	

N0 = No fertilizer,
N1 = 25 lbs. of N/acre in A/S.

It is evident from the above results that, with water remaining constant, the yield of early sown wheat is significantly higher than the late sown wheat. In other words, the early sown crop produces dry matter at a lower water cost than the late sown crop. It is therefore more profitable to start the sowing of wheat in the middle of October, as it enables the cultivator to finish sowing in time and to avoid loss in yield due to late sowing in December.

Application of fertilizer is useful only in early and normally sown crops. It is interesting to observe that fertilizer did not help to counteract the ill-effect of late sowing, but irrigation has gone a long way to make up the loss due to late sowing.

(Q) WATER REQUIREMENTS OF WHEAT SOWN BY DIFFERENT LATE SOWING METHODS

Treatment	Rainfall (inches)	Yield in mds./acre		
		2 x 3" irrigation	3 x 3" irrigation	Average
Closed cultivation and sowing at normal time in preserved rain *wattar*	4.23	14.02	14.58	14.30
Dry sowing after Dec. 7	4.23	10.88	11.45	11.16
Transplanting after Dec. 7	4.23	10.26	10.00	10.13
Average		11.72	12.00	

The data indicates that during a year of normal to high rainfall, sowing in preserved rain *wattar* gives good yield. No increase was effected by third irrigation, due to high rainfall during the growing period of wheat.'

(R) EFFECT OF DIFFERENT LEVELS OF IRRIGATION AND MANURES ON YIELDS OF SOME WHEAT VARIETIES

Treatment		Grain yld. in mds/acre
Irrigations		
3	..	18.71
4	..	20.60
5	..	22.64
6	..	24.23
Manures		
No manure	..	12.15
30 lbs. of N in A/S	..	17.79
60 lbs. of N in A/S	..	21.37
90 lbs. of N in A/S	..	23.16
120 lbs. of N in A/S	..	27.00
150 lbs. of N in A/S	..	27.79
Varieties		
Mexi-Pak 65	..	24.29
Dirk	..	20.79
C 273	..	19.87

It is evident from the data in the above table that 6 irrigations gave significantly higher yield than other irrigation treatments. Increase in irrigation is directly correlated with grain yield, and is a good factor to tap the potentiality of a given variety under favorable conditions.

All manurial treatments gave significantly higher yield than check, and 120 lbs. of N per acre is the optimum dose of fertilizer. Mexi-Pak out-yielded the other two varieties.

(S) WATER REQUIREMENTS OF SUGARCANE UNDER DIFFERENT DOSES OF MANURE AND SHORTENED IRRIGATION PERIOD

The table reveals that withholding of water on September 20 not only saves water but also increases the yield, provided the total water requirements of the crop are met. This is also true when 52" and 64" of water are considered individually, showing thereby that there is no use in irrigating the crop after September 20.

In general, the yield has increased in case of 64", showing thereby that the proper delta is 64".

Applications of 150 lbs. and 75 lbs. N per acre have given a marked increase over control. It is also proved that a larger quantity of water is needed to derive maximum benefit from higher doses of manure.

Treatment	Rainfall (inches)	Average yield of stripped cane in maunds/acre								
		Withholding water after October 30			Withholding water after October 10			Withholding water after September 20		
		N0 (No N)	N1 (75 lbs) N in A/S	N2 (150 lbs) N in A/S	N0	N1	N2	N0	N1	N2
W1=52"	11.49	402.98	616.06	751.26	394.94	680.99	775.94	513.51	670.02	803.12
			590.10			617.29			662.22	
W2=64"	11.49	438.44	699.63	798.80	426.16	697.27	841.68	445.68	750.18	836.21
			645.62			655.04			677.36	
Av. (L.I.P.)			617.86			642.10			669.78	

Manures

N0 = 442.88
N1 = 695.69
N2 = 801.17

Irrigations

W1 = 623.10
W2 = 663.39

(T) Water Requirements and Cultural Practices

Main treatment		Yld. of stripped cane in mds./acre		
		Crop sown mid March	Crop sown 1st. week April	Two yrs. average
Method of meeting total requirements				
F1 = 12" flooding prior to *rauni*; 48" applied in 12 irrigations of 4" each, including *rauni*.	..	519.57	456.96	533.27
F0 = 12 irrigations of 5" each, including *rauni*	..	507.86	542.85	525.36
Method of sowing				
M1 = Sowing in moist seed bed as is normal practice	..	515.82	528.51	522.16
M2 = Sowing in dry soil and applying *rauni* water immediately afterwards	..	511.86	561.30	536.58
Intervals of irrigation				
D1 = Irrigation after *rauni* at equal intervals	..	502.40	532.65	517.52
D2 = 9 irrigations from May 1 to July 20	..	519.03	557.16	538.09
System of application				
A = Irrigation at scheduled depths applied alternately to two of four subplots into which unit plot divided		372.23	350.82	361.53
V = Irrigation at scheduled depths uniformly applied to whole of unit plot.		655.20	738.96	697.08

The following conclusions can be drawn from the study of the above table.

The water stored before sowing can be well utilized by the crop, effecting saving of 3 irrigations in the subsequent watering. The water thus saved can be used for sowing other *kharif* crops.

Dry sowing differs from wet sowing in April sown crop, and is economical in the sense that expenses on blind hoeing can be saved because of after-plowing. Controlled irrigation, *i.e.* D2, increased the yield of cane.

Application of irrigation water to long and narrow strips of sugarcane on alternate turns resulted in significant reduction in yield of cane, as compared with the usual method of irrigation practiced.

(U) Development of Monthly Coefficients of Sugarcane Co. 312 at Lyallpur to Estimate the Consumptive Use of Water for the Crop in Other Areas.

$$U = KF = PKf$$

where U = consumptive use of crop (or evapotranspiration in inches for any period).

P = monthly consumptive use factor for the period (sum of the products of mean monthly temperature and monthly percentage of annual daytime hours for the year).

K = empirical consumptive use coefficient (irrigation season or growing period).

t = mean monthly temperature in degrees Fahrenheit.

p = monthly percentage of daytime hours of the year.

f = $t \times p/100$ = monthly consumptive use factor.

E = monthly consumptive use coefficient.

u = Kf = monthly consumptive use in inches.

The data developed under different values is tabled below.

Month	Irrigation (acre-inches)	Rainfall (inches)	Soil moisture reserve	Total water consumed (acre-inches)	Mean monthly temperature in °F (t)	Monthly percentage of daytime hours in a year (p).	Monthly consumptive use factor (f) $(f=\frac{t \times p}{100})$	Monthly consumptive use coefficient (K).
April	4	0.27	−2.37	6.64	77.65	8.68	6.74	0.98
May	16	0.58	+5.20	11.38	86.95	9.47	8.23	1.38
June	12	0.53	+0.90	11.63	94.20	9.40	8.85	1.31
July	12	2.26	+1.26	13.00	91.20	9.61	8.76	1.48
August	8	3.19	+0.38	10.81	90.00	9.20	8.27	1.30
September	8	1.29	+1.89	7.40	87.70	8.34	7.31	1.01
October	8	0.01	+5.04	2.97	75.70	8.03	6.07	0.48
Total	68	8.13	12.30	63.83			54.23	

Results shown are two-year average

The coefficients of monthly consumptive use (K) of sugarcane Co. 312 developed at Lyallpur can be applied to find out the consumptive use of water for sugarcane at different places (with the help of formula u = Kf), provided complete temperature records and monthly percentage of annual daytime hours in a year at these places are available. Thus, with the help of the mean monthly temperature and monthly percentage of daytime hours in a year, the monthly consumptive use factors (f) of ten different places were calculated per formula $t \times p/100 = f$. The calculated values of consumptive use factors of these places and the actual developed coefficients (K) at Lyallpur were compiled by the formula u = Kf to get consumptive use of water in acre-inches of different places. The results achieved are given in the following table.

Place	Consumptive use in acre inches (Av. 1954-55 & 1955-56).
Jhelum	63.64
Rawalpindi	61.70
Bahawalpur	65.96
Dera Ghazi Khan	65.69
Jacobabad	67.52
Peshawar	63.10
Khanpur	66.86
Multan	65.15
Lahore	65.08
Sialkot	65.02

From the above consumptive use figures of different places, it is evident that it varies from place to place because the climatic conditions of these places are not the same.

(V) EFFECT OF IRRIGATION *cum* MANURES AND SEED RATE ON THE YIELD OF CO. L. 54.

Treatment	Gur yield in mds/acre (4-year av.)
Irrigations	
14 irrigations	84.85
16 ,,	96.51
18 ,,	97.75
Seed Rate	
40,000 sets per acre	94.83
50,000 ,, ,, ,,	92.48
Manures	
Control	86.19
50 lbs. N in A/S	94.49
100 lbs. ,, ,, ,,	96.19
150 lbs. ,, ,, ,,	96.18
200 lbs. ,, ,, ,,	98.39

The data in the above table reveals that among the irrigational treatments, 18 irrigations gave the highest yield of 97.75 maunds, closely followed by 16 irrigations.

As regards seed rate, 40,000 sets proved better than 50,000 sets per acre.

As far as manures are concerned, there is continuous increase in yield with increased doses of fertilizer.

Summary

(1) Water penetrates to a depth of up to 6′ column in the case of 3″ irrigation and 9′ column in the case of 4½″ and 6″ irrigations.

(2) Saving of approximately 12 per cent can be effected by adopting 1/8-acre size irrigation beds over the normal 1/2-acre size.

(3) A 33 per cent larger area can be soaked for sowing wheat by applying soaking irrigation to planked instead of ploughed land.

(4) Flooding of land prior to sowing of wheat has limitations under canal irrigated conditions, but may have great significance for flooded or inundated areas.

(5) Surplus canal water, if applied to cotton in the form of heavy *rauni*, can be deducted from the subsequent irrigation at the time the canal water is scarce, without causing any loss in yield.

(6) Three, six, seven and twenty-one irrigations of 3 inches each after *rauni* are enough to get the maximum yield of wheat, soybean, cotton and sugarcane, respectively. Yield increases with increased irrigations but efficiency of water decreases.

(7) It is the total delta of water that matters for yield not the frequency or depth of irrigation, provided the crop is not allowed to suffer in the critical stages of growth. This finding is of great economic importance in tiding over long canal closures.

(8) The optimum time of first irrigation is 1-1½ months after sowing, and irrigation should be withheld by the middle of March for wheat, the middle of September for sugarcane and the end of September for cotton.

(9) In a year of normal rainfall, high intensity of cultivation combined with fewer irrigations gives similar yields of wheat as low intensity combined with 2 or 3 irrigations.

(10) Application of nitrogenous fertilizers substitutes for irrigation to a certain extent. However, liberal irrigations will be needed to get the maximum benefit of the fertilizer.

(11) To overcome late sowing of wheat as a consequence of deficiency of water at the time of sowing, sowing in properly conserved rain *wattar* at a normal time without *rauni* is the best method. In late sowing of wheat, dry sowing in December gives better results than transplanting.

(12) An application of 120 lbs. of N per acre with 60 lbs. P_2O_5 as a basal dressing and 6 irrigations is the optimum level to get the maximum yield of Mexican varieties of wheat.

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Chapter IX

FARM IRRIGATION AND DRAINAGE SYSTEMS

FARM IRRIGATION AND DRAINAGE PRACTICES IN THE EAST GHOR PROJECT

by

Mohammad D. Hani*

Abstract

The installation of proper irrigation and drainage systems on irrigated farms is a project of great importance to the Ministry of Agriculture of Jordan. The project started in 1964 in the East Ghor canal area and is gradually expanding to other areas.

This is a cost-sharing project between the government and farmers in establishing new farm irrigation and drainage systems, and training farmers to operate and maintain them efficiently. This will lead to more efficient use of irrigation water, which is not adequate to irrigate the whole agricultural area of the country.

It is hoped that the experience and the benefits gained from this program will lead to the development of a soil and water conservation project in other areas of Jordan.

* Head of Irrigation Division, Agricultural Extension Department, Ministry of Agriculture, Amman, Jordan.

Introduction

The Jordan valley is the largest major irrigated agricultural area in Jordan. Water is delivered to individual farms by the following methods :

(1) The diversion of the Yarmouk river by a gravitational conveyance system serving 3,500 farms. The average area of each farm is about eight acres. This is called the East Ghor Canal project.

(2) The side valley streams are stored behind earth-fill dams or directly diverted to the East Ghor canal to increase its capacity, especially during the critical period which occurs in summer.

(3) Pumping from ground water wells,

rivers and streams is used to irrigate farms not included in the East Ghor Canal project. These farms often exceed eight acres in size and are still under the old land reforms.

Farmers in the valley plant vegetables, citrus, bananas and wheat. The farm produce is consumed in the local markets and any excess is exported to neighboring countries.

Existing Farm Irrigation and Drainage Methods

(A) Farm Irrigation

In most of the arable areas of Jordan irrigation is done by the farmers without technical assistance in applying farm irrigation practices. They use meandering, unlined ditches and wild flooding methods, with the following disadvantages:

(1) Wastage of irrigation water through breaks in the banks of irrigation ditches, flooding of farm roads, submergence of part of the neighboring farms and percolation of water through the soil profile below the root zone.

(2) Soil erosion, particularly on steep land. This is very critical in areas with shollow top soil.

(3) Low farm irrigation efficiency. The ratio of water consumed by plants and evaporated from the soil surface, to the water delivered to the farm as measured at the turnout, is called farm irrigation efficiency. This efficiency on most of the irrigated farms of the country does not exceed 50 per cent.

(4) Drainage and salinity problems. The excess irrigation water percolates through the soil profile, causing high water tables and concentration of salts on the surface which will lead to serious damage to plants. This hazardous condition spreads from year to year and in some places has already destroyed the productivity of the land.

(5) Low yield production due to the irregular distribution of water on the soil surface. Uneven soil surfaces cause irrigation water to pond in the depressions, where the root zone will approach saturation. High spots receive less water, which is unable to wet the root zone to field capacity. In both cases the growth of the plant will be affected and production will be low.

(6) High cost of farm irrigation. Farmers need a larger number of laborers to prepare the land for irrigation and to distribute water over the whole surface. Therefore, they have to pay more for irrigating their fields.

(B) Farm Drainage

Farm drainage is generally ignored because its techniques are not known to the farmers. In flat depressions which are under intensive irrigation, the water table is approaching the root zone. Excessive surface run-off caused by rain and wild flooding irrigation is not controlled at all. Erosion, gully formations and sedimentation of eroded soil particles in rivers and streams are increasing. Therefore, applying proper drainage methods is absolutely necessary.

(C) The Farmers

The farmers in the Jordan valley and in all the other irrigated areas have the following problems with regard to farm irrigation and drainage:

(1) Their incomes are limited and do not enable most of them to pay the cost of installing irrigation and drainage systems on their farms.

(2) They do not know modern farming practices. Training and education will encourage them to improve their farming practices, and operate and maintain their irrigation systems more efficiently.

(3) Many farmers are not owners, but rent the irrigated land on a seasonal or annual basis. These temporary farmers are not ready to pay for the installation of new systems, and cannot yet see the advantages of operating and maintaining the existing systems properly.

The Establishment of Modern Methods

The idea of preparing the land in the valley for irrigation started in 1961, when the East Ghor Canal Authority established the Land Develop-

ment division. This division concentrated mainly on two activities: spot scraping of areas which were higher than the water surface and could not be irrigated by gravity flow from the irrigation ditches; smoothing some farm units by running wooden floats over the surface. A total area of about 2,000 acres smoothed by this procedure was soon damaged by the wild flooding methods which the farmers continued to use.

The division failed to achieve any sound progress in the field of farm irrigation and drainage for two reasons :

(1) Qualified technicians who knew about soil and water management were not available to solve existing problems. Most of the senior technicians of the authority believed in leaving the installation of all practices within the farm units to the farmers, with the result that no proposal by the division for assistance in the construction of irrigation projects in Jordan went forwrad.

(2) The division gave farmers free service, which resulted in only limited cooperation from them.

In September 1963, the Land Development division was transferred to the Ministry of Agriculture to be combined with the Agricultural Engineering and Irrigation division.

Considering the facts of the existing situation, a cost-sharing incentive payment program was established by the Ministry of Agriculture and USAID/Jordan to assist farmers in improving their farm irrigation and drainage systems. The program included six main points:

(1) Farmers who make application to establish any part of an irrigation and drainage system on their farms must become members of a cooperative, and agree to pay 50 per cent of the total cost. This cost includes materials and labor and the rental of machinery. The government share cannot exceed $560, which is paid to the farmer by the Cooperative department, acting as banker for the program, upon completion of the work. The farmer is made responsible for the operation and maintenance of the system and is thus the main figure in the program.

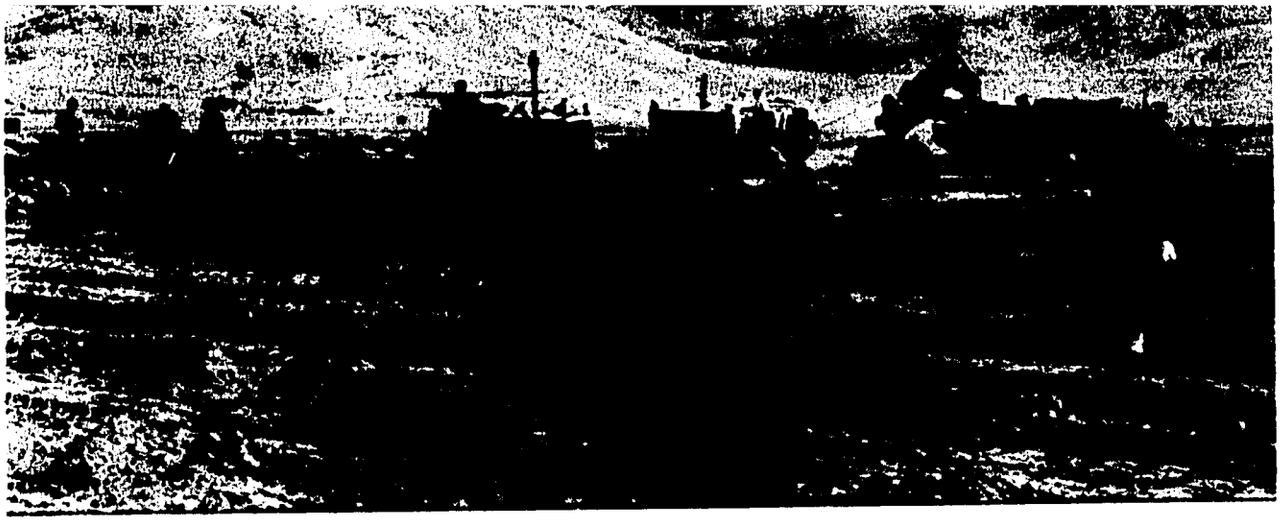
(2) The government provides the required equipment, including the instruments and the machines needed to implement the practices of scraping, land leveling, ditching, etc. Other equipment, intended to mechanize agriculture in the valley, was also imported and is still rented to farmers under the supervision of extension technicians. Rental rates were established by a committee and are generally cheaper than rates charged for private equipment, which is not adequate to cover the needs of this program. The machines are maintained and repaired in a special workshop located in the valley.

(3) Design and execution of the system are by a special team settled in the valley, consisting of a USAID advisor, engineers, surveyors, mechanics, extension agents, a draftsman, a quantity surveyor, rodmen and tractor drivers. The salaries of the team are paid by the government, and their work is considered similar to other technical assistance provided by the Agricultural Extension department, *i.e.* to advise and serve the farmers without charge.

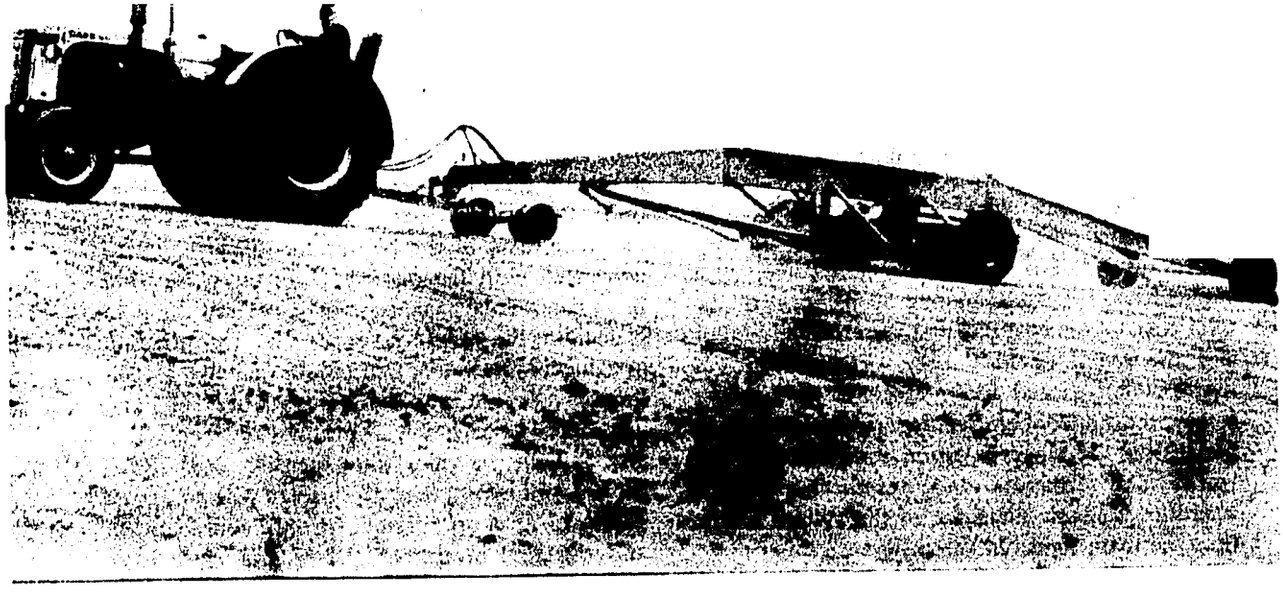
(4) Farmers are encouraged to grow alfalfa, and those who plant this crop receive $22.5 per acre as an incentive payment.

(5) Farmers who have no money to pay their share in the program can get a long-term loan from the Agricultural Credit Corporation. The amount of the loan is estimated, approved and turned over to the Agricultural Credit Corporation by the program engineers.

(6) Formers are not forced to use proper irrigation and drainage practices. The Agricultural Extension department technicians try to convince them of the benefits of the program as compared with the disadvantages of the existing practices. This has been the most critical item in deciding the failure or success of the program in achieving its goals, and usually requires a well-qualified person who knows the work well and has had experience in working with farmers. It is not enough to plan an expensive engineering project and expect that all farmers will accept its value in a short period. Continuous contact and the patient use of strong and clear logic



Spot scraping with bulldozers and scrapers in South Shunih



 Preliminary leveling with Case tractor and Eversman land leveler

Borders ready to be planted with citrus in South Shunih

Irrigating borders with six-inch siphons from unlined irrigation ditch

Sprinkler irrigation demonstration in Deir Alla

will in time convince many of them of the necessity for this engineering work, and will encourage them to apply the practices suggested on their own farms.

Specialized teams started work under the six-point program at the beginning of 1964 by tackling one or more of the following projects:

(*a*) Preliminary scraping and leveling of the soil surface.

(*b*) Irrigation ditches: (*i*) lining of reaches running down steep slopes; (*ii*) constructing unlined reaches on flat slopes.

(*c*) Constructing surface and subsurface drains.

(*d*) Providing farmers who use pumps for irrigation with engineering data to buy the proper pumps. All these farmers are outside the East Ghor project and are not included in the incentive payment program. They can only receive technical assistance.

(*e*) Training extension technicians to become familiar with the engineering elements used in applying irrigation and drainage systems.

(*f*) Training farmers by visiting with them in their farms, meeting them in groups in their villages and taking them to demonstration units and private farms which have work under the program.

(*g*) Planning complete irrigation and drainage systems on extension demonstration farms, nurseries and agricultural research stations.

(*h*) Applying irrigation and drainage methods on private farms requesting the construction of complete irrigation and drainage systems. These have been given priority over farms requesting only partial systems.

If the program continues for several years more, most of the drainage problems will have been handled and the following three irrigation methods will have become common on the irrigated farms in the valley :

Furrow Method, suitable for irrigating vegetables planted on mild slopes and flat land. Plastic dams, and metal and plastic siphons, ranging in size from one to six inches, have been bought to demonstrate this method of irrigation.

Sprinkler Method, for the many farms in the valley which have a rough topography and shallow top soil. Land leveling damages the top soil and reduces its productivity. The ideal irrigation method is the sprinkler method. Two sprinkler units were imported for demonstration purposes. These demonstrations will encourage many farmers to shift to this system.

Border Method. The majority of farmers in the Jordan valley plant citrus or bananas, which give more income than any other crops in the country. The border method is the best for irrigating them, and farmers accept it easily through the incentive payment program.

Design Procedures of the Border Irrigation Method

(1) After the farmer submits his application and is issued his cooperative membership, his farm is visited by the USAID advisor and the engineer, who study the situation and listen to the farmer's problems and ideas.

(2) A preliminary survey is made by a surveying crew to get a general topographic map of the farm (Figure 1).

(3) The topographic map helps in determining the type of preliminary leveling required. If the topography is not very rough, an Eversman land leveler is a very good machine to smooth the surface. This will make the contour lines approximately parallel and the slope of the land becomes more uniform. When the topography is very rough some scraping by bulldozers or scrapers is necessary to cut the high spots and dump the dirt in the depressions. Before scraping, the depth of the top soil profile is checked by augers. The maximum depth of cut is usually controlled by this method in order to avoid overcutting. After scraping, leveling with an Eversman land leveler is carried out.

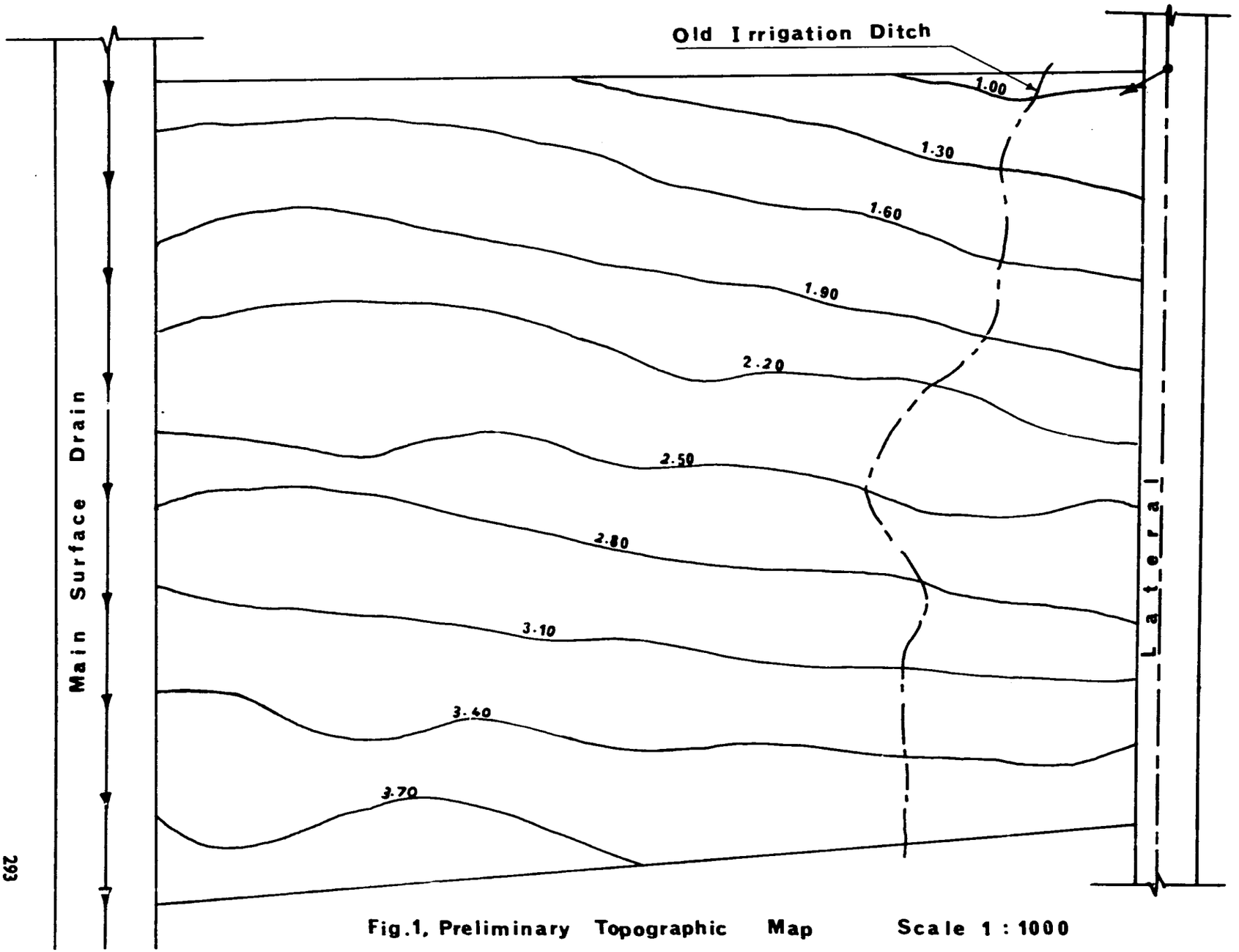


Fig.1, Preliminary Topographic Map Scale 1 : 1000

(4) A final topographic map to be used in the layout of the border system is prepared by the surveying crew (Figure 2).

(5) Infiltrometers are used to get the infiltration rate data. This data is converted into inches per hour and plotted on graphs *vs.* the accumulated time in minutes to determine the average intake rate of the soil in inches per hour.

Actual Irrigation Layout

The following steps are then taken to design the border irrigation system :

(1) The depth (D) in inches, or the quantity of water to be applied at each irrigation, is determined. The following equation might be used :

$$D = \frac{dAsM}{100}$$

where d = depth of soil
As = apparent specific gravity
M = per cent moisture of the soil

(2) The time of application (t) in minutes is determined by using the following equation :

$$t = \frac{15\,D}{I}$$

where D = application depth at each irrigation in inches to wet soil profile to root zone.
I = intake rate in inches per hour.

(3) The maximum discharge (Q), in cubic feet per second, to be delivered to the farm is calculated with a measuring structure such as an orifice, a Parshall flume or a Cipolletti weir. The Cipolletti weir formula is :

$$Q = 3.367\,LH^{\frac{3}{2}}$$

where Q = discharge in cubic feet per second
L = length of crest in feet
H = head in feet

In the East Ghor Canal project the maximum discharge is obtained from the water distribution office.

(4) The area of each border (a) in square feet is determined by the equation :

$$a = \frac{720\,Qt}{D}$$

where Q = maximum discharge in cubic feet per second.
t = time of application in minutes
D = depth of application in inches

(5) The width of the border (w) in feet is assumed not to exceed 15 to 20 Q. The maximum length of run (l) in feet will be the border area (a) divided by its width (w).

$$\text{Thus, } l = \frac{a}{w}$$

(6) The dimensions of the border and the final contour map are used to plot the irrigation layout (Figure 3).

(7) The irrigation ditch profile is drawn. The lined and unlined reaches are fixed (Figure 4), and the cross section (Figure 5) is designed by using a combination of the Manning and continuity equations.

$$Q = \frac{1{\cdot}486}{n} AR^{\frac{2}{3}} S^{\frac{1}{2}}$$

where Q = maximum discharge in cubic feet per second
n = roughness coefficient
A = cross sectional area in square feet
R = hydraulic radius in feet
S = slope of water surface

(8) The turnout dimensions for each border are determined by the orifice equation:

$$Q = Ca\sqrt{2gh}$$

where Q = maximum discharge in cubic feet per second.
C = discharge coefficient
a = cross sectional area in square feet
g = acceleration at 32.2 feet per second
h = head in feet

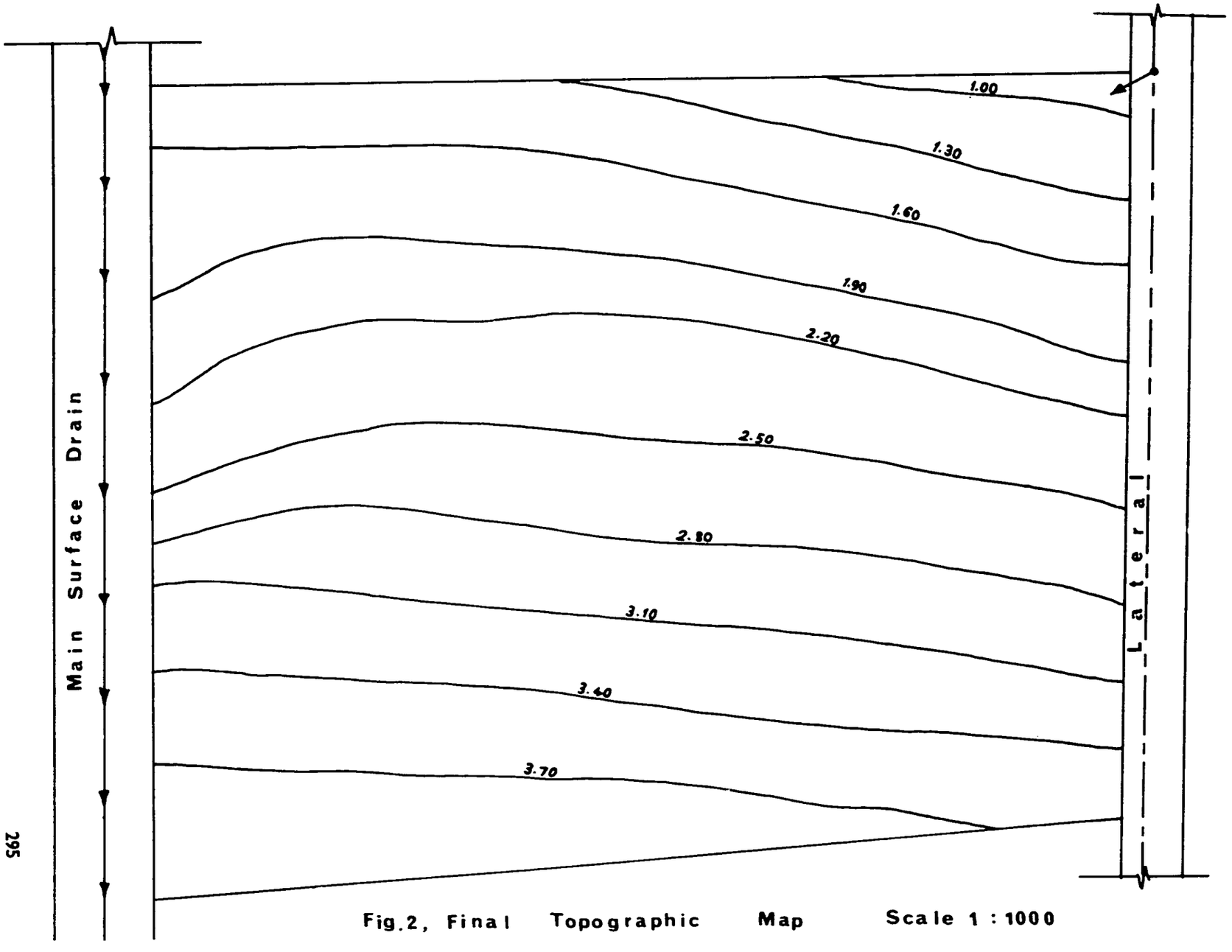


Fig.2, Final Topographic Map Scale 1 : 1000

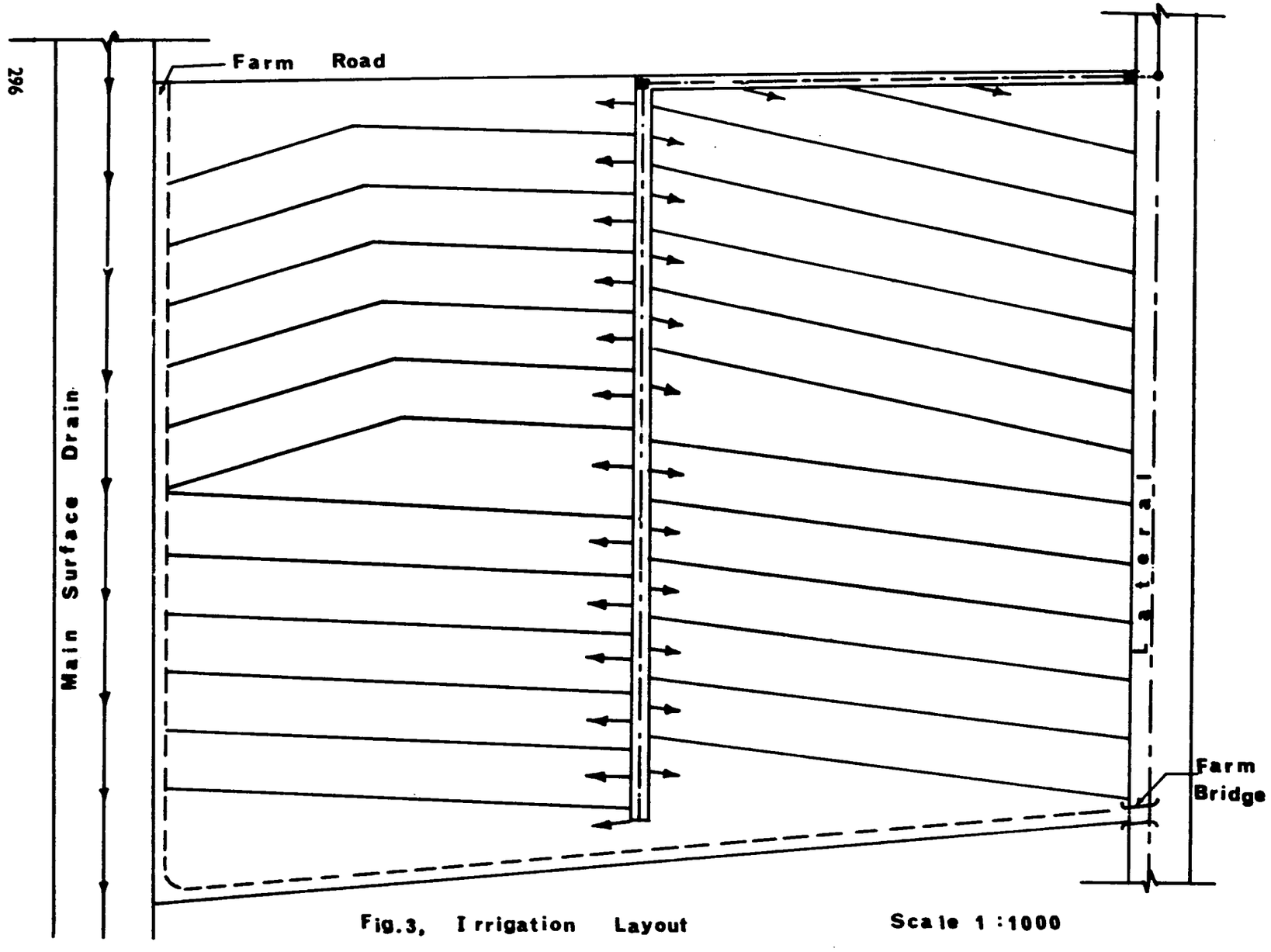


Fig.3, Irrigation Layout Scale 1 :1000

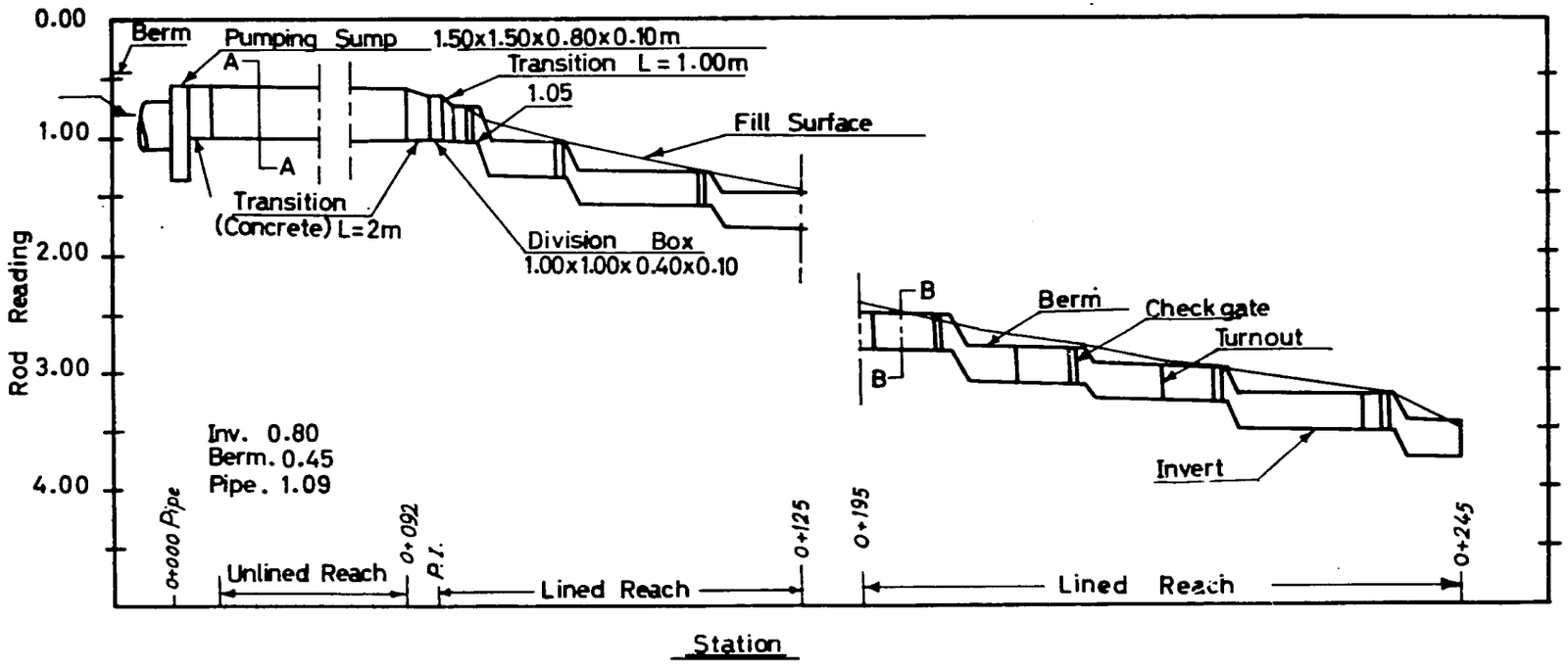
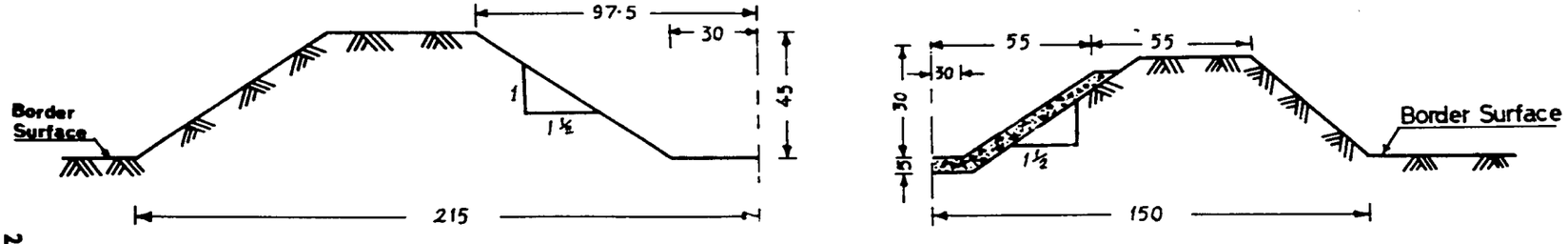


Fig. 4, IRRIGATION DITCH PROFILE



Cross Sec A-A
Unlined Reach·
Dimns In cms.

Cross Sec B-B
Lined Reach
Dimns. In cms.

Fig.5. IRRIGATION DITCH CROSS SEC.

(9) The volume of the dirt to be cut is calculated and balanced with the volume of the fill. (Vcut = 1.30 V fill.)

(10) The estimated cost of the plan is determined in detail and should include: (*a*) type and cost of materials; (*b*) laborers and their wages; (*c*) type, working hours and rental cost of machinery.

(11) The plan is explained to the farmer and an estimated cost form is prepared for signature by him, the USAID advisor and the engineer.

The work now starts under the supervision of extension technicians, and the farmer pays for all the operations. When the work is complete a final form is prepared and signed by the farmer, the USAID advisor and the engineer, and turned over to the Cooperative department, which pays the government's share direct to the farmer. Experience has shown that an average of $1400 is adequate to install a border irrigation system on a farm with an area of eight acres in the Jordan valley.

Future Plans

Proposed guide lines for the establishment of soil and water conservation projects are under discussion by the Ministry of Agriculture and USAID/Jordan technicians. A pilot project of 5,000 to 7,500 acres has been suggested, in which complete agro-economic and engineering studies will be made to develop a master plan. The plan will be implemented by a specialized technical team supervised by a coordinating committee that will include representatives from the Ministry of Agriculture, the Agricultural Credit Corporation, the Jordan Development Board, the Natural Resources Authority and USAID/Jordan.

Summary

The goal of controlling irrigation water for the most efficient use has the advantage of: saving water to irrigate other areas; stopping soil erosion; eliminating drainage and salinity problems; and increasing agricultural yield.

Water is controlled by installing proper irrigation and drainage systems on the farms. Experience in the Jordan valley has shown that the incentive payment program is very effective in achieving this goal, and that success depends on three major factors:

Farmers, whose participation and cooperation are essential.

Technical Staff, organized from among the agricultural engineering and irrigation staff and the extension agents, and responsible for planning the engineering work and training the farmers and other technicians.

Financial Support, from special funds and Agricultural Credit Corporation loans.

The incentive payment program is not compulsory. Farmers have the right to accept or reject it. If it is allowed to continue as a long-term program, border, furrow and sprinkler irrigation will become common in the Jordan valley, and the experience gained will be useful in operating soil and water conservation projects in other areas of Jordan.

DESIGN OF FARM DITCHES AND MEASURING STRUCTURES

by
Mushtaq Ahmad, Abdul Rehman and Abdul Shakoor

This paper deals with two distinct aspects of an uninterrupted, adequate, but measured irrigation supply to the farmer: (a) the design of farm ditches; (b) water measuring devices, *i.e.* adjustable proportional modules. These are dealt with separately in Parts I and II.

Part I: DESIGN OF FARM DITCHES

Synopsis

Small channels and a few farmers' ditches or watercourses have been studied. Ditches running with silted beds and accreted levels drown the measuring outlets and render them non-modular. In some cases the silting of farmers' ditches extends back to the main canal. This points up the importance of the stable design of farmers' ditches.

This study reveals that the shapes of these ditches, *i.e.* their cross sections, width-depth ratio and working slopes, vary under different conditions. The meager field data available is used along with the laboratory data of small streams, and relations are derived for width-depth to discharge for two kinds of channels operating in the lower regime: (a) channel sections with unerodable banks and negligible silt transport; (b) channels with erodable beds and banks, *i.e.* shallow and wide sections, where the capacity and silt load are constant.

Channel dimensions and slopes have been calculated for discharges between 0.5 and 5.0 cusecs. For known sediment concentrations, slopes can be recalculated by using a transport relation.

Introduction

Small channels and farmers' ditches are the arteries of the irrigation distribution system. Channels of less than 5 cusecs capacity are not included in the Lacey's diagrams. Moreover, no data is available on their shapes and governing slopes caused by flow during the course of time. The farmers' ditches are built arbitrarily. The importance of a stable section for a watercourse has not been realized for the reason that it poses a direct problem to the farmer alone.

The authors have come across cases where accretion in ditches has raised the water level, and the effect has traveled right back into the main channel. Accretion in channels and ditches may

be due to the variation in channel section and slope in different reaches, and sediment movement beyond the carrying capacity of the channel. If it is possible to achieve stability in the discharge-slope relations of these small channels and ditches, the farmers will be able to get an uninterrupted water supply.

The Mechanics of Flow in Alluvial Channels

Observations show that movement of the bed material due to the dynamic action of flow is accompanied by undulations on the mobile bed. The bed waves or the roughness of elements can be related to the characteristics of flow and bed sediment grades for negligible sediment movement. But there is no mathematical form that gives complete agreement with the results of measurements. It has been noted that for very low velocities the bed is plane, but as the velocity increases, ripples make their appearance due to variations in the pressure distribution when the boundary layer becomes turbulent for a plane bed. The critical shear stress and water velocities for sediment are functions of mean grain size. A simple relation between bottom velocity and coarse bed grade is:

$$Vb/d^{\frac{1}{2}} = \text{constant.}$$

where Vb = velocity in ft./sec.
d = sediment grade in mm.

For plane bed, the constant in the equation is near about unity. Shields obtained a relation for the critical tractive force related to the submerged weight of the bed material as:

$$\gamma\ R\ S/(\gamma_1-\gamma)d=\varphi\ (V\ \ .d/r)$$

where γ_1 = specific weight of sediment
γ = specific weight of water
R = D = depth
S = slope
d = sediment dia.
V^* = $\sqrt{gRS}$ shear velocity
V = kinematic viscosity

The bed shows different forms depending upon the shear value and bed grade Reynold number. Another useful parameter to predict the state of bed configuration is the stream power $\tau.V$ which relates the form of the bed roughness with the bed grade. The stream power $\tau.V$ or discharge slope product for the small stream and field data is plotted in Figure 2. It will be noted that in the case of the small channels the stream power $\tau.V$ does not exceed .04. According to the demarcation by Simons[1], when the bed is plane and $\tau.V$ is less than .007, roughness is low. But in the ripple regime the roughness is high. In this range the dimension less Chezy's coefficient $V/\sqrt{gRS}$ ranges from 7.5 to 14.

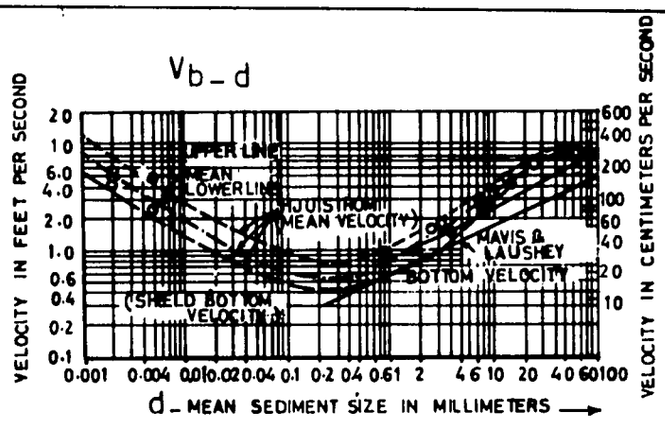
Geometry of Stable Channels

There are two approaches to determine the shape and dimensions of sand bed channels: the regime theory and Lane's tractive force. The regime theory was developed on the data of Indo-Pakistan subcontinent, and the tractive force theory was developed by Lane in America.[2]

Both concepts are based on the knowledge of the permissible velocities, so that the average velocity is relatively low and the banks do not erode in order to develop a stable channel. The regime theory relates to channels where very fine silt makes the banks resistant to scour, while Lane's theory provides for the side slopes to be adjusted according to the angle of repose for the bank material. The angle of repose for the medium sand grade (d = .22 to .4 mm.) is 30° and side slopes 2/1 have to be provided.

The tractive force theory by Lane is based on the shear stress concept; hence the depth-slope product RS is constant at all points along the channel. On the other hand, Lacey's regime theory based on observed data gives $R^{\frac{1}{2}}S$ product as constant along the channel. Lacey's theory is now well-founded, as it has gained some support from Einstein's 'bed load function' by

(1) Simons D.B. and Miller C.R., Sediment Discharge in Irrigation Canals; International Commission on Irrigation and Drainage, Sixth Congress.
(2) Lane E.W., Stable Channels in Erodable Material; Trans. of ASCE, Vol. 102, 1937.



CRITICAL WATER VELOCITIES FOR QUARTZ SEDIMENT AS FUNCTION OF MEAN GRAIN SIZE

FIG. 1

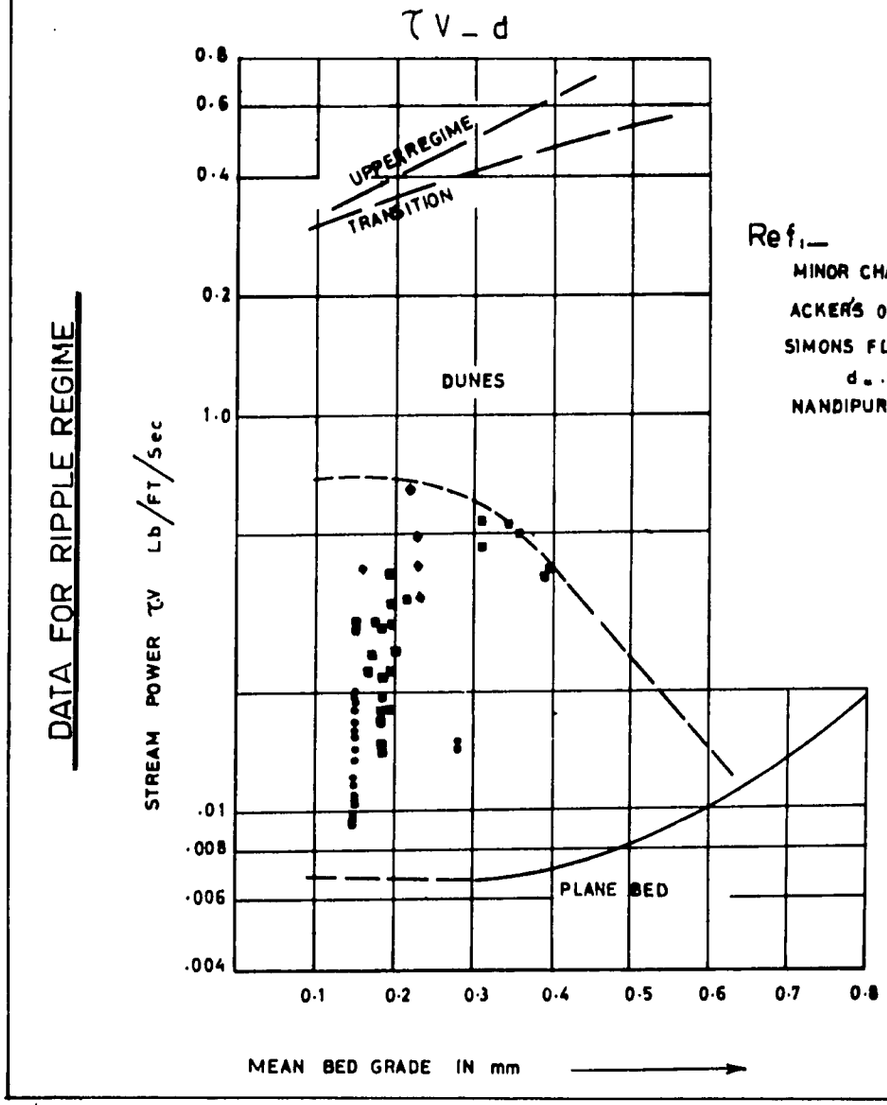


FIG. 2

Ning Chien[3]. The Lacey theory is applicable to sand bed channels with live bed, while Lane's theory is applicable when the bed is on the threshold of motion.

Field and Laboratory Data

The data analyzed in this paper pertains to: (i) minor channels up to 10 cusecs; (ii) small streams up to a range of 10 cusecs studied in experiments in Indo-Pakistan and foreign laboratories.

The field data pertains to channels where the banks are almost firm. The bank material is different from the material in the bed, usually consisting of very fine clay deposits due to berming effect, which make it very resistant to erosion. The range of velocity is 1 to 2 ft., that is, not high enough to erode the banks formed as a result of berming effect. The model data pertains to : (i) channels which do not erode their banks; (ii) moulded in the same material and the banks made stable after erosion.

The field data is from a system of L.B.D.C., L.C.C. and Jhelum distributaries and minors, varying between a discharge of 2 and 10 cusecs. The range of velocity in the field data is from 0.68 to 1.25 ft./sec. Depths range from 0.63 ft. to 1.6 ft., slopes from 0.2 to 0.47 and Lacey silt factor from f = 0.45 to 1.5. The model data is derived from the work done at the hydraulic research station, Nandipur (Q = 10 cusecs), and small streams in alluvium by Ackers[4] for discharges of 0.5 to 5.4 cusecs for a medium diameter of 0.16 to 0.3 mm., and Poona[5] experiments on stable sections of small channels in sand of various grades—series V for discharges between 1 to 6 cusecs with white sand of dia 0.3 mm.

Analysis of Data

The data has been analyzed in the following parameters, and plotted in Fig. 3 (a, b, c) to Fig. 4 (a, b):

1. Perimeter P against discharge Q.
2. Hydraulic depth R against Q.
3. Slope against Q.
4. $R^{\frac{1}{2}}S$ against silt factor[6] ($f = .75V^2/R$).

The relations derived from different parameters against discharge and slope for the field data and model experiments are compared in Table 1.

On comparison it may be inferred that the Ackers model relationships for stable channels are similar to Lacey, except that the constant and indices vary. The index powers of the Poona experiments are not very much different from the field data, but the constants indicate that the model stable channels are wider and shallower. Comparisons of the width-depth ratio for the three cases are :

$B/D^{\frac{3}{2}}$	= constant 4.5
Ackers B/D	= constant 13.0
Poona B/D	= constant 17.6

The behavior of the channels is largely similar, the only differences being due to the erodability of banks. The reasons for this are : (i) the field channels had berms formed by deposit of fine silt; (ii) in Ackers' model the material was allowed to deposit but berming was not achieved as in the field; (iii) in the Poona model probably no berming was allowed, as the objective of the model was to determine the stable dimensions of channels for purposes of scale ratios.

Design of Small Channels

In determining the geometry of the small channels, with a capacity from 0.5 to 5 cusecs, the following procedure was adopted:

P and R were determined by using the relationship derived from the field data in Fig. 3 (a,b) and Table 1:

(3) Ning Chien, Concept of the Regime Theory; Transactions of ASCE, Vol. 122, 1957.

(4) Ackers, Peter, Experiments on Small Streams in Alluvium; Journal of Hyd. Div., Proc: A. S. C. E. July, 1964, Vol. 90, Hy. 4, Paper No. 3959.

(5) Central Board of Irrigation Pub. No. 27, Annual Report 1941, Page No. 3.

(6) Lacey G, Flow in Alluvial Channels with Jandy Mobile Beds; Proc: Institute of Civil Engineers, Feb. 1948, page 27, Table No. 4, serial No. 1.

$P = 3.Q^{\frac{1}{2}}$

$R = 0.48Q^{\frac{1}{3}}$

Area $= PR$

If E denotes the ratio of wetted perimeter to water surface, then

$E = P/Ws = Dm/R$

where P = wetted perimeter
Ws = water surface
Dm = mean depth
hyd. radius R = A/P

TABLE 1

Relation	Field Data of L.B.D.C., L.C.C. & L.J.C. Systems	Model Experiments: Ackers data Q=0.5 to 5.5 Cs.	Model Experiments: Poona Expts. Q=1 to 6 Cs.	Nandipur
Range of data	Q.Q=2 to 10 Cs.	Q=0.4 to 5.4 Cs.	Q=1 to 6 Cs.	Q=10 Cs.
P-Q	$P=K_1 Q^{\frac{1}{2}}$ K=2.6 to 3.3 Average 3	$B=3.6Q^{.42}$	$B=5.4Q^{.478}$	$WS=4.6Q^{\frac{1}{2}}$
R-Q	$R=K_2 Q^{\frac{1}{3}}$ $K_2=0.48$	$D=0.28Q^{.43}$	$D=0.277Q^{.368}$	$D=0.265Q^{\frac{1}{3}}$
S-Q	$S=0.36Q^{-\frac{1}{6}}$	$S \propto Q^{-.29}$		
$R^{\frac{1}{2}}S$-f	$R^{\frac{1}{2}}S=K_3.f$ $K_3=0.2$-0.285 Average 0.25			$R^{\frac{1}{2}}S=0.34f$
		$A=1.0Q^{.85}$		$A=1.1Q^{\frac{5}{6}}$
Velocity	$V=R^{\frac{1}{2}}$	$V=1.0Q^{.15}$		$V=0.91Q^{\frac{1}{6}}$

TABLE 2

Q (cs.)	B (ft.)	D (ft.)	S (%)	V (ft./sec.)	t (lb./ft.)	$\sqrt{gDs}$	Rugosity Manning's N	$\frac{V}{\sqrt{gDs}}$	Bed grade (mm.)	Fall velocity W (ft./sec.)	$\frac{q^{\frac{2}{3}}S}{W^{\frac{1}{2}}}$	Sediment capacity C (gr/liter.)
5	4.0	1.2	.305	.9	.023	.108	.027	8.35	.152	.055	1.37	.020
4	3.7	1.1	.315	.87	.022	.105	.027	8.2	.149	.053	1.33	.017
3	2.8	1.06	.330	.83	.022	.106	.026	7.9	.145	.050	1.35	.018
2	2.2	1.0	.355	.78	.021	.103	.026	7.6	.140	.048	1.32	.016
1	1.4	0.96	.405	.7	.0205	.101	.025	6.6	.130	.043	1.13	.004
.5	0.8	0.7	.445	.7	.0197	.100	.025	5.8	.126	.040	1.22	.009

E is 1.25 for the branch data of L.C.C.; Ws is 0.8 P; Dm is 1.25 R

The section was built up with side slope of $\frac{1}{2}$ to 1 as given in Table 2. The slope was calculated from the curve $R^{\frac{1}{2}}S$: f (Lacey), shown in Fig. 4a. From this figure it is seen that the value of $R^{\frac{1}{2}}S$ varies from 0.2 to 0.3, the average being 0.25. But the value of $R^{\frac{1}{2}}S = 0.275$ from the range of f=0.7 to 0.8 is adopted and slope calculated. The velocity was calculated from the regime formula that fitted the data plotted in Fig. 4b. In the figure, data plotted as $V:R^2S$ gives a slope of $\frac{1}{3}$, that means

$$V = 16R^{\frac{2}{3}}S^{\frac{1}{3}}$$

for the range of discharges 3 to 10 cusecs channels. Below 3 cusecs there is a large scatter. Moreover, the trend of the curve is otherwise, showing that this data pertains to a different regime; it may be plane bed regime, where the regime equation for velocity as cited above does not apply. This is probably the case when the sediment entry in the channel is nil and the longitude slope was very flat. Assuming that the sediment entry does take place, the regime equation of $V = 16R^{\frac{2}{3}} S^{\frac{1}{3}}$ will probably apply. The velocity has been calculated using the same relation. Now taking $R^{\frac{1}{2}}S = 0.275$ and the regime equation for velocity as above, and combining the two equations yields $V = R^{\frac{1}{2}}$, which is a very simple relationship showing that f (Lacey) for small channels is 0.75. The velocities range from 0.62 to 0.905 ft./sec., the slopes from 0.445 to 0.305 for the discharges 0.5 to 5.0 cusecs. The shear value, $V/\sqrt{gRS}$ and Manning's N have been calculated in the table for comparison,

$V/\sqrt{gRS}$ is below 8.5 in all cases.

As regards the channel capacity for sediment transport, it can be estimated if the representative bed grade diameter is known. If the bed grade diameter at the head regulator is known, the probable bed grade diameter at a distance X kilometers is given by a relation, as determined for M.R. Link by Simons[7] :

$$d = M/e \,.\, 001\ X$$

where M is bed grade in mm. at the head regulator and X is distance in kilometers. Inglis[8] gives for the West Pakistan canals, $d = M.Q^{\frac{1}{10}}$ that seems to hold approximately on the average for the canal system, where $M = 0.2$ and d works out as 0.152-0.126 for Q 5 to 0.5 cusecs. The capacity for sediment transportation has been calculated from the transport function in Fig. 6 (a, b).

$$q^{\frac{2}{3}} \cdot S/W^{\frac{1}{2}} = 1 + 5C^{\frac{2}{3}}$$

where $q = Q/(B + 0.5\ D)$, S is slope, W is the fall velocity and C is sediment transported in gm/liter.

The transport function has been found to fit a very wide range of flume ond field data. Fig. 6a presents Simons' flume data and the Rathburn and Guy data and the small stream data of Ackers and the model data from our own model, for the forms of ripple dune regime only. According to the calculation, a channel up to 1 cusec will carry sediment up to 4 to 9 ppm. but those above 2 to 5 cusecs will carry 16 to 20 ppm. or 0.016 to 0.02 gm./liter; any sediment charge above this limit will cause siltation.

Dimensions of Channels that Attained Stability after Erosion of Their Banks

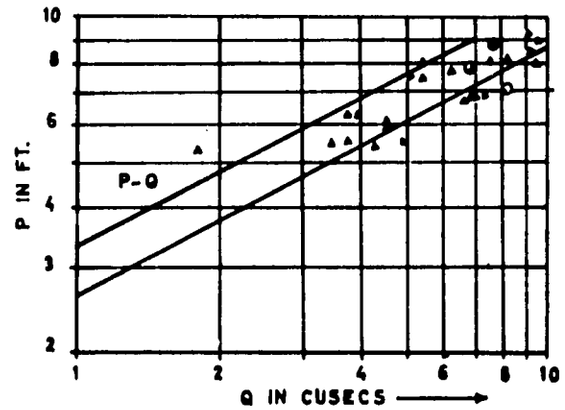
Simons' equations were used to obtain width, depth and velocity such as

$$B = 3.6Q^{\cdot 42}$$
$$D = 0.28Q^{\cdot 43}$$
$$S = \text{constant } Q^{-\cdot 29}$$

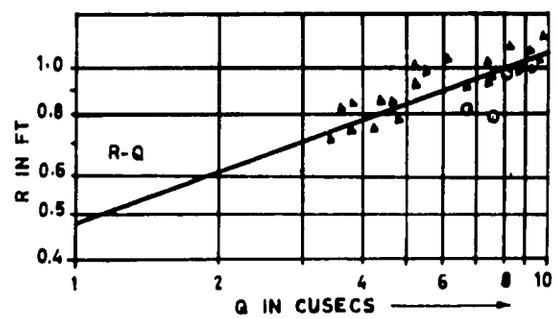
Assuming Manning's N=.025, the slope was calculated. The calculated slopes in Fig. 6a follow the curve $S = K.Q^{-\cdot 29}$, with a constant K=1.45.

(7) Simons B. D. and Miller C. R, Sediment Discharge in Irrigation Canals; Int. Commission on Irrigation and Drainage, Sixth Congress, Page 12.

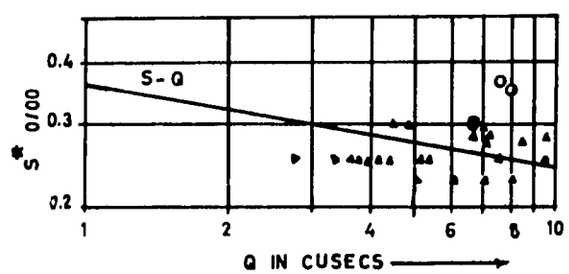
(8) Inglis C. C., Rate of Deposition of Sand as Governed by Charge and Terminal Velocity; Central Board of Irrigation, India, Pub. No. 27, Annual Report 1941, Page 101.



(a)

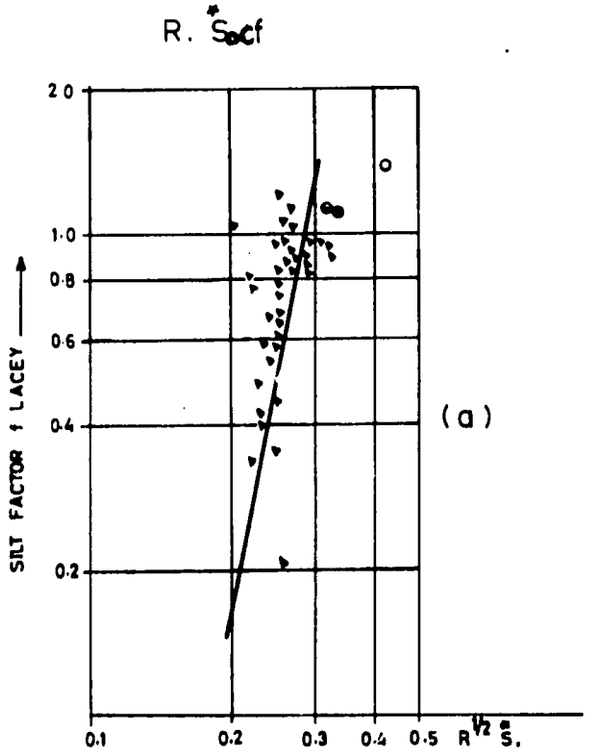


(b)



(c)

FIG.3(a,b,c)


R. S*cf
2.0
1.0
0.8
0.6
0.4
0.2
SILT FACTOR f LACEY
(a)
0.1
0.2
0.3
0.4
0.5
R^1/2 S*.

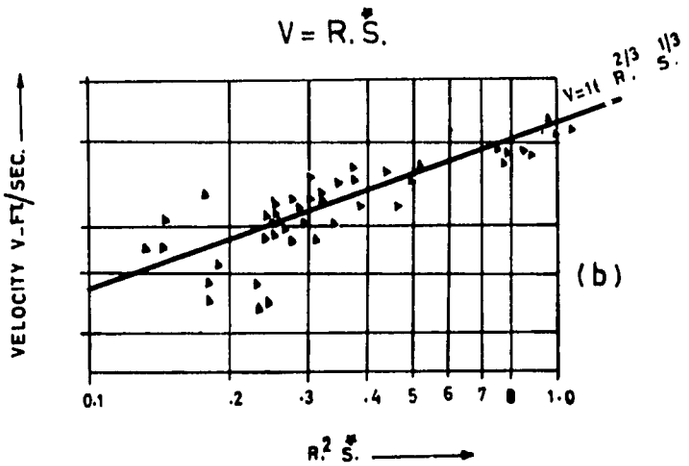
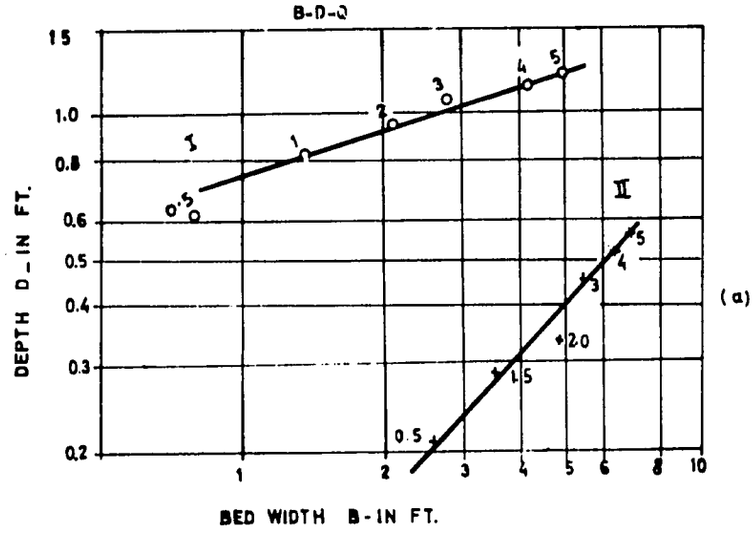

V = R. S*.
V=11 R.^2/3 S.^1/3
VELOCITY V-FT/SEC.
(b)
0.1
.2
.3
.4
5
6
7
8
1.0
R.^2 S*.

FIG. 4(a.b)


B-D-Q
DEPTH D_IN FT.
BED WIDTH B-IN FT.
II
(a)

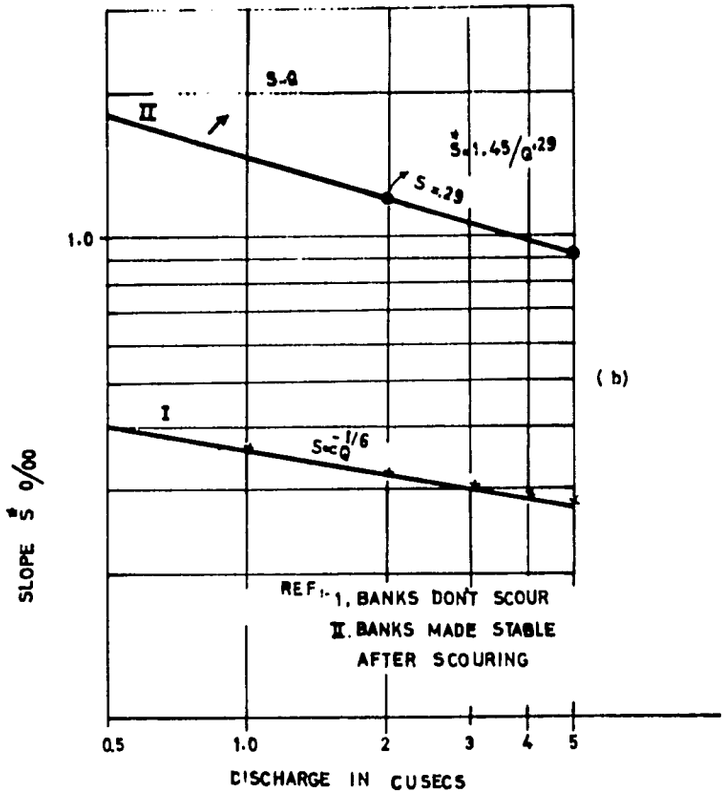
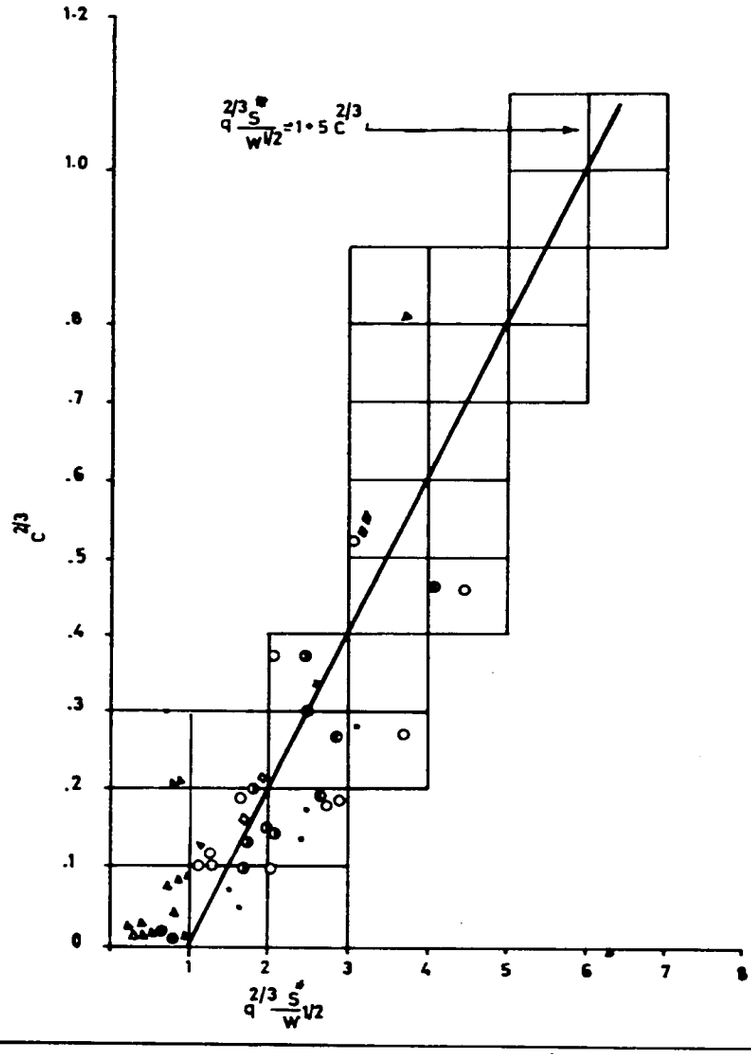

S-Q
II
$S = 1.45/Q^{.29}$
$S \propto .29$
I
$S \propto Q^{-1/6}$
(b)
SLOPE S 0/00
REF:- I, BANKS DONT SCOUR
II. BANKS MADE STABLE
AFTER SCOURING
DISCHARGE IN CUSECS

FIG. 5(a-b)



Ref:- RIPPLE REGIME DATA

ACKERS SMALL STREAMS — Class I ○ ; Class II ◐ ; Class III ◐
- m = .15 to .37 mm.
- Q = 1.5 to 5.3 cs.
- q = .125 to .8 cs.
- c = 10 to 400 ppm.
- Fr = .245 to .56
- Temp = 4° to 20° C

NANDI PUR MODEL ♦
- m = .23 mm
- Q = 30 cs.
- q = 1.2 cs.
- D = .75 to 1.0 ft
- c = 100 to 400 ppm
- Fr = .21 to .32
- Temp = 20 to 30 C°

N' MODEL NO II ♦
- m = .16 mm
- Q = 10 cs.

SIMON'S FLUME DATA ●
- m = .28 mm
- Q = 4 to 10 cs.

m = .45 mm △
- Q = 1.95 to 7.9 cs.

RATH BUN I.A.H.R. △

NOTE:- Class I. Clay banks.
II. eroded.
III. shoaled.

FIG. 6(a)

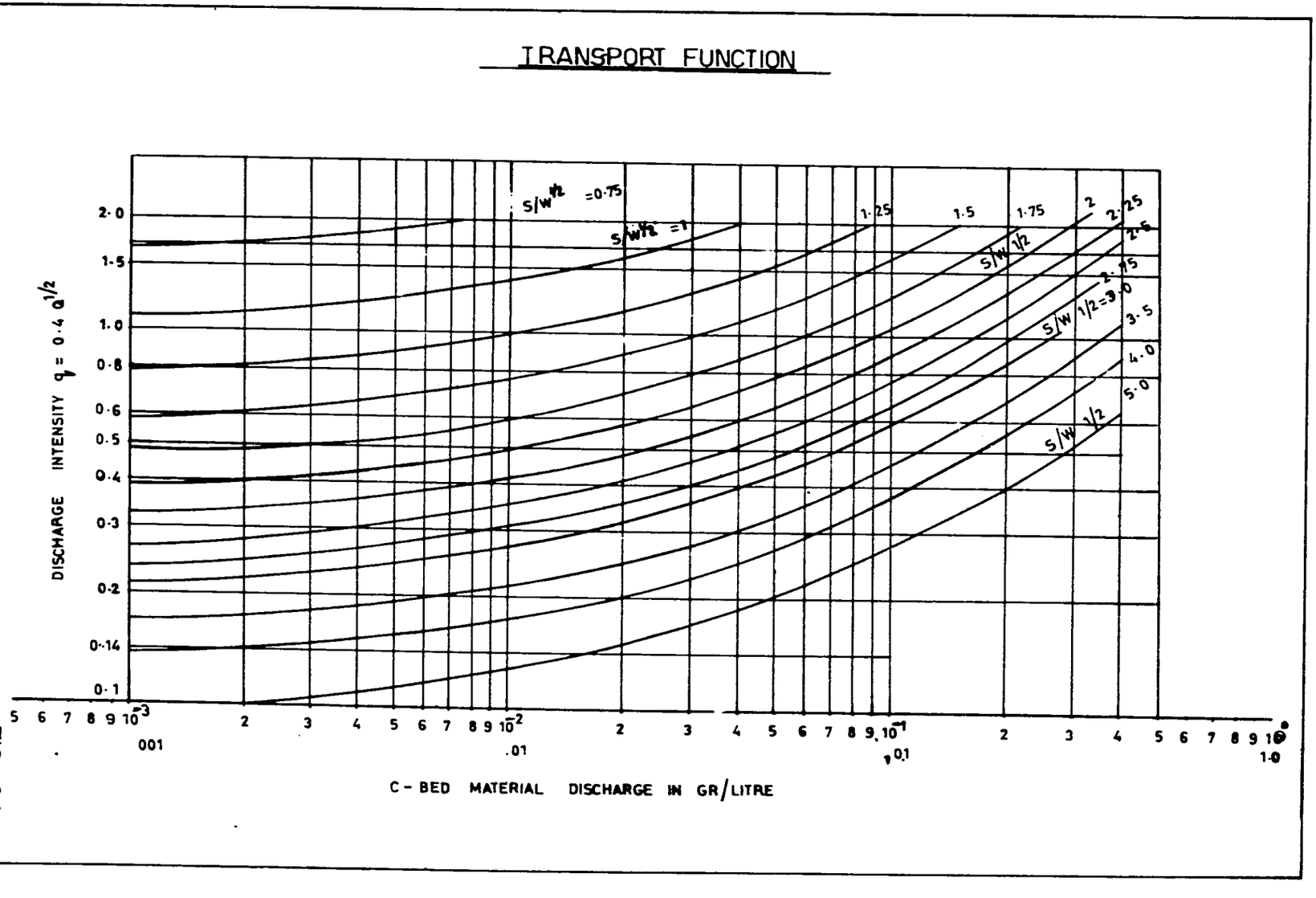

TRANSPORT FUNCTION
DISCHARGE INTENSITY q = 0.4 a^1/2
C - BED MATERIAL DISCHARGE IN GR/LITRE
S/W^1/2 = 0.75
S/W^1/2 = 1
S/W^1/2 = 1.25
S/W^1/2 = 1.5
S/W^1/2 = 1.75
S/W^1/2 = 2
S/W^1/2 = 2.25
S/W^1/2 = 2.5
S/W^1/2 = 2.75
S/W^1/2 = 3.0
S/W^1/2 = 3.5
S/W^1/2 = 4.0
S/W^1/2 = 5.0
2.0
1.5
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.14
0.1
.001
.01
0.1
1.0

FIG:- 6-(b)

The dimensions of the channels in Tables 2 and 3 give the range through which a channel in the field might exist for the conditions depending on sediment entry and bank erodability. The channels that do not erode their banks will be carrying low intensity of the sediment while the shallower channels with steeper slopes can carry sediments up to 250 ppm. or 0.25 gm/liter. In the case of excessive sediment entry the slope can be recalculated from Fig. 6b, which gives wide range of variation of $S/W^{\frac{1}{2}}$, Q and C.

TABLE 3

Parameters of Channels That Erode Their Banks

Q (cusecs)	q (cusecs)	$A=Q^{.85}$ (sq. ft.)	$V=Q^{.15}$ (ft. sec.)	$W=3.6Q^{.42}$	B (ft.)	$D=28Q^{.43}$	P (ft.)	$R=A/P$ (ft.)	P/R	f_{vR}	Slope (%)
.5	.19	.56	.90	2.68	2.58	.208	3.05	.184	16.5	3.15	1.80
1	.28	1.0	1.0	3.60	3.46	.280	4.09	.254	16.0	2.95	1.45
2	.366	1.8	1.11	4.88	4.72	.330	5.46	.330	16.5	2.80	1.20
3	.53	2.54	1.18	5.70	5.47	.450	6.48	.390	16.6	2.70	1.06
4	.625	3.26	1.23	6.45	6.20	.510	7.34	.445	16.5	2.55	0.98
5	.71	3.94	1.27	7.10	6.92	.560	8.17	.480	17.0	2.50	0 90

Part II: WATER MEASURING DEVICES

Synopsis

Crump, in 1922, gave a type design of module outlet or turnout (as it is termed in America) called 'Adjustable Proportional Module'. This type has been found suitable for measuring the supply from the government-controlled channels to farmer watercourses in West Pakistan. Since the publication of this paper, this type of outlet has been introduced on almost all new irrigation systems and remodeling works.

Crump claimed that the coefficient of discharge of an APM of given width was constant and its value was 7.3. He based his conclusions on a few experiments conducted by him in the field with an outlet 0.5 feet wide. It was suggested that the coefficient of discharge might be taken as constant for other widths of the outlet also, pending further experiments.

Keeping the above claims in view, experiments were performed on an outlet research station, specially set up for this purpose on U.C.C. at R.D. 221,000 by the Irrigation Research Institute, Lahore. Extensive experiments were performed on a special distributary channel made for the purpose. Data was collected for eight different widths of the outlet. The results did not confirm the observations made by Crump. The coefficient of discharge of an APM is not 7.3 for the same width, but varies with ratios Y/H and Y/B. Equations are worked out by connecting C with these ratios. Also, the value of coefficient of discharge K in the standard formula

$$K=Q/B\ (H^{\frac{3}{2}}-H_o^{\frac{3}{2}})$$

is worked out, and the equation connecting K with ratio Y/H is given. A relation connecting minimum modular head (hm) to depression head (H_o), as evolved from the observed data, is suggested for use.

Introduction

The device which is used for measurement

of the water supply to a farmer's ditch is called an outlet, or in America, a sluice or turnout. Various types of outlets, such as pipe outlets, open flume outlets, Gibbs modules, Harvey Stoddard improved outlets and adjustable proportional modules (APM), are in use. Outlets are located in the distributary channel at the head of a watercourse. Distributary channels in this country are controlled by the government, whereas the internal working of the watercourse is managed by the farmer whose land it irrigates. About 40,000 outlets of various types (as traced from records)[9] existed in 1944 in the former Punjab region; many more have since been added. Keeping in view the large number of such structures in use, it was considered necessary that the design of an outlet structure should be standardized to cover and cater for all the possible conditions of water level changes in the distributary. In this paper, only studies relating to an APM are discussed. This type is easily adjustable, not easily tampered with and is independent of water levels in the watercourse under certain limits. The water level in the supply channel can vary with respect to the crest and the roof block for different conditions. The main aim is to pass a constant discharge for a particular level in the supply channel which is not affected by large variations of water levels in the watercourse due to silting or other causes.

Adjustable Proportional Module (APM)

Crump introduced the adjustable proportional module (APM) in 1922. It is shown in Fig. 7. It is a long-throated flume fitted with a roof block capable of adjustment. An APM minus roof block differs from the open flume module only in respect of length of throat. It is a flexible module. The upstream and downstream approaches of an APM are similar to the Crump open flume outlet. The length of the crest is H+1.0 ft. The cast iron block comprises a base plate, two check plates and a roof block. The roof block moves vertically within check plates and is adjustable. The cast iron blocks are manufactured in standard sizes of throat width Bt=0.20 ft., 0.25 ft., 0.32 ft., 0.40 ft., 0.50 ft., 0.63 ft., 0.80 ft. and 1.00 ft. The first four are in common use. Laboratory experiments were conducted on all the sizes of an APM.

Experiments on Crump APM

At the outlet research station of the Irrigation Research Institute, Lahore, suitable drop was available to carry out the experiments by fitting the outlets on full scale in the experimental distributary channel. Apparatuses, such as the gauge wells to record water levels, diversion values for instantaneous diversion of discharge from the watercourse into the measuring tank, and straight-edge trollies, were set up for making observations during experimentation. After adjusting the proper slope in the experimental channel, the outlet was worked with a fixed head above the crest of the outlet (H). A series of observations was made by creating different levels in the watercourse downstream of the outlet controlled by stop logs. Near the modular limit range (a limit when the change in downstream water level starts affecting the upstream water level and the discharge coefficient is affected), more readings were recorded. When the flow had attained constant upstream and downstream water levels, it was directed from the escape for a known period into the measuring tanks to volumetrically determine the discharge. The value of H was then altered and the observations repeated with varying H.

After completing the above series with one value of Y (height of opening) and varying H, a new value of Y was selected and observations were repeated. After observations for different values of H and Y were complete for one width (B) of the outlet, it was dismantled and an outlet of a different width was constructed in brick masonry. For each width of the outlet, about 500 observations were taken, and in all the tests about 4,000 observations were recorded.

Experimental Investigations

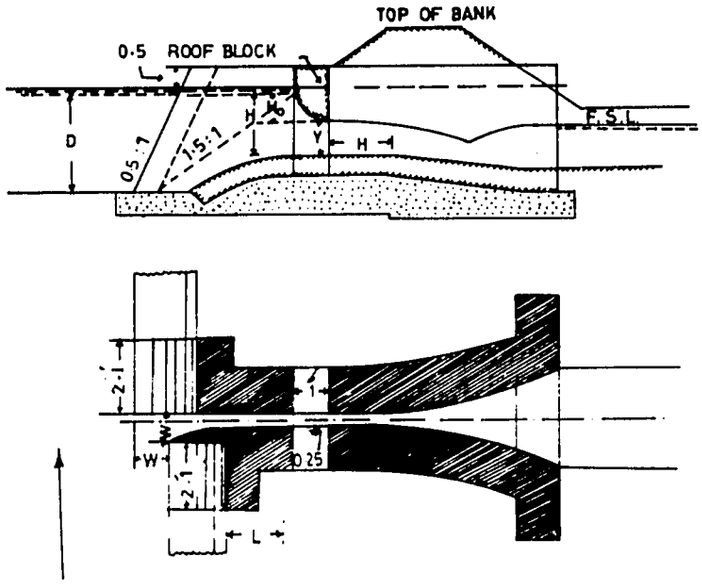
Crump's main conclusions were[10]:

(9) Irrigation Outlets, by S. I. Mahboob and N.D. Gulati.

(10) E. S. Crump, Moduling of Irrigation Channels, Punjab Irrigation Branch Paper No. 26, Class A.

CRUMP

ADJUSTABLE PROPORTIONAL MODULE



REF:-

1. DEPTH OF FLOW IN DISTRIBUTARY CHANNEL (D)
2. DEPTH OF FLOW OVER THE CREST -----(H)
3. DEPRESSION HEAD (H_o)
4. MINIMUM MODULAR HEAD (hm)
5. HEIGHT OF OPENING OF OUTLET (Y)
6. WIDTH OF OUTLET (B).

FIG:- 7.

(1) The value of the coefficient of discharge C is 7.3 in the formula $Q = CBY\sqrt{H_o}$

(2) C is constant for APMs of the same width.

(3) C may be taken as constant for all sizes of outlets.

From the dimensional point of view, Q is a function of the following parameters, representing the boundary geometry, characteristics of motion and fluid: B (width of outlet), Y (opening of outlet), μ (viscosity), ρ (density), g (gravity), and ϵ (roughness) *i.e.* $Q = \varnothing\ (Y, B, V, H, \mu, \rho, g, \epsilon)$.

By dimensional analysis we have

$$C = Q/BY\sqrt{H_o} = \varnothing\ (Y/H),\ (B/H),\ (\epsilon/H),\ (V^2/gH),\ (HV/\mu/\rho) = (Y/H,\ B/H,\ \epsilon/H,\ F,\ R)$$

where *F* is the Froude number and *R* is the Reynold number, ϵ/H is the relative roughness, Y/H and B/H relate the orifice boundary dimension to the flow parameter *H* or H_o.

The present series of experiments was carried out to test the following aspects of the problem in view of Crump's conclusions and a review from dimensional analysis:

(1) The coefficient of discharge $C = Q/BY\sqrt{H_o}$ of adjustable proportional module as a function of boundary geometry of the outlet with respect to flow parameters, *i.e.* $C = f(Y/H)$, $C = f(Y/B)$.

(2) The value of K in formula $K = Q/B\,(H^{\frac{3}{2}} - H_o^{\frac{3}{2}})$ for the same non-dimensional parameters.

(3) Selection of the formula for accurate measurement of discharge for an APM.

(4) The minimum modular head (hm).

The eight different throat widths of outlet, Bt = 0.20 ft., 0.25 ft., 0.32 ft., 0.40 ft., 0.50 ft., 0.63 ft., 0.80 ft. and 1.00 ft., were tested. For each width of the APM the height of orifice Y was varied at intervals of 0.1 ft. from 0.20 ft. to 1.1 ft., for the first four sizes of outlets. For the remaining widths of Bt = 0.63 to 1.0 ft., the height of the orifice Y was varied at intervals of 0.05 ft., from 0.1 ft. to 0. 6 ft. Then for each value of B and Y the tests were performed with head over crest H as the variable quantity. The value of H examined varied from 0.8 ft. to 2.4 ft. at intervals of 0.2 ft. For each width of the outlet and set of conditions the following data was collected and analyzed :

(1) Depth of water over crest (H).
(2) Depression head (H_o).
(3) Volumetric measurement of discharge (Q).
(4) Coefficient of discharge (K) according to standard formula $Q = KB(H^{\frac{3}{2}} - H_o^{\frac{3}{2}})$.
(5) Minimum modular head (hm).

Analysis of Data

The following relations were plotted for each width of outlet examined :

(1) C against Y/H, for all widths of outlet tried.
(2) C against Y/B.
(3) K against Y/H in the formula, $Q = KB(H^{\frac{3}{2}} - H_o^{\frac{3}{2}})$ for all the widths of outlet tried.
(4) hm against H_o for varying B.

The values of C are plotted against the ratio Y/H for all the widths tried, in Fig. 8.

The analysis shows that:

(1) The scatter is of the order of $\pm 7.5\%$ on the mean line. This scatter is due to an absolute control of relative roughness, ϵ/H, or, to some extent, changes in the Reynold number.
(2) The mean lines were worked out passing through the scattered points by the method of least squares. Two straight lines are then obtained and the equations are fitted. For values of Y/H less than 0.17, the straight line equation is:

$$C = 7.04 + 2.4\ (Y/H)$$

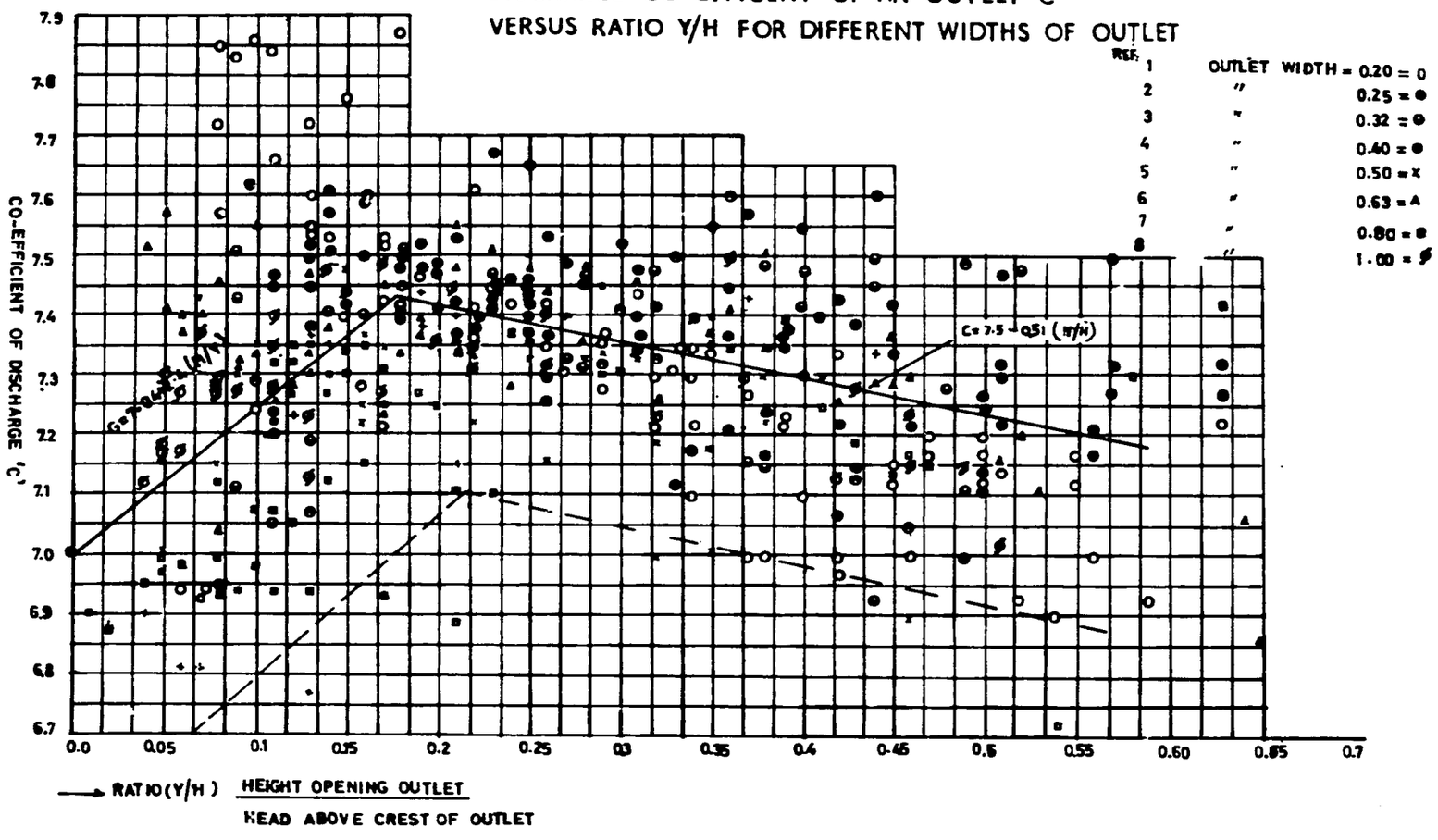

STUDIES IN DESIGN OF OUTLET
DISCHARGE CO-EFFICENT OF AN OUTLET "C"
VERSUS RATIO Y/H FOR DIFFERENT WIDTHS OF OUTLET
REF.
1 OUTLET WIDTH = 0.20 = 0
2 " 0.25 = ●
3 " 0.32 = ⊕
4 " 0.40 = ●
5 " 0.50 = x
6 " 0.63 = A
7 " 0.80 = ■
8 " 1.00 = ∅
C = 7.5 - 0.51 (Y/H)
CO-EFFICIENT OF DISCHARGE 'C'
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
0.0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.60
0.65
0.7
RATIO (Y/H) HEIGHT OPENING OUTLET / HEAD ABOVE CREST OF OUTLET

FIG. 8

For values of Y/H greater than 0.17, the equation is

$$C = 7.5 - 0.51\ (Y/H).$$

An attempt was made to determine the variation in the value of C for different ratios of Y/B. A plot was made in Fig. 9. The following points were noted:

(1) There is quite a scatter of points.

(2) The mean line in this case was worked out by the method of least squares passing through these points. For values of Y/B less than 0.66, mean line equation is:

$$C = 6.50 + 1.64\ (Y/B)$$

For values of Y/B greater than 0.66, the equation is:

$$C = 7.58 - 0.10\ (Y/B)$$

Relationship Between H and K in the Standard Formula

$$K = Q/B(H^{\frac{3}{2}} - H_o^{\frac{3}{2}})$$

The study of the curves between H and K does not show as much scatter as in case of coefficient C. A statement showing the value of K for different values of B is given in Table 4.

TABLE 4

Statement Showing Values of K for Different Values of B

B	Limits of Y	Values of K	
		Higher limits	Lower limits
0.20	.183-1.103	3.50	5.00
0.25	.183-1.126	3.55	4.90
0.32	.200-1.016	3.55	4.90
0.40	.153-0.804	4.65	4.75
0.50	.207-0.872	3.90	4.80
0.63	.107-0.563	3.80	4.90
0.80	.102-0.557	3.70	4.70
1.00	.104-0.506	3.70	4.80

Relationship Between Y/H and K

The curve between K and Y/H (Fig. 10) indicates that there is a linear trend. For $Y/H > 0.1$, a straight line equation is worked out as:

$$K = 5.04 - 2.05\ (Y/H).$$

Relationship Between Minimum Modular Head (hm) and H_o

Further analysis of the results was made to obtain a single expression for hm and H_o. The values of coefficient α and constant β in the formula

$$hm = \alpha H_o + \beta$$

were obtained for different values of B from 0.20 ft. to 1.0 ft.

These are given in Table 5. The examination of the table shows that the width of outlet B has practically no influence on the relationship between hm and H_o. An attempt was then made to determine an equation covering all the widths from 0.20 to 1.0 ft. investigated. The equation obtained is:

$$hm = 0.73\ H_o - 0.2319$$

For all practical purposes, it is recommended that the equation:

$$hm = 0.75\ H_o - 0.20$$

may be used.

Summary and Conclusions of Experimental Investigations

(1) The coefficient of discharge, C is equal to 7.3, is not constant for the same width of the oultet, but is dependent on the boundary geometry and flow characteristics. The following equations were worked out for evaluating the value of C for variables defining the boundary geometry:

(i) $C = 7.04 + 2.4\ (Y/H)$, for ratio < 0.17

(ii) $C = 7.5 - 0.51\ (Y/H)$, for ratio > 0.17

(iii) $C = 6.50 + 1.64\ (Y/B)$, for ratio < 0.66

(iv) $C = 7.58 - 0.1\ (Y/B)$, for ratio > 0.66

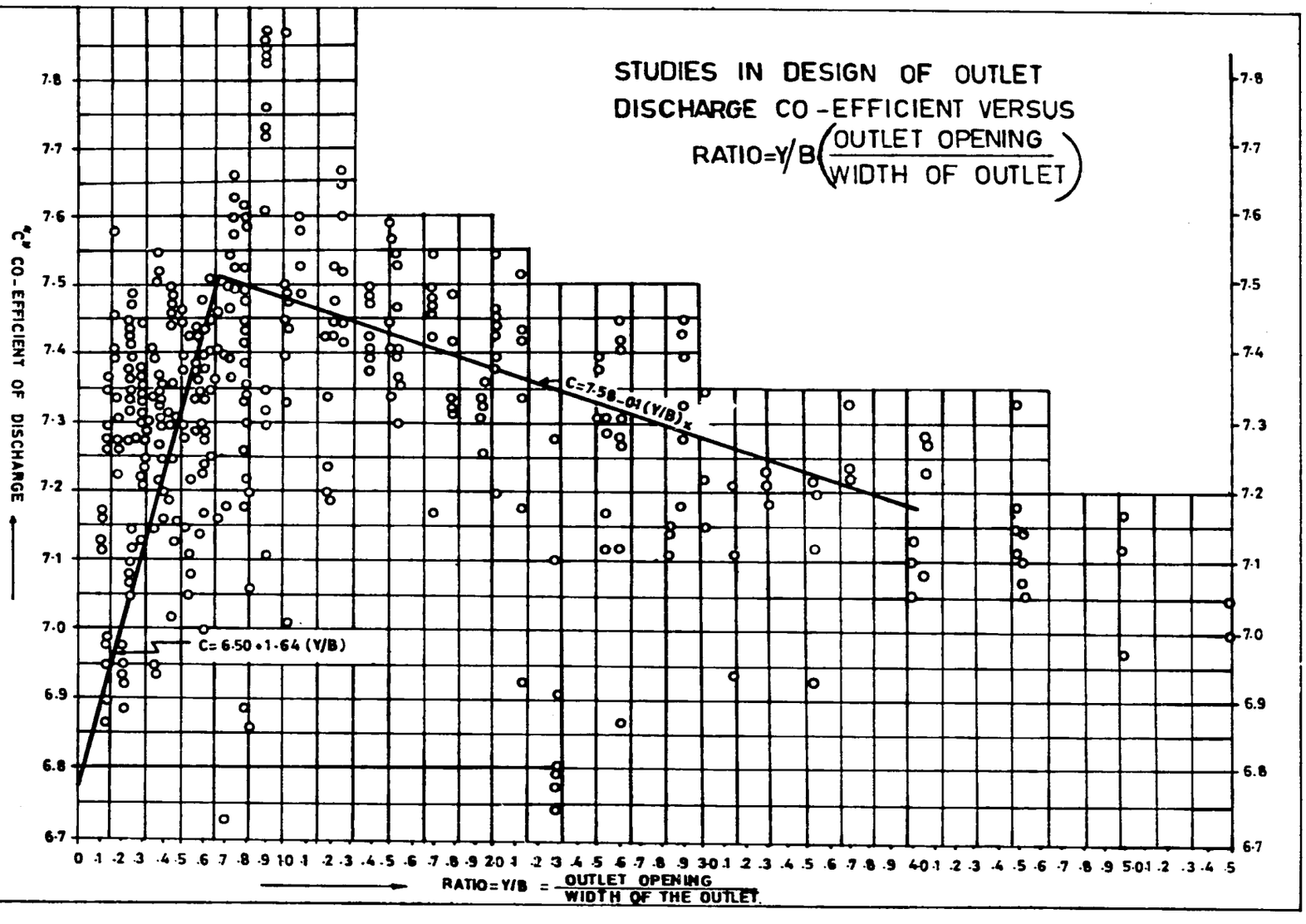

STUDIES IN DESIGN OF OUTLET
DISCHARGE CO-EFFICIENT VERSUS
RATIO=Y/B (OUTLET OPENING / WIDTH OF OUTLET)
"C" CO-EFFICIENT OF DISCHARGE
C=6.50+1.64 (Y/B)
C=7.58-.03 (Y/B)
RATIO=Y/B = OUTLET OPENING / WIDTH OF THE OUTLET

FIG. 9

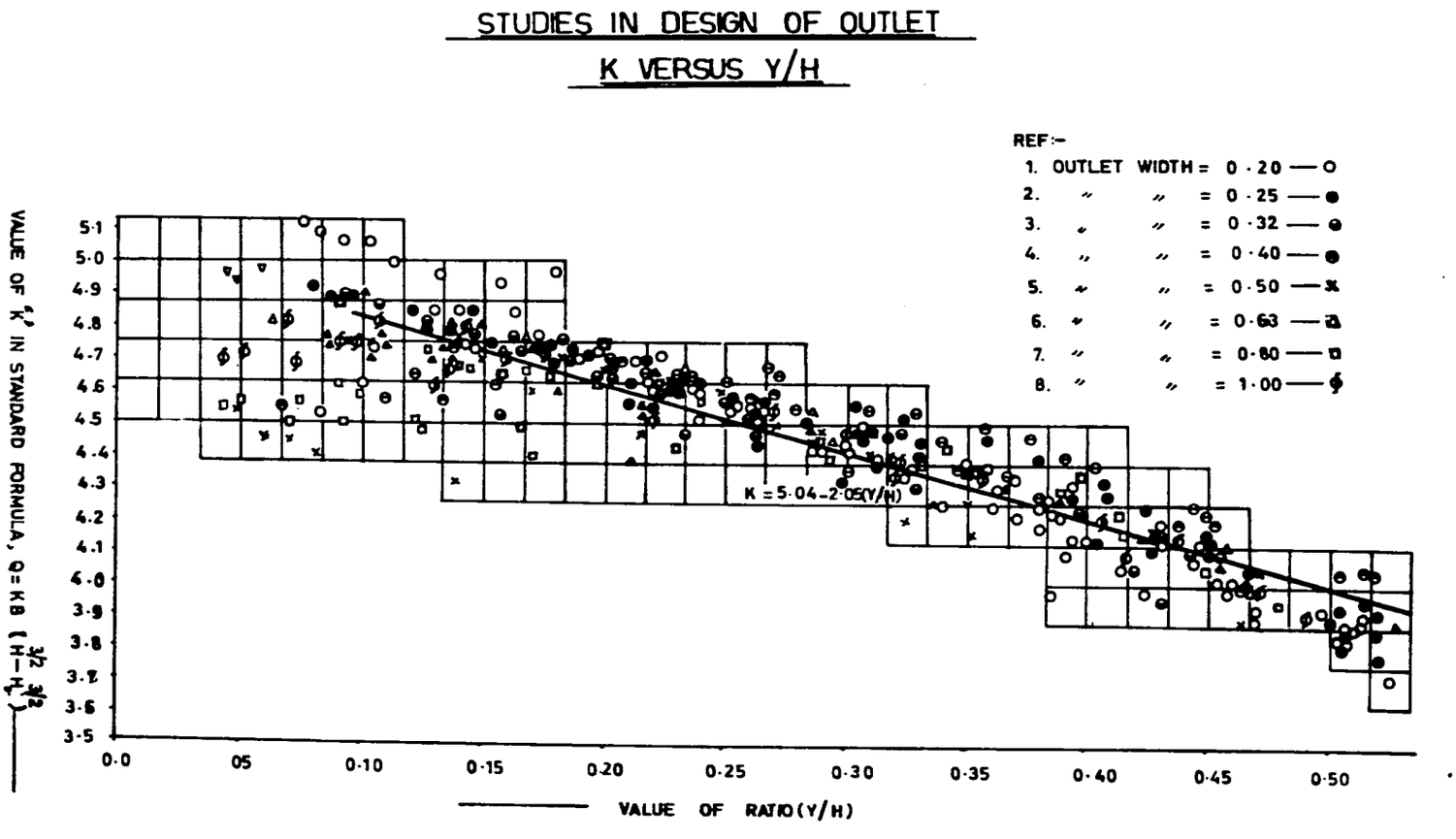

STUDIES IN DESIGN OF OUTLET
K VERSUS Y/H
REF:-
1. OUTLET WIDTH = 0·20
2. " " = 0·25
3. " " = 0·32
4. " " = 0·40
5. " " = 0·50
6. " " = 0·63
7. " " = 0·80
8. " " = 1·00
K = 5·04 - 2·05(Y/H)
VALUE OF 'K' IN STANDARD FORMULA, Q = KB (H - H₁)^3/2
VALUE OF RATIO (Y/H)
5·1
5·0
4·9
4·8
4·7
4·6
4·5
4·4
4·3
4·2
4·1
4·0
3·9
3·8
3·7
3·6
3·5
0·0
05
0·10
0·15
0·20
0·25
0·30
0·35
0·40
0·45
0·50

FIG:- 10.

(2) The following relation was found for the values of K in the formula

$$K = Q/B\,(H^{\frac{3}{2}} - H_o^{\frac{3}{2}}), \text{ for } Y/H > 0.1$$

$$K = 5.04 - 2.05\,(Y/H)$$

(3) It has been found that the evaluation of Q can more accurately be determined by using the coefficient K in the formula

$$Q = KB\,(H^{\frac{3}{2}} - H_o^{\frac{3}{2}})$$

than by using C in the formula.

$$Q = CBY\sqrt{H_o}$$

(4) The present investigation helped to derive an equation relating hm and H_o for all widths of APMs from Bt=0.2 ft. to 1.0 ft. The equation is:

$$hm = 0.73\,H_o - 0.23$$

For all practical purposes the equation,

$$hm = 0.75\,H_o - 0.20$$

is recommended for use.

TABLE 5

Formula Relating hm and H_o for Different Values of B

S. No.	Width	Formula		Correlation
1.	B= .20 ft.	hm=0.7441	H_o=0.1991	0.9896
2.	B= .25 ft.	hm=0.7944	H_o=0.7944	0.9877
3.	B= .32 ft.	hm=0.7340	H_o=0.2129	0.9877
4.	B= .40 ft.	hm=0.6937	H_o=0.2105	0.9755
5.	B= .50 ft.	hm=0.7718	H_o=0.3435	0.9769
6.	B= .63 ft.	hm=0.7070	H_o=0.2305	0.9726
7.	B= .80 ft.	hm=0.7148	H_o=0.2359	0.9780
8.	B=1.00 ft.	hm=0.7657	H_o=0.2818	0.9815

Note : The correlation obtained in each case is very high.

Chapter X

STANDARDS FOR IRRIGATION AND DRAINAGE INVESTIGATIONS

DESIGN STANDARDS FOR IRRIGATION SYSTEMS

by

Ghulam Dastigar Sham and Redvanullah Shinwari*

Preamble

The gap between an ever-increasing world population and the demand for food production is today a phenomenon that throws its shadow on all phases of agricultural activities all over the world. This is why with today's technology and science we seek means, methods and ways to increase our agricultural output. Considerable progress has been made in all phases of agricultural development throughout the world. Engineers have mastered design of storage reservoirs, conveyance systems and irrigation networks, while other disciplines have considered problems of farming techniques, seed selection, pest and disease control, fertilizers and other measures to increase production.

Among the inputs mentioned above, irrigation has the primary role in increase of yield, especially in the arid and semi-arid regions. It is realized that even though application of water to land for production purposes is an old art, still many irrigation problems in today's agriculture remain unsolved.

The scope of this paper is to show how we have put theory into practice through reasonable approximations to fit conditions of climate, soils, water usage and social circumstances, to provide a basis for irrigation development plans.

Irrigation systems of various sizes skillfully developed many centuries ago still exist in

* Respectively Director-General, Irrigation Department, and Director of Irrigation Rehabilitation, Ministry of Agriculture and Irrigation, Royal Government of Afghanistan.

Afghanistan. Most of these schemes are only parts of river basin developments. Independent canal systems have been built along the rivers to serve particular areas, without much consideration about what problems this might cause either upstream or downstream. The engineering and construction of these systems may have been the best at the time, but the structures and distribution systems do not meet standards of required efficiency now. In the present situation, we are facing problems of this type and many more regarding water distribution, water rights, priorities, etc. that require immediate attention for better use of our land and water resources.

The principal function of the designer is to produce a system of any dimension which will adequately and safely function as intended. If the quality of all raw construction materials and manufactured construction components were the same throughout the world, the designer would be deprived of the use of his good judgment and experience and knowledge of local materials. We all know that construction materials vary greatly in different localities. Thus, the designer must have the good judgment, experience and knowledge of the local materials in order to properly design the required works.

In order for the designer to produce proper designs he must have accurate and adequate design data from the field. Many times it is advisable for the designer to inspect the site of the structure to gain firsthand visual information of the conditions at the site. The design data furnished him should not be lacking in any detail. The field engineer should be knowledgeable enough to note all details, even the smallest, and include them in his submission of design data. Here the most valuable information on the local construction materials would be the type of sand and gravel, the location of the pits, and the amounts of materials available. These factors will, in the judgment of the designer, determine to a great extent the design of the concrete. If the sand and gravel are of poor quality, this will definitely affect the strength of the concrete, and other factors will have to be considered. The quality of the reinforcing steel must also be considered. If a certain concrete strength is desired in the structure, poor quality sand and gravel may dictate the use of additional steel. In this case and in all others we must depend on the designer's best judgment.

Modern construction equipment is in many instances entirely lacking and may influence the designer's judgment. Hand mixing of concrete without accurate measurements of the ingredients must certainly come to the mind of the designer. Thus, the designer must compensate for the lack of quality control. Good construction supervision is synonymous with quality control, and the designer must be cognizant of this fact in his design.

In Afghanistan, we are upgrading our quality of designs through training by foreign design engineers. Standards are being adapted to local conditions. Construction practices are being improved through better construction supervision. Quality control is being stressed in construction.

In particular, this paper covers the process by which the design criteria for the Koja Canal project were selected.

Koja Canal Project

The Koja canal, which is located in north central Afghanistan, serves an area of about 4,000 hectares of irrigable land situated at an elevation of 1552 meters. The canal is about 42 km. long. It diverts water from the Panjshir river and skirts the base of the hills above the service area. All service is by gravity.

Temperature: Mean annual temperature fluctuates between 9.4° C. and 15.9° C. The hottest month of the year is July and the coldest is January. The number of days with a maximum temperature above 30° C. recorded by the Jabal-Saraj meteostation is 72, and the number of days with a minimum temperature below 0°C. is 50.

Precipitation: mainly occurs as rainfall. Snow falling in the winter period never forms lasting snow cover, either in this area or in other areas of the same elevation in Afghanistan. The mean annual precipitation recorded is 521 mm.

Air Humidity: The air humidity is low and drops sharply during the summer months. For five months (June-October) it is below 30 per cent. It sometimes reaches 5-8 per cent.

Winds: The maximum wind velocity in summer and autumn is recorded as 30 m./sec. but averages about 6 m./sec.

Cropping Pattern

The demand for food production, cash crops for foreign exchange and crops for domestic industries, combined with indigenous climate, are factors that should determine cropping patterns of all modern irrigation systems. On the other hand, farmers' cultural practices, know-how, habits and needs also play important roles in setting any specific cropping pattern. Many attempts are made to legislate cropping patterns. These attempts are usually unsuccessful. In developing countries, crop prices are another problem because these fluctuate according to international markets and local needs. The cropping pattern for this project was selected on the basis of the existing cropping pattern that has survived these vicissitudes, not on any arbitrary, unproven assumption. (It is expected that cropping patterns will evolve during the life of the project.)

A series of interviews was conducted within the project area. These interviews indicate that the following cropping pattern is typical.

TABLE I

Cropping Pattern

CROP	AREA	PERCENTAGE
Wheat	7	35
Corn	2	10
Small vegetables	3	15
Tree culture	5	25
Legumes	3	15

Soils

Some 29 auger holes were made in the project area and the samples were tested in the laboratory. The results of the laboratory analysis are tabulated in Table 2.

The samples represent a depth from 0-30 cm. The table shows that pH values range from 7.9 to 8.4, which is rather typical for arid regions and is not a problem. Nitrogen and organic matter content of the soil are very low but can be remedied by green manuring and other cultural practices. Other essential elements, especially phosphorus and potassium amounts, are low. Artificial fertilizer could be added to compensate for these deficiencies. A study of the physical properties showed that: (a) land had natural drainage; (b) topography could be solved by some leveling; (c) soil in the project area is medium textured.

Broadly speaking, this type of soil permits water to reach the root zone easily. The air circulation through pore spaces of such soils allows the bacterial and soil inhabitant life to function properly.

Water Resource

Koja canal water comes from the Panjshir river. The intake is near Gulbahar and the gauging station is located some 215 meters upstream. The drainage area is about 4,000 square km. A study of the river hydrology indicates that in six years of record the maximum was 584 $m.^3/sec.$ (July 10, 1960) and the minimum was 6.7 $m.^3/sec.$ (January 21, 1960). The river rises in the Hindu Kush mountains about 400 km. above the gauging station and is sustained by snow melt. The high discharge occurs when the snow melt starts, and lasts from late May until the end of August. This is the time when irrigation requirements are largest. The low flow occurs in the winter months, usually November, December and January, and in these months the irrigation requirement is least. The foregoing discussion reveals that the river regime is favorable for crop water supply. Precipitation occurs in the winter months when river discharge is low. This supplies moisture for winter crops.

Consumptive Use

The determination of consumptive use is a key factor in designing irrigation systems, especially bringing new land under irrigation. A proper division of stream or river water among the users is not possible without a knowledge of

TABLE 2
Soil Samples from Kohistan

No.	Depth (cm.)	pH	N	Organic matter	P_2O_5	K	Sand	Silt	Clay
			(Percentages)						
1	1 (0-20)	8.3	0.046	0.533	0.0044	Traces	44.71	18.25	24.25
2	3 (0-18)	8.3	0.044	0.565	0.0098	"	48.0	32.75	19.25
3	4 (0-22)	8.2	0.070	0.479	0.0050	"	42.25	33.50	23.50
4	5 (0-20)	8.2	0.042	0.452	0.0033	"	27.50	49.00	21.50
5	6 (0-21)	8.1	0.042	0.239	0.0040	"	36.22	41.5	21.50
6	7 (0-22)	8.0	0.044	0.387	0.0060	"	39.75	27.75	32.0
7	8 (0-20)	8.0	0.046	0.485	0.0074	"	37.75	30.75	28.75
8	9 (0-21)	7.9	0.044	0.614	0.0064	"	39.25	30.75	28.50
9	10 (0-23)	8.0	0.042	0.452	0.0132	"	46.75	25.0	26.5
10	11 (0-24)	8.1	0.078	0.670	0.0050	"	46.50	27.5	25.0
11	12 (0-23)	7.9	0.042	0.462	0.0038	"	50.50	16.50	31.0
12	13 (0-22)	8.0	0.002	0.489	0.0058	"	49.25	22.0	27.75
13	14 (0-24)	8.3	0.044	0.607	0.0038	"	36.75	34.0	29.0
14	15 (0-20)	8.1	0.082	0.495	0.0064	"	48.24	25.75	24.75
15	16 (0-25)	8.2	0.075	0.620	0.0058	"	36.00	27.75	36.75
16	17 (0-23)	8.0	0.004	0.973	0.0020	"	34.00	37.00	27.5
17	18 (0-24)	8.1	0.062	0.622	0.0028	"	32.7[illegible]	37.25	28.5
18	18A (24-35)	8.3	0.042	0.550	0.0033	"	42.[illegible]	35.50	19.50
19	19 (0-24)	8.3	0.044	0.416	0.0050	"	44.75	35.00	19.50
20	20 (0-25)	8.3	0.044	0.751	0.0040	"	32.75	32.25	22.25
21	21 (0-30)	8.3	0.044	0.447	0.0040	"	—	—	—
22	22 (0-28)	8.2	0.072	0.447	0.0032	"	32.25	40.05	26.0
23	23 (0-26)	8.3	0.070	0.510	0.0040	"	40.75	30.0	27.55
24	24 (0-22)	8.3	0.042	0.350	0.0033	"	42.75	30.75	22.75
25	25 (0-26)	8.3	0.042	0.894	0.0032	"	48.5	27.5	22.75
26	26 (0-23)	8.2	0.040	0.271	0.0044	"	43.25	32.25	22.25
27	27 (0-21)	8.2	0.070	0.510	0.0028	"	37.0	39.25	22.25
28	28 (0-24)	8.2	0.042	0.570	0.0048	"	37.50	41.50	19.50
29	29 (0-25)	8.4	0.072	—	0.0075	"	—	—	—

how much water a certain piece of land will need. Consumptive use computation is a good index of how to solve these rather delicate problems. Different methods are involved to evaluate the water amount consumed through agricultural crops or directly evaporated from the soil surface. The Blaney-Criddle method, using temperature and daylight hours, has been adopted partly because of its simplicity and partly because of the available data. The application of this method is possible even in countries with scarce scientific information in hand. It says:

$$U = KF$$

where:

U = monthly consumptive use in inches

K = empirical coefficient

F = monthly consumptive use factor

$$\frac{t \times p}{100}$$

t = mean monthly temperature in °F.

p = monthly percentage of daylight hours in the year

Table 3 shows the consumptive use computation at Kohistan for wheat, the principal crop.

The monthly coefficients (K) used in the formula vary from crop to crop and with the length of the growing season, and are usually developed by measurement of consumptive use. There is no actual data available in Afghanistan which could be used to determine the monthly coefficients, and it was necessary to use figures that in our judgment appeared reasonable. For example, Criddle has determined that for small grains with a three-month growing season, the maximum monthly coefficient could be as high as 1.00. In this case the growing season is somewhat longer and it was felt that a maximum of .85 would not be excessive.

TABLE 3
Consumptive Use for Wheat in Kohistan

Month	Mean monthly temperature°F (t)	Percentage of daylight hours (p)	$\frac{t \times p}{100}$	Cons. use coeff. (K)	Monthly cons. use (inches)
March	46.2	8.38	3.87	0.30	1.16
April	51.1	8.80	4.76	0.60	2.86
May	66.0	9.72	6.41	0.85	5.44
June	76.8	9.70	7.45	0.85	6.33*
July	80.2	9.88	7.75	0.75	2.90

*Average daily consumptive use for June =0.21 inches.

Water Requirement

Consumptive use computed in the preceding paragraph is the requirement for plant needs only. To bring this amount of water to the field in a conveyance system, other losses must be measured, *i.e.* irrigation efficiency, salt balance and conveyance efficiency. Irrigation efficiency varies with the method of applying water to land: sprinkler, flooding, furrowing, etc. In our case we have accepted the existing method of flooding. Through observation we have arrived at the conclusion that this method is about 60 per cent efficient in Kohistan project.

Conveyance efficiency under similar conditions in other localities was determined to be about 70 per cent, and this factor was applied here. Canal capacity was calculated, using the observed 70 per cent conveyance (see typical observation, Figure 1) and 60 per cent irrigation efficiencies. The average daily consumptive use during the maximum month, June, being 0.21 inches or 0.53 cm., the water requirement at diversion should be

$$\frac{0.53}{0.7 \times 0.6} = 1.20 \text{ cm./day}$$

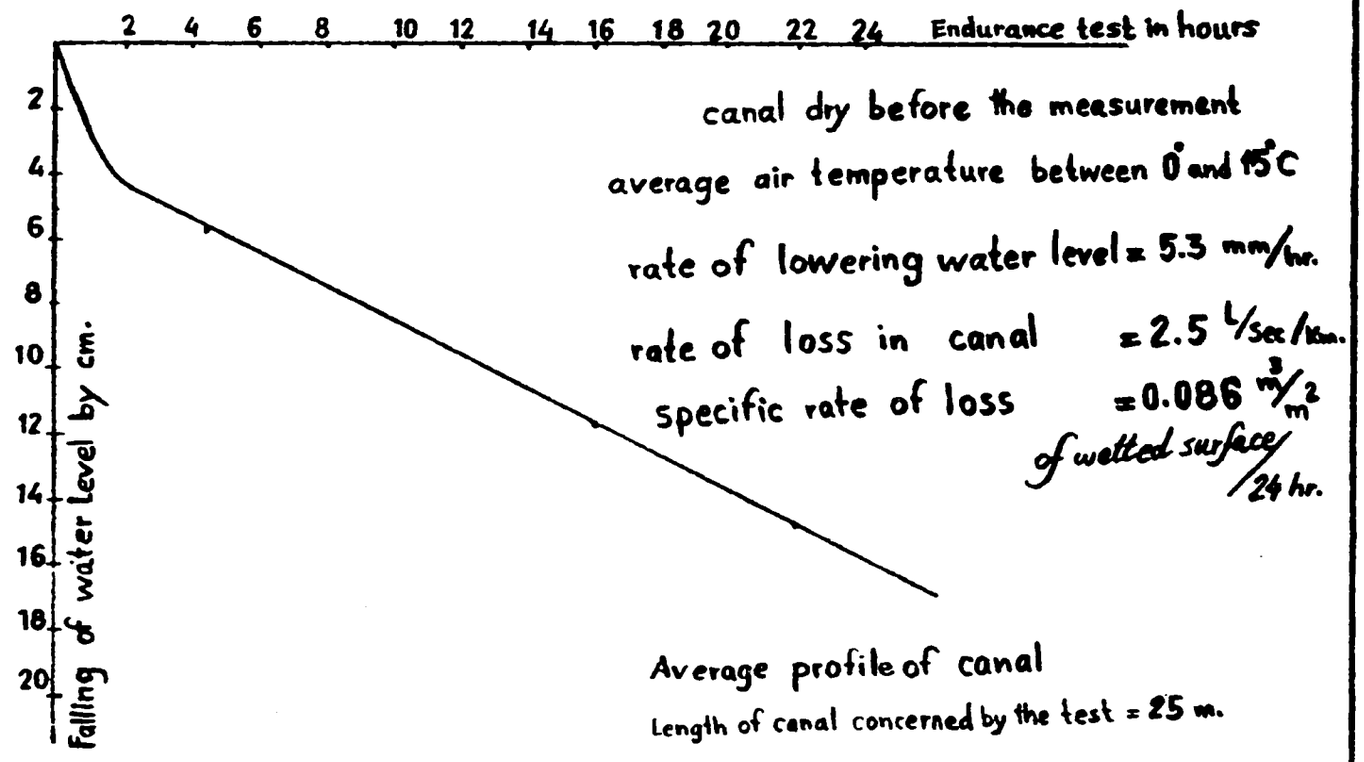
or

$$\frac{10{,}000 \times 0.0120 \times 1{,}000}{86{,}400} = 1.4 \text{ lit./sec./ha.}$$

The Kohistan project contains 4,000 gross hectares, of which it was assumed 3,600 hectares would be irrigable. The diversion requirement would therefore be 3,600 ha. × 1.4 lit./sec./ha. or 5,040 lit./sec. or 5.04 m.^{3}/sec. The above diversion amount is based on monthly consumptive use demands. In order to provide for peak demand during the month, this diversion amount of 5.04 m.^{3}/sec. was increased by 20 per cent, resulting in a total diversion of 6.0 m.^{3}/sec.

Fig (1)

Loss by infiltration test in canal at Baghi-Miri



canal dry before the measurement

average air temperature between 0° and 15°C

rate of lowering water level = 5.3 mm/hr.

rate of loss in canal = 2.5 L/sec/km.

specific rate of loss = 0.086 m^3/m^2 of wetted surface/24 hr.

Average profile of canal

Length of canal concerned by the test = 25 m.

PREPARATION OF IRRIGATION GUIDES IN TURKEY

by
Ragip Boyaci*

I. Introduction

Present estimates indicate that about 16.7 million hectares out of a total of 23.5 million hectares of cultivated land could be irrigated in Turkey. Soil classification studies indicate that the irrigable land amounts to about 12.6 million hectares. It is also estimated that the potential water resources will supply adequate irrigation water to about 8.5 million hectares.

The total irrigated area in 1967 was about 1.5 million hectares, or approximately 6.6 per cent of the cultivated land. In the Second Five Year Plan period (1968-1972) new irrigation systems will supply a potential area of 540,800 hectares. The systems constructed will actually irrigate an area of about 392,000 hectares. This means that 8.2 per cent of the total cultivated land will be irrigated. During the Second Five Year Plan about $ 900 million will be invested in the development and construction of irrigation systems. This investment will amount to 53 per cent of the total agricultural investment in the plan.

Surveys conducted in 18 large operating irrigation systems indicate that only 49.4 per cent of the project area is actually irrigated. On about 73 per cent of this area wild flooding is practiced. Irrigation efficiencies are low due to such problems as inadequate design and construction, incomplete irrigation facilities, improper irrigation practices and small land ownerships.

Measures will have to be taken to increase irrigation efficiencies. This includes: (a) improved planning of new irrigation projects; (b) rehabilitation of the existing systems; (c) training of farmers. Implementation of these measures requires irrigation guides.

Irrigation guides were required in the design of Yuregir and Tarsus plains irrigation and drainage system by TAMS in 1957. This resulted in the preparation of the first irrigation guide by Tarsus Irrigation Research Institute.

* Director of Research Division, General Directorate of TOPRAKSU.

Criteria for preparation of the first irrigation guide were taken from USDA-SCS publication "Instructions and Criteria for Preparation of Irrigation Guides". Some tables and graphs in this handbook were converted to the metric system and included in the guide. We will not include all tables and graphs of the mentioned handbook in this paper.

The handbook, entitled "Adana-Yuregir and Icol-Tarsus Plains Irrigation Guide", is representative of 200,000 hectares. It includes all the tables and graphs that are essential for a complete guide. This can be used as an example for preparation of other irrigation guides.

The second irrigation guide was prepared by Eskisehir TOPRAKSU Research Institute and is representative of 6,000 hectares. This was published in 1962 and is entitled "Eskisehir-Alpu Plain Irrigation Guide".

A third guide was prepared and published in 1965 by Menemen Irrigation Research Institute and is representative of 90,000 hectares. This is entitled "Gediz Watershed, Manisa-Salihli, Menemen Plains Irrigation Guide". The institute has prepared another guide published in 1968 covering other watersheds, "Bakircay-Gediz-Kucuk Menderes-Buyuk Menderes Watersheds Irrigation Guide".

Surveys, tests and experiments are being continued in order to prepare irrigation guides for other watersheds or plains.

II. Required Information and Criteria for the Preparation of Irrigation Guides

(A) Area of Coverage

Irrigation guides should cover large plains or watersheds with similar climatic characteristics. The boundaries of the area of coverage should be delineated and the name of the guide decided.

(B) Soils

Soil survey and classification and soil mapping for the area should have been completed. All other related data is examined. An initial soil grouping is made in relation to the top soil and subsoil textures and standard symbols for irrigable soils. This is based on the irrigation land use and land use capability classifications. Infiltration curves and basic intake rate values obtained from double-ring or Bull-recording infiltrometers on soil classes, series and types in these groups should be available. Physical analysis of these soils should be made in the laboratories. Also, the available moisture holding capacities of soils for each 30 cm. increment of depth should be determined. This data should be reviewed in relation to earlier groupings. If necessary, new groupings can be made by considering available water holding capacities, intake rates and profile characteristics. Each soil group requires a different irrigation guide. Therefore, it is preferable to limit the number of groups as much as possible.

Briefly, four characteristics of the soil are considered for groupings: soil class, textural and profile characteristics, available moisture holding capacities and basic intake rates.

Some basic intake rate values from the Tarsus and Eskisehir irrigation guides are given in Table 1.

For 200,000 hectares of Tarsus and Adana plain, first class soils were divided into 5 groups, second class into 8 groups and third class into 7 groups. For 100,000 hectares of the Gediz watershed, first class soils were divided into 2 groups, second class into 4 groups and third class into 4 groups. The irrigation land classification considers classes 4,5 and 6 as non-irrigable. These classes are not included in the irrigation guides.

(C) Slope Group Separations

Slope grouping should be made to fit local conditions. In areas of irrigation guide surveys, the maximum land slope for surface irrigation was two per cent. Three slope groupings were made :

Slope Group	Values Used in Computing Guide
0.0 - 0.5 %	0.25 %
0.5 - 1.0 %	0.75 %
1.0 - 2.0 %	1.50 %

Irrigation recommendations were made in relation to the values used in computing the guide.

TABLE I

Some Results of Intake Rate Tests by Double Ring Infiltrometer

Location	Soil Texture	Basic Intake Rate (mm/hours)
Eskisehir-1966	Clay	28
"	Sandy loam	55
"	Clay	10
"	Clay loam	40
"	Clay	6
"	Clay loam	44
Eskisehir-1965	Clay	3
"	Clay loam	35
"	Clay	10
"	Silty loam	60
"	Loamy clay	4
"	Clay	6
Eskisehir-1964	Sandy loam	110
"	Clay loam	14
"	Sandy clay	54
"	Clay loam	22
"	Sandy loam	88
Tarsus-1958	Clay loam	7
"	Clay	4
"	Silty clay loam	8
"	Silty clay	6
"	Clay loam	8
"	Silty loam	15
"	Sandy loam	40

(D) CROPS

Major irrigated crops grown or that can be grown should be considered. These crops are grouped in relation to their effective root zone depths, water requirements and growth characteristics. Average effective root zone depths are determined for these groups. Root zone depths and densities for several crops grown on Eskisehir plain are given in Table 2.

(E) CONSUMPTIVE USE OF CROPS

Irrigation research institutes and stations are conducting field experiments, tests and lysimeter studies to determine the consumptive use of major crops in their regions. Most of these studies employ the moisture depletion method. The Blaney-Criddle method is used to estimate the CU values for some other crops. From these sources, the normal growing period, the total seasonal net irrigation requirement, annual consumptive use, monthly peak consumptive use and daily CU requirement for the peak month for each crop are estimated. Tables 3 and 4 present related information for Eskisehir and Adana plains respectively.

(F) IRRIGATION METHODS AND CROP IRRIGATION CHARACTERISTICS

Irrigation methods already practiced or recommended are evaluated. The following data should be available from tests and surveys : (1) the level at which the available soil moisture will need to be replaced; (2) furrow spacing; (3) border or check widths; (4) maximum size of streams; (5) maximum length of run; (6) furrow basic intake rates in lit./sec./100 m.; (7) water application efficiencies.

We do not feel that a detailed explanation of the listed items is necessary. Tables 5 and 6 give samples for Eskisehir and Menemen regions.

III. Explanation of Irrigation Guide Tables

The three irrigation guides present data in 16 columns for three slope groups. Four samples selected for different soil groups are given in Appendices 1, 2, 3 and 4.

TABLE 2

Root Zone Depths and Densities for Various Crops on the Eskisehir Plain

CROP	DEPTH (cm.)	DENSITY (%)	CROP	DEPTH (cm.)	DENSITY (%)
Beans	0-30	44	Sunflower	0-30	67
	30-60	43		30-60	18
	60-90	13		60-90	6
				90-120	8
Potatoes	0-30	32	Sugar beet	0-30	25
	30-60	35		30-60	35
	60-90	23		60-90	19
				90-150	21
Corn	0-30	39	Tomatoes	0-30	18
	30-60	36		30-60	26
	60-90	25		60-90	27
				90-150	29
Onions	0-30	63	Sorghum	0-30	42
	30-60	22		30-60	50
	60-90	15		60-90	8
Wheat	0-30	48	Senfoin	0-30	50
	30-60	23		30-60	22
	60-90	22		60-90	13
	90-120	6		90-150	15
Barley	0-30	55	Grass (lolium perenne)	0-30	48
	30-60	15		30-60	35
	60-90	22		60-90	13
	90-120	7		90-150	4

Following is a brief explanation of these columns:

Column 1. *Site Index* describes the soil class in relation to irrigation land use classification.

Column 2. *Profile Description.* Profile characteristics and mapping units of soil groups are indicated with standard symbols. Topsoil and subsoil textures, type of parent material, soil depths and salinity status are presented.

Column 3. *Available Moisture Holding Capacity* of the soil (wilting point to field capacity) should be shown in millimeters for each 30 cm. increment of depth. Soils can be grouped if their available moisture holding capacities in the top 30 cm. do not differ by more than 6.0 mm.

Column 4. *Locally Adapted Crops* include the major irrigated crops that are adapted or recommended for the soil and slope conditions. Crops not extensively grown and those that are not economical are not listed. All fruits with

TABLE 3

Consumptive Use Values Determined by Moisture Depletion Method

Locations	Crops	Growing season (days)	Seasonal consumptive use (mm)	Seasonal K for Blaney-Criddle
Eskisehir (1966)	Tomatoes	161	520	0.75
"	Corn	105	610	1.00
"	Onions	137	540	0.70
"	Sunflower	152	685	0.85
"	Sugar beet	185	730	1.00
"	Wheat	285	530	0.80
"	Alfalfa	220	1270	1.30
"	Beans	132	630	0.85
Eskisehir (1965)	Sugar beet	183	800	0.90
"	Potatoes	130	425	0.80
"	Alfalfa	225	1080	1.10
"	Beans	122	610	0.95
Eskisehir (1964)	Barley	270	510	—
"	Wheat	285	610	—
"	Sugar beet	162	535	—

the exception of citrus, and all vegetables except tomatoes and potatoes, are discussed as a group of fruits and a group of vegetables, respectively.

Column 5. Effective Root Zone Depth. Average effective root zone depths of crops are given in centimeters. These are the depths from which soil moisture is extracted by the crops and replenished by irrigation.

Column 6. Net Moisture to be Replaced Each Irrigation. Water in millimeters required to bring the root zone depth of soil to field capacity is given in this column. The level of available moisture to be maintained in order to get the maximum economic yields should be determined. In these guides, 50 per cent depletion of available moisture in the root zone depth is used as an index for irrigation. In cases where irrigation water supply is deficient, this level may be as low as 30-40 per cent of the available moisture. Values given are calculated from the information listed in columns 3 and 5.

The net moisture to be replaced is estimated by taking one-half of the available moisture capacity of the root zone, or by taking the upper one-fourth of root zone and multiplying by two.

Column 7. Peak Period Consumptive Use Rate. Consumptive use values estimated by the field moisture depletion method or the Blaney-Criddle method are given in column 7. Because of the differences in soil characteristics, the values obtained from field experiments and estimations and values given in column 6 are used to get the peak daily design rates in mm./day presented in Table 7.

Column 8. Irrigation Frequency During Period of Maximum Consumptive Use. The value for this column is found by dividing the net moisture to be replaced each irrigation (column 6) by the peak period consumptive use rate (column 7). This is the frequency of irrigation only when consumptive use is at a maximum.

TABLE 4

Peak Water Requirements of Various Crops at Farm Headgate for Adana-Cukurova Plain in July and August

Crops	Monthly peak water requirements(mm.)					Irrigation module (lit./sec./hectare)				
	Furrow	Border	Basin (check)	Flooding	Sprinkler	Furrow	Border	Basin (check)	Flooding	Sprinkler
Alfalfa	—	322	—	—	347	—	1.20	—	—	1.30
Cotton	246	—	—	—	—	0.92	—	—	—	—
Peanuts	232	—	—	—	—	0.87	—	—	—	—
Rice	—	—	352	493	—	—	—	1.31	1.84	—
Sugarcane	292	—	—	—	—	1.10	—	—	—	—
Citrus	217	—	234	—	—	0.81	—	0.87	—	—
Fruit	247	—	—	—	—	0.92	—	1.00	—	—
Vegetables	292	—	314	—	314	1.10	—	1.17	—	—
Grass	—	292	—	409	341	—	1.10	—	1.53	1.27
Flax	—	277	—	388	298	—	1.03	—	1.45	1.11
Clover	—	292	—	409	314	—	1.10	—	1.53	1.17
Legumes	232	—	—	—	—	0.87	1.10	—	1.53	—
Corn	262	—	—	—	—	0.98	—	—	—	—
Cereals	—	232	—	325	250	—	0.87	—	1.21	0.93
Others	247	247	247	247	247	0.92	0.92	0.92	0.92	0.92

Note: Irrigation application efficiencies are 70 % for furrow and border, 65-70 % for basin or check, 50 % for flooding and 60-65 % for sprinkler methods.

Column 9. *Suggested Irrigation Methods.* The conservation irrigation methods generally used in an area are adapted to the slope group, the soils described in column 2 and the crop shown in column 4. These methods are listed in column 9. Methods already used in common practice are considered. In Appendix 4, the border method of irrigation is also included for cotton because farmers have preferred this method for years.

Column 10. *Basic Intake Rate.* Basic intake rate values are important factors in irrigation system design and watershed management practices. These are given in mm./hour for border, check and sprinkler methods. These values are the average result of infiltrometer tests on grouped soils. Basic intake rate values in lit./sec./100 m. for furrows are based on the values in Table 8. Some field tests on soil and slope groups were also made but the data in this table was largely depended on.

Column 11. *Size of Stream.* For furrow irrigation the size of stream is given in lit./sec. flow per furrow. Maximum non-erosive streams for furrows are computed from the following formula :

$$\text{maximum } Q = 0.63/S$$

where Q is in lit./sec. and S is % slope.

Size of stream for check (basin) method in lit./sec. was obtained from field tests and observations.

TABLE 5

Some Results of Irrigation Methods Test

Location	Soil texture	Intake rate (mm/hours)	Crop	Slope (%)	Irrigation method	Suitable Irrigation Specifications			
						Width or spacing	Size of stream (lit./sec.)	Length of run (m.)	Irrigation efficiencies (%)
Eskisehir 1966	Clay loam	40	Sugar beet	1.5	Border	8-9	10	120	90
"	Clay	110	Sunflower	0.1	Furrow	1.4	3.5	60	80
Eskisehir 1965	Clay	3	Sugar beet	2.0	Border	14	4	100	80
"	Clay loam	35	—	0.2	Border	6	12	60	80
"	Sandy clayloam	80	—	0.2	Furrow	1.2	2.5	120	—
Eskisehir 1964	Silty loam	44	—	1.6	Border	8-10	12	50	—
"	Silty loam	25	Grass	1.6	Furrow	0.85	1.0	180	80
"	Clay	30	Sugar beet	1.0	Furrow	0.70	1.5	150	80
Menemen 1962	$\frac{2S\ dt}{LSL}$	36	Cotton	0.5	Border	6-8	24	80	70
"	$\frac{2S}{m.SICL}$	30	Cotton	0.2	Border	10	37	120	70
"	$\frac{3S\ dt}{m.SIL}$	35	Cotton	0.7	Border	8	22	70	70

Size of stream for border irrigation is shown as a unit stream. A unit stream is that stream in lit./sec. required for a strip 1m. wide and 100 m. long. Values given in Table 4, USDA-SCS Eng. Handbook, section 15, part 1, have been modified by field observations.

With unit streams shown in the irrigation guide, the irrigating stream needed for any given border or contour ditch layout, or the dimensional area requirement to fit a given total irrigating stream can be estimated from the formula:

$$Q = q \times \frac{L}{100} \times W$$

where Q is required or available irrigating stream in liters per second; q is required unit stream in liters per second; L is length of run in meters; W is width of border strip or length of contour ditch to be set at one time in meters.

The formula can be transposed to provide direct solutions for L or W.

Stream sizes are not shown for sprinkler irrigation. Water must be applied at rates equal to or less than the basic intake rates given in column 10.

TABLE 6

Some Results of Irrigation Application Efficiency Measurements

Location	Soil texture	Crop	Irrigation	Irrigation application efficiencies (%) $Ea = \frac{Ws}{Wf} \times 100$
Eskisehir	Loamy clay	Sugar beet	Wild flooding	52
"	Clay	Alfalfa	Basin	67
"	Clay loam	Sugar beet	Wild flooding	56
"	Clay	Beans	Furrow	87
"	Clay	Irrigated pasture	Border	77
"	Clay	Sugar beet	Controlled flooding	67
"	Clay	Sugar beet	Controlled flooding	65
"	Clay loam	Sugar beet	Controlled flooding	76
"	Clay loam	Sugar beet	Border	70
Menemen	Silty sandy loam	Cotton	Furrow	75
"	Silty sandy loam	Cotton	Border	72
"	Silty sandy loam	Cotton	Sprinkler	58
"	Silty loam	Cotton	Flooding	35
"	Silty clay loam	Vineyard	Furrow	90
"	Silty clay loam	Cotton	Border	47
"	Sandy loam	Cotton	Basin	50
"	Silty clay loam	Cotton	Border	52
"	Silty loam	Cotton	Controlled flooding	68
Eskisehir	Clay	Beans	Furrow	63
"	Clay	Sugar beet	Furrow	64
"	Clay	Alfalfa	Controlled flooding	67
"	Loam	Sugar beet	Wild flooding	23
"	Loam	Sugar beet	Wild flooding	40
"	Clay. loam	Sugar beet	Wild flooding	62
"	Clay loam	Sugar beet	Wild flooding	54

Column 12. *Border, Basin Widths and Furrow Spacings.* Border strip widths are dependent upon the size of irrigating stream available, cross-slope, soil texture, kind of equipment that will be used and local practices.

For basin (check) widths, soil texture, slope, kind of equipment available and spacing of orchard trees are considered.

Furrow spacing will be determined by the row spacings customarily used for row crops.

Column 13. *Maximum Length of Run.* For border method, maximum lengths of run are estimated by using unit streams, slope and water depths. Data is obtained from tables and charts. These results are modified by actual tests and border sizes customarily used.

TABLE 7

Peak Daily Consumptive Use Rates

Depth of application required (mm)	Computed peak monthly consumptive use rates (mm)										
	100	113	125	138	150	163	175	188	200	213	225
	Peak daily design rates (mm/day)										
25	5.5	6.3	6.8	7.5	8.3	8.8	9.5	10.3	11.0	11.8	12.5
38	5.0	5.8	6.3	7.0	7.5	8.3	8.8	9.5	10.0	10.5	11.3
50	4.5	5.3	5.8	6.5	7.0	7.5	8.0	8.8	9.3	9.8	10.3
63	4.3	4.7	5.5	6.0	6.5	7.0	7.8	8.3	8.8	9.3	9.8
75	4.3	4.7	5.3	5.8	6.3	6.8	7.3	7.8	8.3	8.8	9.3
88	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
100	3.8	4.3	4.7	5.3	5.8	6.3	7.0	7.3	7.8	8.3	8.8
113	3.8	4.3	4.7	5.3	5.8	6.3	6.8	7.0	7.5	8.0	8.5
125	3.8	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.3	7.8	8.3
138	3.5	4.0	4.5	5.0	5.5	5.8	6.3	6.8	7.3	7.8	8.0
150	3.5	4.0	4.5	4.5	5.3	5.8	6.3	6.8	7.0	7.5	7.8

Some field tests were conducted on several slopes and soil groups to determine the maximum length of run for furrow irrigation. Other values were taken from USDA-SCS Eng. Handbook, section 15, part 1.

For basin method, the lengths of runs customarily used by the farmers were used as a basis for the recommended lengths of run in relation to soil texture and slope groups.

The maximum length-of-run data for contour ditch irrigation was taken from the Eng. Handbook, Table 9, by considering the slope group, soil texture and basic intake rates.

Column 14. *Estimated Water Application Efficiencies.* Application efficiencies were estimated by considering the water application efficiency tests, slope, soil texture, crop and irrigation methods used. For slightly saline soils, application efficiencies are reduced by 5 per cent due to leaching water requirements. On medium saline soils this reduction is 15 per cent.

Column 15. *Gross Irrigation Application.* The gross irrigation application is estimated by dividing net moisture to be replaced each irrigation (column 6) by estimated field efficiency (column 14) and multiplying by 100.

Column 16. *Estimated Time Required.* For estimating the time required in the second and third irrigation guides, the following formula by O. W. Israelsen was used :

$$t = \frac{d \times A}{3.6 \times Q}$$

where t is time required to deliver the gross irrigation application in hours; d is gross application in mm.; A is area to be covered in decares; Q is unit stream in lit./sec.

TABLE 8

Basic Intake Rate for Furrows (lit/sec/100 m.)

	Sandy Clay Silty Clay Clay (H)	Sandy Clay Loams Clay Loams Silty Clay Loams (F)	Loams Silty Loams (M)	Sandy Loam (S)	Loamy Sands (L)	Sands (C)
Basic intake rate (mm/hours)	0.5-7.5	6.3-18.8	12.5-37.5	25-75	50-100	75+
Slope %						
0.00-0.25	0.05-0.11	0.07-0.16	0.11-0.25	0.16-0.39	0.25-0.58	0.41+
0.25-0.50	0.04-0.09	0.06-0.13	0.09-0.21	0.14-0.31	0.21-0.48	0.35+
0.50-1.00	0.04-0.08	0.06-0.12	0.08-0.16	0.12-0.29	0.19-0.41	0.31+
1.00-2.00	0.03-0.07	0.04-0.10	0.07-0.12	0.10-0.25	0.16-0.35	0.27+

For the first irrigation guide, time required for border and contour ditch irrigation was estimated by Meyer's slide rule or by the following formula:

$$T = \frac{D}{36 \times q}$$

where T is time required to deliver the gross irrigation application in hours; D is gross application in mm. (column 15); q is unit stream in lit./sec. (column 11).

The Israelsen formula was employed to calculate the time required for basin irrigation.

The estimated time required for furrow irrigation was found by using Meyer's slide rule, considering the size of stream and net depth of water to be applied.

IV. Use of Irrigation Guides

The first irrigation guide was published in 1958. Observations since this time have led us to classify its usage into three groups :

(A) By technicians who design projects for the development of water and soil resources covered by the irrigation guide or places having similar conditions.

Technicians of State Hydraulic Works (DSI), Soil Conservation and Farm Irrigation Works (TOPRAKSU) and private firms have made use of the guide for the following purposes :

(1) Determining the capacities of water delivery and control facilities (main and secondary canals) (columns 7 and 14).

(2) Determining the capacities of water distribution canals (tertiaries and quaternaries), control and measuring facilities of the canals. (columns 7, 13 and 14).

(3) Determining the sizes of farm head gates (columns 7, 11 and 14)

(4) Design and planning of farm irrigation and drainage systems (all columns).

(5) Preparation of land leveling projects (columns 2, 9, 12 and 13).

(B) By technicians who manage irrigation systems, extension staff and irrigation foremen.

(1) Preparation of program for the management and maintenance of the irrigation system and in its use (columns 4, 6, 8, 11 and 16).

(2) Supplies data to Department of Agriculture extension staff who recommend crop and row spacings to farmers (columns 2, 4 and 12).

(3) Supplies data to technicians and irrigation foremen to recommend irrigation practices to farmers (all columns).

(C) By irrigation agriculture farmers.

Use of irrigation guides has been less than expected because our farmers are conservative and scattered and operate relatively small fields. All irrigation farmers could make use of these guides in selecting crops, row spacings, farm equipment and machinery, irrigation water requirement, preparation for irrigation, irrigation frequencies, irrigation practices, etc.

V. Criticisms and Recommendations by Irrigation Guide Users

Technicians who have made use of the irrigation guides have offered the following criticisms and recommendations :

(A) include the soil classification maps with the irrigation guides.

With the exception of the Eskisehir-Alpu plain irrigation guide, the guides do not contain soil classification maps. Without these maps it becomes difficult to locate the soil class or group of the area under study. The soil survey and classification publications being issued for the irrigated areas can be used to assist the guides.

(B) Maximum lengths of run generally inapplicable.

The maximum lengths of run for furrow and borders are usually inapplicable under field conditions. The 300-800 meter lengths of run for heavy textured soils are especially criticized for being too long. Agricultural lands in Turkey have been reduced to relatively small units due to several reasons. To enlarge these units will require land consolidation (the average farm unit is 8.5 hectares, and on the average 7 parcels are owned by one farm family).

(C) Sprinkler irrigation system designs can be prepared from the general data given in the irrigation guides. Other standards related to sprinklers need not be included.

(D) Technicians, especially of the first and second groups, want the following information included in the guides :

(1) Average and maximum irrigation modules (continuous flow lit./sec./ha) for the crops grown.

(2) Monthly and seasonal consumptive use of crops (in mm.)

(3) Number of irrigations for irrigated crops throughout one season.

(4) Initial and final dates for irrigation.

(5) Approximate drainage tile spacing in relation to soil groups.

(6) Yields of crops grown under dry and irrigated conditions to aid the economic analysis of planning and designing.

(7) Stage of plant growth when irrigation is most beneficial.

(8) Most suitable and economical crop rotation patterns for land management.

(9) Fertilizer requirements, application methods and times for the crops grown.

(10) Recommended chemical amendment rates for the alkali soils.

(11) Cropping and related agricultural techniques for growing crops.

VI. Evaluation of Criticisms and Recommendations and Development of Irrigation Guides

The criticisms and recommendations made of the irrigation guides have been considered by the research organization. Further studies were made. Some results were published as special bulletins. Others were given in personal correspondence. Recent bulletins include the growing techniques and production costs of crops.

A more complete irrigation guide has been developed by the Menemen Irrigation Research Institute, following the completion of surveys and studies on the three other large watersheds. This guide includes four watersheds of the highly potential Aegean region. The additions and improvements in this guide are as follows :

(A) Consumptive Use

The values of consumptive use of major crops determined by the moisture depletion method are explained in detail and given in tables. Seeding, harvest, irrigation and vegetation periods of all crops grown, and maximum seasonal and monthly (K) values for the Blaney-Criddle formula were also included (Tables 9 and 10).

(B) Water Application Efficiencies and Farm Losses

This section covers the results of studies made on farmers' fields on water application efficiencies and farm losses, such as seepage, deep percolation, run-off and evaporation in earth canals of different textures.

(C) Irrigation Modules

The data required to estimate the irrigation modules of some major crops is presented in Table 11.

(1) *General Irrigation Module (Mg.)* : This represents the water requirement of a crop on one hectare of land by continuous flow (lit./sec.) during vegetation period, estimated by the following formulae:

$$Mg. = \frac{10{,}000 \; \frac{H-A-B}{R \times S}}{T \times 24 \times 3{,}600} \quad \text{and} \quad Mg. = \frac{H-A-B}{3.6\ T}$$

where :

- Mg = general irrigation module (lit./sec./ha.)
- H = consumptive use during vegetation period (mm)
- A = 70 % of the precipitation during vegetation period (mm)
- B = 30 % of the precipitation occurring out of vegetation period (mm)
- R = water application efficiency (accepted 60 %)
- S = consumptive use efficiency (accepted 70%)
- T = vegetation period (days)

(2) *Maximum Irrigation Module (Mm)*: represents average daily consumptive use during the month of maximum consumption on one hectare, estimated by the following formula:

$$Mm = \frac{Ud \times 10{,}000}{86{,}400} : R$$

where :

- Ud = daily consumptive use during the month of maximum consumption (mm)
- R = water application efficiency (%)

(D) Irrigation Guide Tables

For classified soil groups, the new irrigation guide tables have two additional columns (Appendix 5). The added column 9 gives the maximum number of irrigations during the irrigation period. Added column 18 gives the maximum irrigation modules in lit./sec./ha.

The tables do not contain data for sprinkler irrigation. This assumes that the given information will be adequate for planning and designing of sprinkler irrigation systems. Tables for only two slope groups were included.

TABLE 9

Results of Consumptive Use Tests by Soil Moisture Depletion

Months and Items	Cotton (Manisa)		Cotton (Saraykoy)		Cotton (Nazilli)		Cotton (Soke)		Vineyard (Menemen)		Alfalfa (Menemen)		Alfalfa (Nazilli)	
	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K	Cons. use (mm.)	Monthly K
April	—	—	—	—	—	—	—	—	61	0.46	102	0.77	106	0.77
May	48	0.28	99	0.60	95	0.54	38	0.22	94	0.55	178	1.05	183	1.05
June	57	0.29	104	0.56	104	0.53	107	0.55	105	0.54	184	0.96	189	0.96
July	196	0.93	258	1.26	190	0.90	207	0.98	204	1.00	243	1.18	249	1.18
August	225	1.42	242	1.27	264	1.35	191	0.97	209	1.10	205	1.08	224	1.15
September	80	0.51	81	0.54	91	0.58	131	0.82	192	1.26	150	0.99	165	1.06
October	28	0.22	16	0.11	48	0.33	50	0.39	140	1.10	101	0.80	116	0.80
Total	634		800		792		724		1005		1163		1232	
Seasonal K		0.64		0.77		0.74		0.68		0.86		1.0		1.0
Soil texture	SIL L		SL LS		SIL, SICL		SICL SIL		SL,SIL L		SL,LS SIL			
Available moisture holding capacity (mm 30 cm. depth.)	45		35		50		50		55		30			

TABLE 10

Crops	Growing period (days)	Drilling period	Harvesting period	Irrigation period	Seasonal K values*	Max. Month K values by
Cotton	180-200	April 15-May 15	Oct. 1 - Nov. 30	June 15 - Aug 31	0.65 - 0.75	1.42
Vineyard	Frost free	—	Aug. 10 - Sept. 20	June 15 - July 31	0.80 - 0.85	1.26
Citrus Orchard	"	—	Oct. 15 - March 1	June 15 - Nov 1	0.70 - 0.75	0.86
Other Fruits	"	—	May 1 - Sept. 15	June 1 - Sept 1	0.65 - 0.70	0.95
Alfalfa	"	—	May 1 - Nov. 1	May 1 - Oct 20	0.90 - 0.95	1.18
Pasture Grass	"	—	May 15 - Oct. 15	May 15 - Oct 1	0.75 - 0.85	1.15
Potatoes	110 - 120	Feb. 15 - Mar. 15	June 15 - July 15	Apr. 1 - July 1	0.65 - 0.70	0.75
Sesame	110 - 120	Apr. 15 - May 15	Aug. 15 - Aug. 30	June 10 - Aug 10	0.65 - 0.70	1.20
Peanuts	150 - 160	Apr. 20 - May 15	Sept. 15 - Oct. 1	May 20 - Sept 1	0.70 - 0.75	1.20
Corn	110 - 120	Apr. 15 - May 15	Aug. 15 - Aug. 30	June 10 - Aug 10	0.65 - 0.70	1.20
Sunflower	110 - 120	Apr. 15 - May 15	Aug. 15 - Aug. 30	June 10 - Aug 10	0.70 - 0.75	1.20
Melon	90 - 110	Apr. 15 - May 10	July 15 - Aug. 31	May 20 - June 10	0.65 - 0.70	0.80
Watermelon	90 - 110	Apr. 15 - May 10	July 15 - Aug. 31	May 20 - June 10	0.65 - 0.70	0.80
Vegetables	160 - 180	Apr. 10 - May 10	June 1 - Nov. 1	May 5 - Oct 15	0.70 - 0.75	1.20
Rice	110 - 130	May 1 - June 15	Sept. 1 - Oct. 15	—	1.20 - 1.30	2.30
Wheat (Mexican)	210 - 220	Nov. 1 - Dec. 31	May 25 - June 15	Apr. 1 - May 1	0.70 - 0.75	0.75

*Values of first column are for Gediz and Bakircay basins; values of second column are for Kucuk and Buyuk Menderes basins.

TABLE II

Irrigation Modules of Main Irrigated Crops

Crops and Locations	H (mm)	A (mm)	B (mm)	T (days)	Mg. (lit./sec/ha)	Ud. (mm)	R (%)	Mm. (lit./sec/ha)
Cotton (Manisa)	665	52	154	184	0.69	8.2	0.70	1.36
Alfalfa (Menemen)	1160	190	104	260	0.92	8.1	0.70	1.34
Vineyard (Menemen)	1004	190	104	260	0.76	6.8	0.70	1.13
Cotton (Nazilli)	792	73	140	184	0.87	8.5	0.70	1.40
Cotton (Saraykoy)	800	73	140	184	0.87	8.3	0.70	1.40
Cotton (Soke)	724	90	166	184	0.71	6.9	0.70	1.14
Alfalfa (Nazilli)	1232	166	102	260	1.0	8.3	0.70	1.37
Citrus Orchard (Aydin)	830	197	120	260	0.55	6.1	0.70	1.0

In Appendix 5 some columns contain two sets of figures : first values are for Gediz and Bakircay watersheds, and second values for Small and Great Menderes watersheds.

The improved guide has more detailed explanations of the data given in the columns. Maximum length of runs is generally limited by the average size of farm lands.

The need for irrigation guides was recognized and received due attention in Turkey. Before we take steps to prepare an irrigation guide for other irrigated areas, required modifications and improvements will be discussed by a technical committee. This committee will plan the preliminary work required and the arrangement of tables of the irrigation guides.

IRRIGATION GUIDE FOR ÇUKUROVA – YÜREĞİR and TARSUS plains

AP-1 Prepared by: TARSUS Irrigation Research Institute in 1958

SOILS			CROPS					IRRIGATION SPECIFICATION							
Site index	Profile Description	Available moisture holding capacity-mm/30cm of depth.	Locally adapted crops	Depth of effective root zone.cm.	Net moisture to be replaced each irrigation.mm.	Peak period consumptive use rate.mm/day	Irrigation frequency during period of Max. Consumptive use.days.	Suggested Irrigation methods	Basic intake rate.mm/hour for border, basin, sprinkler.lt/sec/100m for furrow.	Size of stream lt/sec	Border or basin width and furrow spacing.m.	Max. Lenght of run.m.	Estimated water application efficiency.%.	Gross irrigation application.mm.	Estimated time of irrigation. hours.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
								Slope : % 0.0–0.5 (%0.25)							
1	$\frac{1}{mk}, \frac{1}{lm}, \frac{1}{ml} u_2, \frac{1}{lm} u_2$	37.5	Cotton	120	75	5.3	14	Furrow	0.23	2.5	1.0	240	70	107	2.9
			Peanuts	90	58	5.5	11	Furrow	0.23	1.5	0.9	160	70	82	2.0
			Tomatoes	120	75	6.3	12	Furrow	0.23	3	1.0	270	70	107	2.9
	S. medium – slightly light texture		Other vegetables	90	58	5.5	11	Furrow	0.23	2	1.0	180	70	82	2.1
								Basin	25	10	20	25	65	89	1.2
								Sprinkler	12.5	—	—	—	65	89	—
	Deep (120cm+)		Sugarcane	120	75	8.8	8	Furrow	0.23	3	1.2	270	70	107	2.9
	Top soil: SiL, SiCL, SCL.		Citrus orchard	90	58	4.5	13	Furrow	0.23	3	1.5	240	70	82	3.1
								Basin	25	45	50	50	65	89	1.4
	CL, SL, fSL, vfSL, L		Other Fruits	90	58	5.5	11	Furrow	0.23	3	1.5	240	70	82	3.1
								Basin	25	45	50	50	65	89	1.4
	Sub soil: some textures		Second crops	90	58	5.5	11	Furrow	0.23	2	0.9	180	70	82	2.0
								Border	25	5.8	9	96	70	82	0.4
								Sprinkler	12.5	—	—	—	65	89	—
	Bottom lands and alluvial soils		Cotton	120	75	5.3	14	Slope % 0.5 – 1.0 (% 0.75)							
								Furrow	0.20	1	1	150	65	115	3.1
			Peanuts	90	58	5.5	11	Furrow	0.20	0.8	0.9	120	65	89	2.2
			Tomatoes	120	75	6.3	12	Furrow	0.20	1.5	1.0	180	65	115	3.1
			Other Vegetables	90	58	5.5	11	Furrow	0.20	1	1.0	135	65	89	1.4
								Sprinkler	12.5	—	—	—	65	89	—
								Border	25	10	20	25	65	89	2.1
			Sugar cane	120	75	8.8	8	Furrow	0.20	1.5	1.2	180	65	115	3.8
			Citrus Orchard	90	58	4.5	13	Furrow	0.20	1.5	–	165	65	89	3.9
								Basin	25	45	50	50	65	89	1.4
			Other Fruits	90	58	5.5	11	Furrow	0.20	1.5	1.5	165	65	89	3.9
								Basin	25	45	50	50	65	89	1.4
			Second crops	90	58	5.5	11	Furrow	0.20	1	0.9	135	65	89	2.2
								Border	25	3.6	9	145	70	82	0.6
								Sprinkler	12.5	–	–	–	65	89	–
			Cotton	120	75	5.3	14	Slope: % 1–2 (%1.5)							
								Cont.Furrow	0.17	0.6	1.0	115	65	115	3.6
			Peanuts	90	58	5.5	11	Cont.Furrow	0.17	0.6	0.9	100	65	89	2.6
			Tomatoes	120	75	6.3	12	Zigzag Furrow	0.17	0.8	1.0	135	65	115	3.6
			Other Vegetables	90	58	5.5	11	Cont.Furrow	0.17	0.5	1.0	85	65	89	2.8
								Cont.Basin	25	10	20	25	60	92	1.3
								Sprinkler	12.5	–	–	–	65	89	–
			Sugarcane	120	75	8.8	8	Cont.Furrow	0.17	0.8	1.2	135	65	115	4.4
			Citrus orchard	90	58	4.5	13	Cont.Furrow	0.17	0.8	1.5	120	65	89	4.1
								Cont.Basin	25	18	30	30	60	92	1.5
			Other Fruits	90	58	5.5	11	Cont.Furrow	0.17	0.8	1.5	120	65	89	4.1
								Cont.Basin	25	18	30	30	60	92	1.3
			Second crops	90	58	5.5	11	Cont.Furrow	0.17	0.5	0.9	85	65	89	2.6
								Cont.Ditch	25	–	–	50	60	92	1.7
								Sprinkler	12.5	–	–	–	65	89	–

IRRIGATION GUIDE FOR ÇUKUROVA – YUREGİR and TARSUS plaines

AP-2 Prepared by: TARSUS Irrigation Research Institute in 1958

SOILS			CROPS					IRRIGATION SPECIFICATION							
Site index	Profile Description	Available moisture holding capacity-mm/30cm of depth.	Locally adapted crops	Depth of effective root zone.cm.	Net moisture to be replaced each irrigation.mm.	Peak period consumptive use rate.mm/day	Irrigation frequency during period of Max. Consumptive use.days.	Suggested Irrigation methods	Basic intake rate.mm/-hour for border, basin, sprinkler.lt/sec/100m for furrow.	Size of stream lt/sec	Border or basin width and furrow spacing.m.	Max. Lenght of run.m.	Estimated water application efficiency.%.	Gross irrigation application.mm.	Estimated time of irrigation. hours.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
II	$\frac{2sd}{hha_2}$, $\frac{2sd}{mha_2}$, $\frac{2sd}{hh_2 a_2}$ H.Heavy, fine texture Deep (120 cm+) Topsoil and subsoil: SC, SiC, C, SiL, SICL, SCL, CL Bottom lands and alluvial soils that have drainage and slightly salinity problems.	57.5						Slope: % 0.0-0.5 (%0.25)							
			Cotton	90	86	5	17	Furrow	0.7	2.5	1	420	65	132	12.9
			Alfaalfa + clover	90	86	6.5	10	Border	4.0	0.6	14	805	65	132	6.0
								Sprinkler	4.0	–	–	–	60	143	–
			Irrigated pasture	60	57.5	7.5	8	Border	4.0	0.8	14	730	65	88	3.0
								Sprinkler	4.0	–	–	–	55	104	–
			Rice	60	57.5	9.3	6	Basin	4.0	2/hec	10/dec	–	–	–	–
			Second Crops: watermelon, Corn, grass, bean sorghum e.t.c	60	57.5	5.5	11	Furrow	0.7	2	0.9	270	65	88	7.6
								Border	4.0	0.8	14	730	65	88	3.0
								Ditch flooding	4.0	–	–	75	55	104	7
								Sprinkler	4.0	–	–	–	55	104	–
			Cotton	90	86	5	17	Slope % 0.5-10 (%0.75)							
								Furrow	0.6	1	1	250	60	143	14.8
			Alfaalfa + clover	90	86	6.5	10	Border	4.0	0.6	14	805	65	132	6.0
								Sprinkler	4.0	–	–	–	60	143	–
			Irrigated pasture	60	57.5	7.5	8	Border	4.0	0.6	14	805	65	88	6.0
								Sprinkler	4.0	–	–	–	55	104	–
			Rice	60	57.5	9.3	6	Basin	4.0	2/hec	10/dec	–	–	–	–
			Second crops	60	57.5	5.5	11	Furrow	0.6	1	0.9	190	60	96	9.0
								Border	4.0	–	–	–	55	104	–
								Ditch flooding	4.0	–	–	75	55	104	7
								Sprinkler	4.0	0.6	14	805	65	88	6.0
			Cotton	90	86	5	17	Slope: % 1-2 (%1.5)							
								Cont.furrow	0.5	0.5	1	190	60	143	17.9
			Alfaalfa + clover	90	86	6.5	10	Cont.border	4.0	0.5	12	680	60	143	8.0
								Sprinkler	4.0	–	–	–	60	143	–
			Irrigated pasture	60	57.5	7.5	8	Cont.border	4.0	0.6	12	680	60	96	4.3
								Sprinkler	4.0	–	–	–	55	104	–
			Rice	60	57.5	9.3	6	Cont.basin	4.0	2/hec	10/dec	–	–	–	–
								Cont.furrow	0.5	0.5	0.9	130	60	96	10.5
			Second crops	60	57.5	55	11	Cont.ditch flooding	4.0	–	–	75	55	104	7
								Sprinkler	4.0	–	–	–	55	104	–

IRRIGATION GUIDE FOR ESKİŞEHİR and ALPU plaines

AP-3 Prepared by: ESKİŞEHİR TOPRAKSU RESEARCH INSTITUTE in 1961

SOILS			CROPS					IRRIGATION SPECIFICATION							
Site index	Profile Description	Available moisture holding capacity-mm/30cm of depth.	Locally adapted crops	Depth of effective root zone.cm.	Net moisture to be replaced each irrigation.mm.	Peak period consumptive use rate.mm/day	Irrigation frequency during period of Max. Consumptive use.days.	Suggested Irrigation methods	Basic intake rate.mm/-hour for border, basin, sprinkler.lt/sec/100m for furrow.	Size of stream lt/sec	Border or basin width and furrow spacing.m.	Max. Lenght of run.m.	Estimated water application efficiency.%.	Gross irrigation application.mm.	Estimated time of irrigation.hours.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	3sd / hh H. Heavy fine texture Topsoil and subsoil are clayey. Deep, bottom lands flactuating water table.	65						Slope: % 0.0_0.5 (% 0.25)							
			Sugar beets	90	98	6.6	15	Furrow	0.24	1.3	0.66	430	70	140	8.5
			Alfaalfa	120	130	7.7	17	Border	12.5	0.57	12	350	70	180	8.8
			Cereals	90	98	5.5	18	Border	12.5	0.86	12	320	70	140	4.5
			Fruits (orchard)	90	98	6.3	15	Furrow	0.24	2.0	1.0	400	70	140	8.0
								Basin	12.5	0.70	30	50	65	151	6.0
			Irr. pasture+ Grass	60	64	7.0	9	Border	12.5	1.40	12	350	70	91	3.9
								Sprinkler	3.5	0.6	–	–	60	100	–
			Beans+Corn	60	64	6.0	10	Furrow	0.22	1.0	0.60	420	70	91	6.4
								Slope: % 0.5_1.0 (%0.75)							
			Sugar beets	90	98	6.6	15	Furrow	0.15	1.0	0.66	280	65	151	7.7
			Alfaalfa	120	130	7.7	17	Border	12.5	0.79	12	250	65	120	4.2
			Cereals	90	98	5.5	18	Border	12.5	0.56	12	220	65	151	7.2
			Fruits (orchard)	90	98	6.3	15	Furrow	0.15	2.0	1.0	200	65	151	4.2
								Basin	12.5	0.56	30	50	65	151	7.5
			Irr.pasture+ Grass	60	64	7.0	9	Border	12.5	1.05	12	250	65	98	2.6
								Sprinkler	3.5	–	–	–	60	100	–
			Beans+Corn	60	64	6.0	10	Furrow	0.15	1.0	0.60	300	65	98	4.9
								Slope: % 1_2 (%1.5)							
			Sugar beets	90	98	6.6	15	Cont.furrow	0.10	0.8	0.66	200	65	151	6.9
			Alfaalfa	120	130	7.7	17	Cont.border	12.5	0.68	12	190	65	120	4.9
			Cereals	90	98	5.5	18	Cont.border	12.5	0.49	12	170	65	151	8.5
			Fruits (orchard)	90	98	6.3	15	Cont.furrow	0.10	1.0	1.0	180	65	151	7.5
								Cont.basin	12.5	0.49	30	30	65	151	8.6
			Irr.pasture+ Grass	60	64	7.0	9	Cont.border	12.5	0.92	12	210	65	98	3.0
								Sprinkler	3.5	–	–	–	60	106	–
			Beans+Corn	60	64	6.0	10	Cont.furrow	0.10	0.8	0.60	230	65	98	4.7

IRRIGATION GUIDE FOR MANİSA + SALİHLİ + MENEMEN PLAINES

AP-4

Prepared by: MENEMEN Irrigation Research Institute in 1964

SOILS			CROPS					IRRIGATION SPECIFICATION							
Site index	Profile Description	Available moisture holding capacity-mm/30cm of depth.	Locally adapted crops	Depth of effective root zone.cm.	Net moisture to be replaced each irrigation.mm.	Peak period consumptive use rate.mm/day	Irrigation frequency during period of Max. Consumptive use.days.	Suggested Irrigation methods	Basic intake rate.mm/-hour for border, basin, sprinkler.lt/sec/100m for furrow.	Size of stream lt/sec	Border or basin width and furrow spacing.m.	Max. Lenght of run.m.	Estimated water application efficiency.%.	Gross irrigation application.mm.	Estimated time of irrigation.hours.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
II	$\frac{2sd}{m}$, $\frac{2sd}{m}a$, $\frac{2sdt}{m}au$, $\frac{2st}{m}u$ M.Medium texture. Deep (120cm+) Topsoil: SIL, SICL Sub Soil: SICL, SIC, C Bottom lands and alluvial soils	56						Slope: % 0.0–0.5 (% 0.25)							
			Cotton	90	84	7.2	12	Furrow	0.65	2.5	0.9	180	70	120	2.1
								Border	25	22	10	100	70	120	1.2
								Sprinkler	25	—	—	—	65	129	—
			Vineyard	120	112	6.5	17	Furrow	0.75	3	2.0	180	70	160	5.3
								Border	25	14	8	80	70	160	2.0
			Fruits (orchard)	90	84	4.8	17	Furrow	0.65	2.5	1.0	130	70	120	2.3
								Basin	25	37	40	50	65	129	1.9
			Potatoes	60	56	3.8	15	Furrow	0.65	2.5	0.7	180	70	80	1.1
			Sesame	60	56	5.0	11	Furrow	0.65	2.5	0.6	180	70	80	1.0
			Peanuts	40	38	4.0	9	Furrow	0.65	2.5	0.9	180	70	54	1.0
			Corn	90	84	6.0	14	Furrow	0.65	2.5	1.0	180	70	120	2.4
			Rice	60	—	10.0	—	Basin	25	3.5/Hec	3/Dec	—	—	—	—
			Alfaalfa	120	112	7.5	15	Border	25	15	10	100	70	160	3
								Sprinkler	25	—	—	—	65	172	—
			Tomatoes	90	84	6.8	12	Furrow	0.65	2.5	1.0	180	70	120	2.3
			other Vegetables	90	84	5.8	14	Furrow	0.65	2.5	0.8	180	70	120	1.9
								Slope: % 0.5–1.0 (% 0.75)							
			Cotton	90	84	7.2	12	Furrow	0.30	1.0	0.9	140	70	120	4.1
								Border	25	11	8	80	70	120	1.9
								Sprinkler	25	—	—	—	65	129	—
			Vineyard	120	112	6.5	17	Furrow	0.30	1.5	2.0	140	70	160	8.3
								Border	25	5	8	60	70	160	4.3
			Fruits (orchard)	90	84	4.8	17	Furrow	0.30	1.0	1.0	140	70	120	4.5
								Basin	25	24	40	40	65	129	2.3
			Potatoes	60	56	3.8	15	Furrow	0.30	1.0	0.7	140	70	80	2.2
			Sesame	60	56	5.0	11	Furrow	0.30	1.0	0.6	140	70	80	1.9
			Peanuts	40	38	4.0	9	Furrow	0.30	1.0	0.9	140	70	54	1.9
			Corn	90	84	6.0	14	Furrow	0.30	1.0	1.0	140	70	120	4.7
			Rice	60	—	10.0	—	Basin	25	3.5/Hec	2/Dec	—	—	—	—
			Alfaalfa	120	112	7.5	15	Border	25	8	10	80	70	160	4.4
								Sprinkler	25	—	—	—	65	172	—
			Tomatoes	90	84	6.8	12	Furrow	0.30	1.0	1.0	140	70	120	4.5
			other Vegetables	90	84	5.8	14	Furrow	0.30	1.0	0.8	140	70	120	3.6
								Slope: %1–2 (%1.5)							
			Cotton	90	84	7.2	12	Furrow	0.17	0.6	0.9	90	65	129	4.7
								Border	25	7	8	60	65	129	2.4
								Sprinkler	25	—	—	—	65	129	—
			Vineyard	120	112	6.5	17	Furrow	0.25	1.0	2.0	90	65	172	8.6
								Border	25	5	8	50	65	172	3.8
			Fruits (orchard)	90	84	4.8	17	Furrow	0.17	0.6	1.0	90	65	129	5.2
								Basin	25	12	30	30	60	140	2.8
			Potatoes	60	56	3.8	15	Furrow	0.17	0.6	0.7	90	65	86	2.5
			Sesame	60	56	5.0	11	Furrow	0.17	0.6	0.6	90	65	86	2.1
			Peanuts	40	38	4.0	9	Furrow	0.17	0.6	0.9	90	65	59	2.2
			Corn	90	84	6.0	14	Furrow	0.17	0.6	1.0	90	65	129	5.4
			Rice	60	—	10.0	—	Basin	25	3.5/Hec	1.5/Dec	—	—	—	—
			Alfaalfa	120	112	7.5	15	Border	25	6	8	60	65	172	3.8
								Sprinkler	25	—	—	—	65	172	—
			Tomatoes	90	84	6.8	12	Furrow	0.17	0.6	1.0	90	65	129	5.2
			other Vegetables	90	84	5.6	14	Furrow	0.17	0.6	0.8	90	65	129	4.2

IRRIGATION GUIDE FOR BAKIRÇAY + GEDİZ + KÜÇÜK MENDERES + BÜYÜK MENDERES PLAINES

AP-5 Prepared by: MENEMEN Irrigation Research Institute in 1968

Site index	SOILS: Profile Description	SOILS: Available moisture holding capacity. mm/30cm of depth.	CROPS: Locally Adapted crops	CROPS: Depth of effective root zone. cm.	CROPS: Net moisture to be replaced each irrigation. mm.	CROPS: Peak period consumptive use rate. mm/day	CROPS: Irrigation frequency during period of Max cons-use. days.	CROPS: Max. number of irrigation during growing season.	IRRIGATION SPECIFICATIONS: Suggested Irrigation methods	Basic intake rate. mm/hour for border+basin. lt/min/100m for furrow.	Size of Stream. lt/sec	Border+basin width and furrow spacing. m.	Maximum Lenght of run. m.	Estimated water application efficiency. %	Gross irrigation application. mm.	Estimated time of irrigation. hours.	Maximum irrigation modula at field gate. lt/sec/hectar.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
									Slope: % 0.0 _ 0.5 (% 0.25)								
1	1/mm 1/ml 1/ll	40	Cotton	90	60	5.6	11_10	4_5	Furrow	30	2	0.8	150	70	85	1.4	0.83_0.98
	Medium Texture								Border	20	25	10	100	70	85	0.9	
	Deep (120cm+)		Vine yard	120	80	6.7	12_11	3_4	Furrow	40	2	1	150	70	114	2.4	0.98_1.16
									Border	20	17	9	100	70	114	1.7	
	Topsoil: L, SiL, SiCL.		Fruit orchard	90	60	5.6	11_10	4_5	Furrow	40	2	1	150	70	85	1.8	0.83_0.98
									Basin	20	22	9	100	70	85	1	
	Subsoil: SiL,		Citrus orchard	90	60	5.6	11_10	6_7	Furrow	40	2	1	150	70	85	1.8	0.83_0.98
									Basin	20	22	9	100	70	85	1	
	SiCL, L, SL, LS		Alfa alfa	120	80	6_7	13_12	12_14	Border	20	20	10	100	70	114	1.6	0.98_1.16
			Irr. pasture+grass	120	80	7_8	11_10	4_5	Border	20	20	10	100	70	114	1.6	1.16_1.31
			Potatoes	60	40	4.5	10_9	4_5	Furrow	30	1.5	0.7	130	70	57	1	0.66_0.83
			Sesame	90	60	6_7	10_9	4_5	Furrow	25	1.5	0.6	130	70	85	1.2	0.98_1.16
			Peanuts	60	40	4_5	9_8	7_9	Furrow	30	2	0.8	150	70	57	1	0.66_0.83
			Corn	90	60	6_7	10_9	4_5	Furrow	35	2	0.9	150	70	85	1.6	0.98_1.16
			Sunflower	90	60	6_7	10_9	4_5	Furrow	35	2	0.9	150	70	85	1.6	0.98_1.16
			W. melon+melon	60	40	4_5	9_8	2_3	Furrow	40	2	1	150	70	57	1.2	0.66_0.83
			Vegetables	60	40	5_6	8_7	16_18	Furrow	30	2	0.8	150	70	57	1	0.83_0.98
									Slope: % 0.5 _ 1.0 (% 0.75)								
			Cotton						Furrow	25	1.5		110			1.4	
									Border	20	18		80			1.1	
			Vine yard						Furrow	35	1.5		120			2.5	
									Border	20	12		80			1.9	
			Fruit orchard						Furrow	35	1.5		120			1.9	
									Basin	20	14		80			1.2	
			Citrus orchard						Furrow	35	1.5		120			1.9	
									Basin	20	16		80			1.1	
			Alfa alfa						Border	20	14		80			1.8	
			Irr. pasture+grass						Border	20	14		80			1.8	
			Potatoes						Furrow	25	1		100			1.1	
			Sesame						Furrow	20	1		100			1.4	
			Peanuts						Furrow	25	1.5		110			0.9	
			Corn						Furrow	30	1.5		110			1.6	
			Sunflower						Furrow	30	1.5		110			1.6	
			W. melon+melon						Furrow	35	1.5		120			1.3	
			Vegetables						Furrow	25	1.5		110			0.9	

Chapter XI

HOW TO LIVE WITH SALINITY

THE SCOPE FOR LIVING WITH SOIL SALINITY AND ALKALI CONDITIONS IN INDIA

by

B. Ramamoorthy*

Abstract

There is a large area of the country in which farmers are living with soil salinity and alkali conditions, and the sometimes attendant circumstances of a high water table and ground waters of poor irrigation quality, with varying degrees of success.

Farmers themselves have found that *kharchi*, a local variety of red wheat, will grow with moderately saline waters containing nitrates. Agricultural scientists are also selecting suitable varieties of many of the common crop plants with marked salt tolerance, as well as designing appropriate crop rotations.

Recent scientific research in the country has shown easy methods of distinguishing saline-alkali conditions through the symptoms on an indicator plant, even before obvious signs become visible on the soil surface and the crops grown on them, so that proper practices can be adopted before it is too late. The soil testing laboratories in the country are also helping farmers with the needed soil and irrigation water analysis for selecting the proper techniques suited to individual soil conditions.

Under conditions of a high water table and the concentration of salts on the surface, with the subsoil remaining relatively non-saline, simple soil inversion was found to be effective.

Agronomic techniques for alternate ditch irrigation for all crops and all latitudes, and cropping on the northern slopes of ridges running east to west for winter crops in the northern

* Soil Testing Laboratory, Indian Agricultural Research Institute, New Delhi.

latitudes, have been developed for living with soil salinity.

Proper conditions for the safe utilization of irrigation waters of poor quality have also been specified.

There is great scope for applying these findings at appropriate places wherever the soil has already deteriorated to a great extent.

Report

In India, as in many other countries, there is a large area under cultivation which is not so severely affected by saline and alkali conditions that it requires either abandonment or the application of standard reclamation measures, which are rather expensive. On a considerable portion of this area, farmers are unknowingly living with these conditions because the plants are not visibly affected, even though their growth would be greatly improved if these adverse conditions were removed. In the rest of this area, farmers are consciously living with salinity with varying degrees of success. In some cases they will exploit these lands till they are compelled to abandon them, if in the meantime they have not adopted the findings obtained from long experience by other farmers or from research by the agricultural scientists. In other cases farmers have developed certain practices empirically which deserve to be noted by the agricultural scientists. There are also cases in which the recent findings of the agricultural scientists are helping the farmers to live successfully with soil salinity, completing a two-way traffic between the agricultural scientists and the farmers. It has been shown that if the farmer can distinguish the saline, alkali and saline-alkali conditions, he can adopt suitable measures to live with them. If he also knows the salinity distribution in the soil profile, he can choose simpler methods of living with soil salinity. The 57 soil testing laboratories now operating in

TABLE I

Extent of Saline and Alkali Affected Areas in Some States of India

Name of State	Area under cultivation (million acres)	% of samples with pH of 8.5 or greater	Estimated alkali affected area (million acres)	% of samples critical for germination	Estimated salinity affected area (million acres)
Andhra Pradesh	27.302	26.4	7.21	20.3	5.54
Assam, including NEFA	5.118	—	—	28.0	1.43
Bihar	19.690	3.4	0.67	21.6	4.25
Maharashtra and Gujarat	67.438	8.1	5.46	3.75	2.53
Kerala	4.587	3.7	0.17	7.2	0.33
Madhya Pradesh	38.786	8.6	3.335	3.2	1.24
Madras	14.326	21.4	3.07	4.3	0.61
Mysore	25.140	19.3	4.85	7.7	1.94
Orissa	13.854	1.9	0.26	5.6	0.78
Punjab and Haryana	18.488	10.6	1.96	10.5	1.94
Rajasthan	31.104	7.2	2.24	7.9	2.46
Uttar Pradesh	42.122	14.4	6.07	8.0	3.37
West Bengal	12.929	0.3	0.039	5.3	0.685
Delhi	0.217	16.6	0.036	—	—
Himachal Pradesh	0.667	1.6	0.010	—	—
Manipur	0.232	—	—	—	—
Tripura	0.510	0.2	0.001	—	—

this country are helping farmers with the needed soil analysis. A brief account of the work being done is given in this paper as an outline of the scope for living with soil salinity in India.

Extent of Area Under Saline-Alkali Conditions

Saline-alkali areas often occur in small patches in an otherwise good field, and sometimes without readily visible symptoms either on the soil or on the plants. It is therefore difficult to include them in any regular field survey without the aid of chemical analysis. The soil testing laboratories in India had analyzed 1.58 million soil samples up to the end of 1967, and obtained the percentage of samples with a pH greater than 8.5, which is characteristic of alkali soils, as also the percentage with an electrical conductivity greater than one millimho per centimeter in one : two soil : water extracts, characteristic of saline soils on which germination of most of the crop plants is adversely affected. These values give an estimate of the areas in the different states of the country under alkali and saline conditions, excluding those which have been abandoned (Table 1).

This indicates that an average of 11.28 per cent of the samples tested were alkali affected, or the equivalent of 36.56 million acres out of a net area of 324.12 million acres under cultivation. This is greater than the older rough estimate of 15 million to 16 million acres. Similarly, the saline soils work out to 7.8 per cent of the soil samples analyzed, or 25.28 million acres. The committee on natural resources of the Planning Commission, 1963, reported that 0.653 million acres in Punjab, 3.1 million acres in Uttar Pradesh, 0.075 million acres in Deccan and 0.21 million acres in West Bengal have been abandoned due to damage caused by salinity and alkali, leaving the remainder as land in which farmers are living with this problem and in which there is scope for applying the knowledge now available in the country to make this living successful.

Living with Salinity and Alkali Conditions by a Proper Choice of Crop

In Rajasthan, the *rabi* crops are mostly wheat and barley which are resistant to saline conditions. By a process of natural selection, the farmers of this state have found that *kharchi*, a local variety of red wheat, is resistant to salinity, and have been growing it under these conditions. Recent work at the Indian Agricultural Research Institute, New Delhi, has shown how the farmer can recognize his problem, even when it is mild, from the symptoms produced on grain (*Cicer arietinum*) as an indicator plant, and can adopt appropriate measures.

Plants grown on a non-alkali-medium-saline substrate (sodium adsorption ratio of six and salinity of eight millimhos per centimeter) showed a purple tinge on the margins of leaflets in the fourth week. This purple tinge increased towards the midrib and went on darkening. Drying of leaves started when they had crossed the age of nine weeks. This proved fatal for 75 per cent of the plants in the 17th. week.

Plant growth on a non-alkali-highly-saline substrate (sodium adsorption ratio of six and salinity of 16 millimhos per centimeter) was very poor and stunted, Deep purpling developed from margins of leaflets of old leaves during the third week. These symptoms went on spreading to the whole plant. In the ninth week, drying of leaves started, which resulted in the death of all the plants by the 12th. week.

Plant growth on a non-saline-medium-alkali substrate (sodium adsorption ratio of 24 and salinity of two millimhos per centimeter) showed yellowing of new leaves in the fourth week. On old leaves, burning of tips was also noticed. Symptoms became severe with the advance of age but caused no death.

In non-saline-highly-alkali conditions (sodium adsorption ratio of 48 and salinity of two millimhos), the plants showed prominent yellowing on new leaves, which went on intensifying with age. During the ninth week, tip burning was also observed. However, it did not cause death.

Plants grown on medium-saline-medium-alkali conditions (sodium adsorption ratio of 24 and salinity of eight millimhos) showed yellowing

of new leaves and burning of old leaves in the fourth week. In the ninth week, drying of tops and deep purpling were noted, and 75 per cent of the plants died in the 16th. week.

Plants developed on highly saline and highly alkali substrate (sodium adsorption ratio of 48 and salinity of 16 millimhos) were stunted from the beginning. Yellowing of new leaves and burning and falling of old leaves were common in the fourth week. These led to complete drying of lower leaves, and plants tended to die. In the ninth week drying of tops was also observed, which led to the death of all the plants in the 11th. week.

Miglani (1964) found that, as far as germination was concerned, both saline and alkali tolerance of crops was the same, decreasing in the following sequence : barley, gram, wheat and peas. But once the initial germination difficulty is overcome by a higher seed rate, the alkali tolerance for the growth of crops was in the decreasing order : gram, barley, wheat and peas. Thus, gram is better adapted to alkali conditions. Under both saline and alkali conditions, more frequent irrigation mitigated the conditions when they were not very severe.

Among *kharif* crops there is a great difference between the different varieties of *bajra* and *jowar*, as shown below in data taken from the report of the committee on natural resources of the Planning Commission, 1963 (Table 2).

Thus, the new *bajra* varieties, Manihari and Kata, and *jowar* varieties, M 47-3, Gadra Road and Pokran, are what the scientist is giving the farmer to live with salinity. Sathra and Jhona varieties of paddy and the local varieties of mustard (Taramira) were also found to be highly salt-tolerant in Punjab.

Management of Soils with Salts Concentrated on Surface, Leaving Subsoils Relatively Safe

At the Indian Agricultural Research Institute, Bains (1967) found that mechanical burying of salts immediately before sowing increased the yields of a salt-sensitive crop like berseem (*trifolium alexandrium*), and that the placement of fertilizers 20 cm. deep enabled wheat, barley and oats to live with salinity, as shown in Tables 3 and 4.

TABLE 2

Salt Tolerance at Germination of Bajra and Jowar Varieties

	Conductance of Saturation Extract (millimhos/cm. at 25°C.
Bajra Varieties	
RSK	8.0
T5	8.0
Bikaner	12.0
Sardar Shahar	12.0
T55	12.0
Jetsar	12.0
Gadra Road	12.0
Agra	12.0
Manihari	16.0
Kata	16.0
Jowar Varieties	
Texas Hybrid 610	8.0
M 47-3	12.0
Gadra Road	12.0
Texas Milo 25245	8.0
Pokran	12.0
Sweet Sudan 1.5-704	0.7
Nebraska JW 5809	4.0
J 118	4.0
T 1	0.2
PJ 4R	4.0
M 35-1	0.7

TABLE 3

Yield of Berseem as Affected by Pre-sowing Soil Inversion

Treatment	Green Fodder		Seed	
	(q/ha)	(relative)	(q/ha)	(relative)
Normal method of sowing	406	100	0.5	100
Soil inversion before sowing	732	180	1.4	280

TABLE 4

Yield of Rabi Cereals as Affected by Fertilizer Application*

	Wheat (q./ha.)	Barley (q./ha.)	Oats (q./ha.)
No fertilizer	12	16	10
Broadcast	17	24	18
Placed 20 cm. deep	22	30	24

*40 kg. N+20 kg. P_2O_5+20 kg. K_2O per ha.
Water table: 85-175 cm.

The northern slopes of ridges running from east to west, desalinized in winter months by the translocation of salts by solar radiation, have been found safe for germinating seeds and transplanted plants in the northern latitudes. Similarly, alternate ditch irrigation transported salts to the unirrigated ditches by the lateral movement of water, making the irrigated areas quite safe and useful under both *kharif* and *rabi* and at all latitudes.

Role of Crop Rotations and Organic Matter Application

At Kamma and Nilokheri in Haryana, reclamation became possible, as shown by Kanwar (1962), through the use of ordinary amounts of water and normal doses of fertilizer, adopting a paddy-barley rotation. Sugar beet Q S-75 was found to be more successful than berseem in saline-alkali soils of Punjab. At Kamma, on saline-alkali soils with a low water table, the best results were obtained by growing sesbania with superphosphate and green manure at the rate of 10 tons of green matter per acre.

Leaf powder was found by Ramamoorthy and Agrawal (1966), and Agrawal (1966) to be useful in ameliorating the alkali condition of the calcareous soils of Pusa (Bihar) and the black soil of Katol (Maharashtra) containing calcium carbonate, but not the alkali alluvial soils of Delhi and the alkali red soils of Anantapur (Andhra Pradesh). The addition of calcium carbonate and fertilizer application with N and P improved the efficiency of organic matter in the Delhi and Anantapur soils.

Extent of Water-Logging in Different States of India

As a high water table also causes salinity, the distribution of the water-logged areas is important in considering the scope for living with salinity. Data assembled by the committee on natural resources of the Planning Commission (1963) on this aspect is presented in Table 5. It shows that this problem is most acute in Punjab and Maharashtra.

TABLE 5

Distribution of Water-logged Soils in India

STATE	AREA WITH WATER TABLE FROM 0 TO 5 FEET (ACRES)	
	Water logged	Salt affected
Punjab	2,513,838	1,300,000
Maharashtra	10,821	17,900
Jammu & Kashmir	4,500	—
Delhi	3,200	—
U.P.	—	—
Madhya Pradesh	300	—

Organizations set up in public works divisions of states like the Punjab and Uttar Pradesh are taking responsibility for planning and executing surface drainage schemes to check water-logging caused by improper surface drainage. In Punjab, four pilot projects involving the use of tubewells were started in Amritsar, Sangrur, Sunam and Fazilka, to check water table rise by construction of tubewells and pumping out the ground water.

Living with Salinity Caused by Irrigation with Ground Water of Poor Quality

In northern India, where the soils are mostly alluvial, ground water is a very important potential source of irrigation which has not been fully exploited in some areas due to the highly saline nature of these waters. Living with salinity caused by irrigation with ground waters of poor quality must follow the principles of safe utilization which have emerged from experience

and research. The farmers of Gurgaon (Haryana) and Baprola (Delhi state) have found from long experience that waters of high salinity can safely be used on their soils. The salinity of these waters is more than what is permitted in the classification of irrigation waters by the U.S. Salinity Laboratory (1954). Kanwar (1961) showed that the reason for this lay in the higher nitrate and potash content of the water of these areas. Thus, better nutrition of the crop mitigated the effect of salinity. In Rajasthan, also, trials conducted by the state agricultural chemist showed that 10 tons of farmyard manure on an average gave an increase of 352 lbs. of wheat per acre, when saline water with an electrical conductivity of six millimhos per cm. was used. The pH of the soil was 8.1 and conductivity 1.15 millimhos per cm., as against a pH of 8.3 and electrical conductivity of 2.2 millimhos per cm. in the control.

The findings of Kanwar (1961) showed that by considering the soil-plant-irrigation water characteristics, better use can be made of irrigation waters of lower quality. Ramamoorthy (1964) gave the following ratings for soil texture and plant tolerance: 4 for clay, 3.5 for clay-loams, 3.0 for loams, 2.5 for sandy loams and 2.0 for sandy soils, 3 for sensitive crops, 2 for semi tolerant and 1 for tolerant crops. It has been shown that when the irrigation water does not contain appreciable amounts of nitrates, it can still be safely used so long as the sum of all ratings of soil texture, plant tolerance, and the sodium and salinity hazard class numbers, according to the U.S. Salinity Laboratory, does not exceed 9. This principle is now being followed in many of the soil testing laboratories in India in determining the safe utilization of irrigation waters.

Wagdi and Dinesh (1966) found that the boron content of the irrigation waters of Delhi state increased with the SAR of the water, as given by the following equation :

$$\text{Log B (in ppm. of water)} = 2.042 \log \text{SAR} - 2.359$$

A boron content above 1 ppm, which is undesirable, can be countered by adding 1.7 to 2 milliatoms of calcium as gypsum, lime and superphosphate, and 2 milliatoms/l. of phosphorus. The amount of lime added depends on the amount required to raise the pH from 6.8 to 7.6.

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THE USE OF HIGH SALT WATERS BY GRADUAL DILUTION IN THE RECLAMATION OF SALINE AND ALKALI SOILS

by
Seref Ozgul*

Summary

Highly saline water, after successive dilutions, was used for reclaiming sodic soils in an experimental plot of Pamukova plain in north-west Anatolia.

In this experiment, inadequate soil permeability, which was the major problem, was increased by utilizing high salt water. This salt water had an electrical conductivity of $EC \times 10^6 = 14,100$ and sodium adsorption ratio (SAR) = 21.00.

Increase in permeability was obtained by the flocculating effect of salt water, and maintained by progressive dilutions and/or decrease in exchangeable sodium content in the sodic soil.

Exchangeable sodium of sodic soil was reduced through a leaching process from 84 per cent to 15 per cent by percolating 825 cm. depth of water for the 60 cm. depth of soil profile. This relief in exchangeable sodium was obtained by replacement of Ca+Mg from initial and diluted leaching solutions for exchangeable sodium cations on the soil exchange complex. For that reason it was found that the higher the Ca+Mg ratio to total cations, the less the depth of water needed for reclamation.

In the same area for the same degree of reclamation, five tons of gypsum per decare (1,000 m^2) were applied.

When these two methods were compared, the high salt water dilution method was about six times cheaper and much more efficient than the gypsum application.

As a conclusion, salt water can preferably be used when suitable conditions are available.

I. Introduction

In the reclamation of sodic soils, the major problem encountered is low or inadequate permeability. Many studies have been made and much research is being conducted all over the world to determine the most effective method of reclamation. Effectiveness of a method involves technical and economic feasibility. Reclamation

* Head, Soils and Drainage Branch, Directorate General of State Hydraulic Works, Ankara, Turkey.

of a soil must be practical and conducted with the lowest possible cost and time. Conventional methods, such as the application of gypsum and sulphur, usually entail considerable time and expense. For these reasons, especially in arid regions where crop adaptability is limited, reclamation by conventional methods may be impracticable. In recent years in the U.S.A., some scientific studies have shown that high salt waters can be used for alkali reclamation. During one of our field investigations, we found that sodic soils can successfully be reclaimed utilizing certain high salt waters.

This paper presents the results of the high salt water dilution method and its comparison with one conventional method.

II. Sodic Soils

Sodic soils are usually defined as soils having 15 per cent or more exchangeable sodium and low soluble salts (less than 4 mmhos/cm.). Various countries identify sodic soils by different names, such as black alkali, solonetz, rokkor, karacorak, etc. The pH readings are usually greater than 8.5.

The chief soluble cation is sodium and it may be present as sodium carbonate or bicarbonate salts. A high proportion of adsorbed sodium in the soil particles may have a marked influence on the physical properties of the soil. As the proportion of exchangeable sodium increases, the soil tends to be more dispersed. This results in poorer water penetration and aeration, with a consequent lowering of crop yields.

Replacement of the exchangeable sodium is required for reclamation of these soils.

III. Conventional Methods and Their Applicability

Conventional methods used for replacement of the exchangeable sodium from these soils include the application of various chemical amendments. These amendments are activated by water through a leaching process, during which soluble calcium ions are transported into the soil and exchanged for the adsorbed sodium on the soil-cation exchange complex. Egression of the replaced sodium is completed through drainage of the effluent. The most common amendments are gypsum and sulphur.

Gypsum (calcium sulfate hydrate) furnishes a soluble calcium supply directly. It is fairly soluble in water to about 2.5 gr. per liter. It must be finely ground before it is applied to the soil. The degree of fineness influences the rate at which gypsum goes into solution.

Purity of calcium sulfate content is between 15-95 per cent, according to the grade. Gypsum that contains less than 70 per cent calcium sulfate generally costs too much to transport, except for locations very near the deposit.

Elemental sulphur is also widely used for reclamation, but since it is not a direct source of calcium, lime must also be present in the soil. It is not soluble in water and must be oxidized to sulfuric acid. This action is completed by microorganisms or soil bacteria in the presence of air and moisture. Under favorable conditions this bacterial oxidation requires three to four weeks.

Other amendments, such as calcium chloride, sulfuric acid, iron and aluminum sulfate, and lime sulphur, are not extensively used. These chemicals are usually expensive and not practical for use in the field.

IV. High Salt Water Dilution Method

This method is not much different from the conventional methods just discussed. In principle, the adsorbed sodium is also replaced by calcium. The major difference stems from the means used to supply calcium. In this method, calcium is obtained from the water used in a readily dissolved form, and can react after application. It involves :

(1) Recognition of the severity and extent of the sodic soil, as with conventional methods.

(2) Determination of the suitability of waters available from any source in the vicinity of the reclamation area.

(3) Testing for water transmission properties of the soil, as related to salt concentration of the water and the exchangeable sodium percentage and cation exchange capacity of the soil.

(4) Determination or estimates of the depth of water and time required for reclamation.

(5) Application of high salt water through successive dilutions down to a level of exchangeable sdoium which is not harmful for cropping.

(A) Theoretical Aspects of High Salt Water Dilution Method

The method depends upon the theory of cation exchange equilibria for soil-water systems. In this system, the adsorbed cations are in equilibrium with the cations in solution. This equilibrium can only be altered when cations of unequal valence are added by a solution.

During this equilibrium process, the added cations are adsorbed on the surface of soil particles, and an equal number of cations of unequal valence are displaced to the solution. The kind and amount of replaceable cations have great influence on the physical conditions of sodic soils. For instance, a soil high in cations of higher valence, as calcium, is usually flocculated, friable and porous, and air and water penetrate easily. Conversely, a soil high in sodium is single grained, deflocculated, puddled, hard and often impervious to water and air. Either of these conditions may develop, depending on the concentration and kind of cations in solution.

For these reasons, water with a high salt content and also relatively high in calcium is needed and preferred. Otherwise the flocculating effect of the water cannot be achieved to create and maintain a sufficient intake rate by the soil. The salt concentration of the water will decrease progressively through dilution to the usable level for irrigation.

In regard to dilutions, equilibrated ESP (exchangeable sodium percentage) is calculated by using the SAR (sodium adsorption ratio). According to R.C. Reeve and his co-workers, the SAR for nth. dilutions can be found by the equation:

$$SARn = SAR_o(dn)^{-\frac{1}{2}}$$

where SAR_o = sodium adsorption ratio of the high salt water originally used
dn = dilution factor obtained from the equation:

$$dn = Vw/Vs + 1$$

where Vw = volume of good water to be added for each dilution
Vs = original high salt water.

TABLE I

Physical and Chemical Properties of Soil

ANALYSIS	UNIT	DEPTH 0-30 cm.	30-60 cm.	60-120 cm.
PHYSICAL				
Saturation Percentage		110	100	60
Volume Weight	gr/cm³	1.67	1.61	1.2
PARTICLE SIZE DIST.				
Clay (2μ)	%	61.6	58.6	47.6
Silt (2-50μ)	%	12.6	15.6	14.7
Sand (50μ-2mm.)	%	25.8	25.8	37.7
CHEMICAL				
E.C.e (25°Cx.10³)	mmhos/cm	2.60	2.15	4.5
Ca+Mg	meq lit	1.5	1.41	5.27
Na	"	26.54	24.90	12.22
K	"	0.49	0.46	0.40
Cl	"	6.00	5.76	4.93
CO_3	"	4.00	1.94	0.00
HCO_3	"	5.00	8.76	6.14
Cation Exchange Capacity	meq/100gr.	16.70	16.46	18.2
Lime Content		High	High	High
pH of Sat. Paste of Soil		9.4	9.2	8.1
ESP	%	84	82	12

The estimated equilibrium ESPn is calculated from the equation:

$$ESPn = 100\ (SARn)/(1/k + SARn)$$

where k is a constant and can be taken between 0.010 and 0.025 $(me/lt)^{-\frac{1}{2}}$

(B) RECLAMATION EXPERIMENTS

For application of the method, a field study was made in 1966-67 in Pamukova, which is a proposed irrigation project located in north-western Anatolia. This study was conducted in the following steps:

(1) Soil examination was made and it was found that the sodium was uniformly distributed through the profile over an area of 1,000 hectares. It consisted of non-saline alkali or sodic soil and had a clay texture and no structure, except some cracks in some areas. The results of soil analysis are shown in Table 1. Measurements of laboratory permeabilities on disturbed samples were made. These results are shown graphically in Figure 1. Surface water regularly used for irrigation in this area was also used in the permeability test. Its chemical content is shown in Table 2.

(2) Both surface and ground water sources in the vicinity were investigated. Table 2 gives the analysis of these waters. Water no. 1 was the surface water currently used for irrigation in the area; the others were ground waters from depths between 20 and 70 meters below the surface. The dynamic level ranged from 4 to 16 meters.

Considering the ratio of Ca+Mg to the total cation concentration and degree of electrical conductivity and flow or pumping capacity, the first selection of waters suitable for reclamation was completed. Table 2 also shows the suitability of water for irrigation, reclamation and/or both.

(3) Infiltration tests were made using waters nos. 1, 4, 6, 8 and 9 at 10 cm. below ground surface on the sodic soils and on normal soils which had the same texture and nature. Intake rate readings for these measurements as

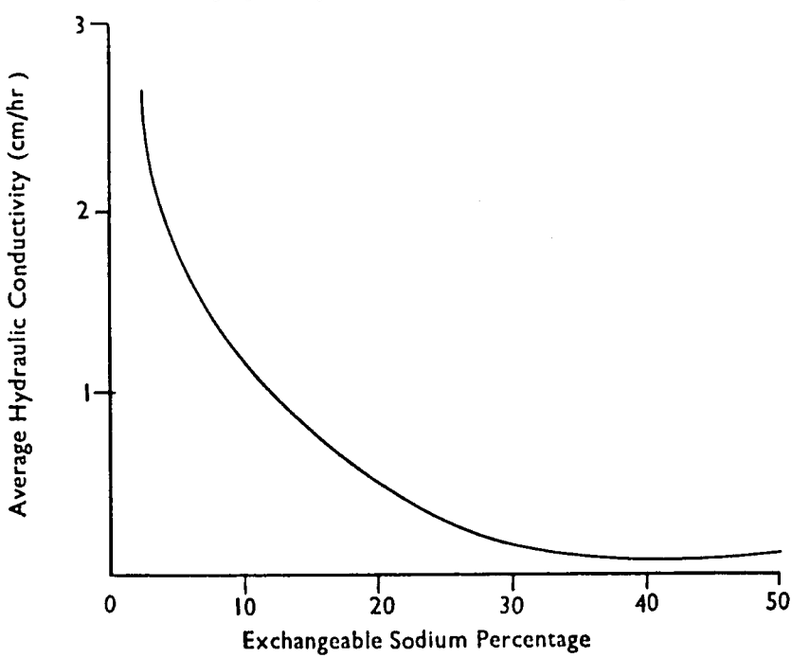


FIGURE 1. Hydraulic Conductivity of Disturbed Samples at 24 Hours vs. Exchangeable Sodium Percentage for CEC 10-20 meq/100 gr.

TABLE 2

Chemical Analyses of Waters Available in Experiment Area, and Calculated Equilibrium ESP for Soils with These Waters

No.	Water	Capacity (lit/sec)	ECx10^6	pH	Na	K	Ca+Mg	Total Cations (C)	Cl	SO_4	CO_3+ HCO_3	SAR	Calc. ESP	$\frac{Ca+Mg}{C}$	Use
					(meq./liter)										
1	Surface water	5.3	490	7.6	0.6	0.2	4.3	5.1	0.3	1.6	3.1	0.4	7	0.86	Irr.
2	Ground water	35.0	680	8.1	1.4	0.2	5.5	7.1	0.7	2.4	4.1	0.9	4	0.77	Irr.
3	" "	5	1000	7.7	1.6	0.2	7.8	9.6	1.3	3.2	5.2	0.8	4	0.81	Irr.Re.
4	" "	13.8	1250	7.4	2.0	0.2	10.5	12.7	1.3	5.6	5.8	0.9	4	0.83	Irr.Re.
5	" "	3.6	1400	7.6	2.1	0.2	12.6	14.9	1.5	3.7	9.7	0.8	5	0.85	Irr.Re.
6	" "	10.8	2950	8.0	1.5	0.1	28.0	29.6	14.2	12.2	3.1	0.4	2	0.95	Re.
7	" "	10.8	6100	8.2	24.9	1.0	36.1	61.9	19.1	35.1	7.7	5.8	29	0.59	Re.
8	" "	14.1	12500	7.9	45.7	0.3	81.0	127.0	50.0	71.9	5.1	7.2	31	0.64	Re.
9	" "	9.2	14100	8.1	97.7	0.4	43.0	141.0	50.0	83.8	7.2	21.0	25	0.30	Re.

Abbreviations : Irr.=Irrigation Water; Re.=Reclamation Water; C=Total Cation Concentration.

a function of salt concentration of water are shown in Table 3. The same data is presented graphically in Figure 2. After evaluating intake rates and considering such conditions as distance, yield, topographical positions, etc., ground water no. 9 (with a total cation concentration of 141 meq/lit.) was selected as the high salt water to be used for reclamation.

TABLE 3

Water Intake Rates for Various Concentrations of Water on Sodic Soil in Experiment Area

SOIL	Salt Concentration (meq/lit.)				
	5	13	30	127	141
	Average Intake Rate (cm/hr.)				
NORMAL	3	2.5	2	—	—
SODIC	0.05	0.08	0.15	0.41	0.42

(4) To determine the volume of water required, a pit was dug leaving an undisturbed soil column 1 m. in diameter and 60 cm. in depth. A cylinder was placed over the column to a depth of 60 cm., and 35 cm. of the cylinder was left above the ground surface. This was to enable the water to be ponded on the soil surface. The soil was tamped around the inside face of the cylinder to eliminate leakage down the face of the cylinder. Evaporation losses were measured from a pan having the same diameter and water ponding depth as that used during the infiltration test.

(5) In each experiment, water to a depth of 25 cm. was ponded in the cylinder and progressive application was maintained, until ESP of the soil reached the estimated equilibrium ESP from applied high salt water and/or diluted solutions steps.

(6) Soil samples were first taken after 50 cm. of water had percolated; then at intervals following every 25 cm. depth of water treatment from each 30 cm. depth of profile.

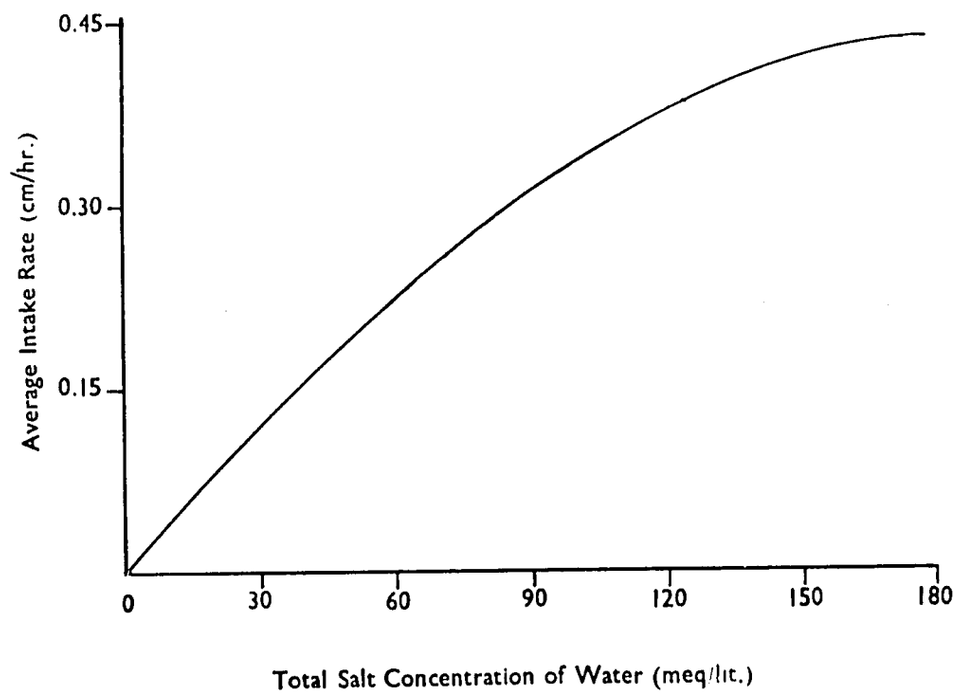


FIGURE 2. Water Intake Rate vs. Salt Concentration of Water

(7) During treatment the following dilution series were used :

Dilution ratio	Dilution number (n)	Dilution factor (dn)	Cation concentration (meq/lit)	Ca+Mg in solution (meq/lit)	Na in solution (meq/lit)	SAR (meq/lit)	Estimated ESP
Ground water no. 9	0	1	141.0	43.0	97.7	21.0	25
1+1	1	2	70.5	21.2	49.0	14.9	18
1+3	2	4	35.0	10.0	20.0	10.5	14
1+7	3	8	17.5	5.0	12.5	7.5	10

(8) When equilibrium was reached for the estimated ESP in the soil, the depth of water applied for that step was calculated. Correction in depth was made by subtracting the amount lost through evaporation from the actual depth applied.

(9) Following completion of the above studies a field plot of 1250 m^2 was established. For drainage of the plot, deep open canals were constructed.

(10) The results from the cylinder study indicated the desired treatment.

(11) When leaching was complete the plot was divided into four parcels, which, after the application of chemical fertilizers, were planted to barley, agropyron elongatum, wheat and alfalfa. These were irrigated by surface water (no. 1) as needed.

(C) Results and Discussion

Data from Table 1 indicates that the soils treated were very poor in chemical and physical properties. Results from the treatment have been satisfactory.

TABLE 4

Depth of Water Percolated, Time for Ponding and Intake Rates with Various Concentrations of Water

Water used	Dilution step	Water concentration (meq/lit)	Estimated equilibrium ESP (%)	Depth of water used*		Average intake rate (cm/day)
				cylinder (cm 60)	field plot (cm/soil)	
Ground water no. 9		141.0	25	250	300	10.0
"	1	70.5	18	175	225	7.5
"	2	35.0	14	225	300	6.0
"	3	17.5	10	150	200**	5.9
			Total	800	1025	

*The depth of evaporation is not included in the figures presented.
**This was not obtained in the field plot. Value is estimated.

Estimated equilibrium ESP and depth of waters used for equilibration are presented in Table 4.

A total depth of 800 cm. of water was applied in the cylinder for a decrease in ESP from 84 per cent to 10 per cent.

In the field plot, 1025 cm. depth of water was applied to achieve the same decrease in ESP. The difference in depth of water between the two treatments was about 20 per cent. This was probably caused by cracks and other openings in the field, or compaction of the soil in the cylinder.

During the equilibration of exchangeable sodium, values found in the field were always slightly higher than the calculated ESP values. These values are given in Table 5.

TABLE 5

Calculated and Actual Equilibrium Exchangeable Sodium Percentage

Water and Dilution Used	Concentration (meq/lit)	Calculated Equilibrium ESP	Actual Equilibrium ESP	Depth of Profile (cm)
Ground Water	141	25	29	0-60
" (1st. dilution)	70.5	18	21	0-60
" (2nd. dilution)	35.0	14	15	0-60

This lower value was probably due to under estimation of the soil exchange factor or uneven displacement of exchangeable sodium under leaching.

Below 60 cm. depth of the profile, exchangeable sodium status was as low as 20 per cent. After treatment, about 4 per cent decrease was found.

Reclamation with this high salt ground water and its dilutions by surface irrigation water was completed in about five months. This included a 3-4 day waiting period at the end of each dilution step and the time allowed for preparatory works. Intake rates decreased from 10.0 cm/day to 5.9 cm/day during the leaching period, and remained unchanged when surface irrigation water was applied following reclamation. For this reason, further dilution steps were not conducted. To reduce the salts, which were around 8 mmhos/cm. and had accumulated from the original water, one meter depth of surface irrigation water was applied.

Establishing growth and yield on winter wheat, barley and agropyron elongatum was satisfactory. Alfalfa germination and growth were uneven and unsuccessful. Yields of wheat and barley were 2 and 5 tons/ha. respectively for the first year.

Hay obtained from agropyron elongatum was 7.0 tons (dry weight) per hectare. Failure of the alfalfa was probably the result of a heavy application of water which killed aerobic bacteria.

V. Comparison of High Salt Water Dilution and Conventional Methods

A comparative study of the two methods was made in the same area. For the conventional method, gypsum was chosen as the amendment. The intake rate of the soil under gypsum saturated surface water (no. 1) was 0.2 cm. per day, with a cation concentration of 36 meq/lit. Calculations indicated that 100 tons of gypsum per hectare would be required to reclaim the same soil to the same depth, but only 50 tons per hectare were added for economic reasons. At the end of one year, 200 cm. of water were applied and the ESP reduced from 84 per cent to 26 per cent in the first 15 cm. depth of soil only. In the lower depths of the profile, the ESP either remained the same or increased slightly. From this result it was concluded that at least four years would be required for complete reclamation.

For a cost appraisal of the two methods the following differences should be considered:

Steps	Gypsum Application	High Salt Water Dilution
Preparation of land	Needed	Needed
Supply of amendment	Needed	Not needed
Grinding gypsum	Needed	Not needed
Transportation of gypsum	Needed	Not needed
Incorporation of amendment with soil	Needed	Not needed
Leaching	Needed	May be needed
Availability of high salt water	Not needed	Needed
Availability of low salt water	Needed	Needed

Cost figures taken from actual practices are presented in Table 6.

It can be observed from Table 6 that the cost of reclamation by the high salt water dilution method is six times less than by gypsum application. If high salt water had not been supplied from an artesian well, the cost of pumping and amortization or rent of pump would need to have been added. This method, when applicable, has considerable advantages over conventional methods, among these being less time, lower cost and higher efficiency.

VI. Minimum Requirement for Application of High Salt Water Dilution

On the basis of the experiment explained above and additional studies carried out in the laboratory and with lysimeters, the recommendations as to the minimum requirements for waters to be used in reclamation can be summarized as follows :

(A) The high salt water available should have these characteristics :

(1) A concentration to create an intake rate of 2.5 cm. or more per day.

(2) The ratio of the divalent cations Ca + Mg to the monovalent cations Na + K must be 0.40 or more, preferably with a calcium content equal to or greater than Mg.

(3) The $CO_3 + HCO_3$ content of the salt water should preferably be less than the Ca + Mg.

(4) The calculated ESP from equilibration of the salt water must be less than the ESP of the soil to be reclaimed.

(B) The distance to the reclamation area, and depth to dynamic level for free and semi-artesian ground waters must be within the economic limits determined for given conditions

TABLE 6

Comparative Costs of High Salt Water Dilution and Gypsum Application for Sodic Soil Reclamation (1)

Type of practice	Gypsum application	High salt water dilution (2)
	TL/DECARE	
Plowing	10.00	10.00
Bordering	15.00	15.00
Light leveling	7.50	7.50
Gypsum (5 tons @ 110 TL/ton)	550.00	—
Transportation of gypsum (distance of 40 km.)	200.00	—
Broadcasting and incorporation of gypsum	15.00	—
Labor for water application etc.	20.00	100.00
TOTAL	817.50	132.50

(1) Cost of drainage is not included, as this is the same for both methods.
(2) High salt water was obtained from an artesian well; otherwise the cost of pumping and/or transportation will need to be included.

(C) A source of low electrolytic water to be used in dilution must be available, and the concentration must be less than 20 meq/lit.

(D) The volume of the salt and dilution waters must be sufficient for the maximum dilution needed for the size of the area assumed to be practical to work on as a parcel in the reclamation area.

VII. Conditions for Use of High Salt Water Dilution Method in Turkey

Natural conditions for use of the high salt water dilution method are generally favorable in Turkey. In a majority of the irrigation projects ample saline and ground waters are available. In reclamation areas generally, the water can be supplied from surface and/or ground water resources.

Most of the surface waters have qualities that make them suitable for dilution as well as for irrigation. Adequate quantities of these waters can be had when the high flow or dead season is chosen for treatment. Underground and sea waters are the best sources of original high salt water in Turkey. It is always possible to find one of these two sources in saline and/or sodic soil areas.

Due to the abundance of readily soluble limestone, calcium is the predominating cation in ground waters in Turkey and may reach a concentration of 100 meq/lit. or more. At the same time, the total cation concentrations are generally high due to the lack of natural drainage and subsurface flow in low-lying areas. Sometimes the concentration goes up to 1,500 meq/lit., which is twice the concentration of the Mediterranean and Black Sea waters.

It is difficult to assess such conditions of ground water as depth, yield and pressure, unless investigation is made and the location is known. Depending upon previous ground water investigations, it may be concluded that the depth to the dynamic level of ground water is from 4 to over 100 meters, and that yields range from 2 to over 50 liters per second. The most important difficulty or disadvantage is the deficiency of power for pumping water where the ground water is not by artesian flow. For this condition, diesel pumps and/or pumps run by means of tractors and small engines can be successfully used.

Turkey is surrounded by the sea on three sides. Sea water can be another source of high salt water for the low-lying coastal areas.

To estimate the benefits from utilization of high salt waters for reclamation of sodic soils, the State Hydraulic Works has begun a program of collecting and evaluating data relating to salt waters in connection with land classification, drainage and underground water investigations.

Chapter XII

FIELD TRIPS

The Seventh NESA Irrigation Practices Seminar field trips were taken on September 28 and 29. The first trip was to Salinity Control and Reclamation Project (SCARP) No. 1, the Chakanwali reclamation station, and the Qadirabad headworks and link canal. The second trip was to the recently completed Mangla dam and power plant.

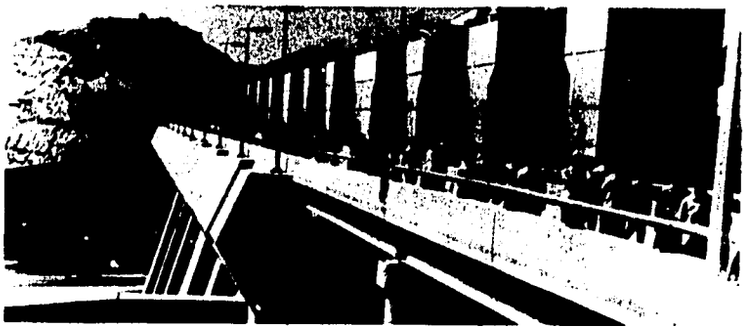
Several sight-seeing tours and visits made in Lahore included the BECO Pump and Engineering Works, Packages Limited, the Badshahi Mosque, the Old Fort, Jehangir's Tomb, Pakistan Memorial, Shalimar Gardens and Rana Tractor Assembly Plant, all of which were educational and enjoyed.

SCARP and Chakanwali Tour

The first stop on this tour was at tubewell KD 210, which is typical of most of the 2,200 tubewells in the area. Most of the watercourse from this well has been rehabilitated and the latest in bifurcation structures used. The Engineering Wing had charts and graphs to show the increase in water supply, and also the fact that the water table had been lowered from an average of about six feet in 1962 to a present level of about twenty feet. This has eliminated water-logging in the project area.

The second stop of this tour was at a private farm belonging to Chaudhry Rafi, where water was being supplied from three sources: canal, government tubewell powered by electricity and a private diesel-powered tubewell.

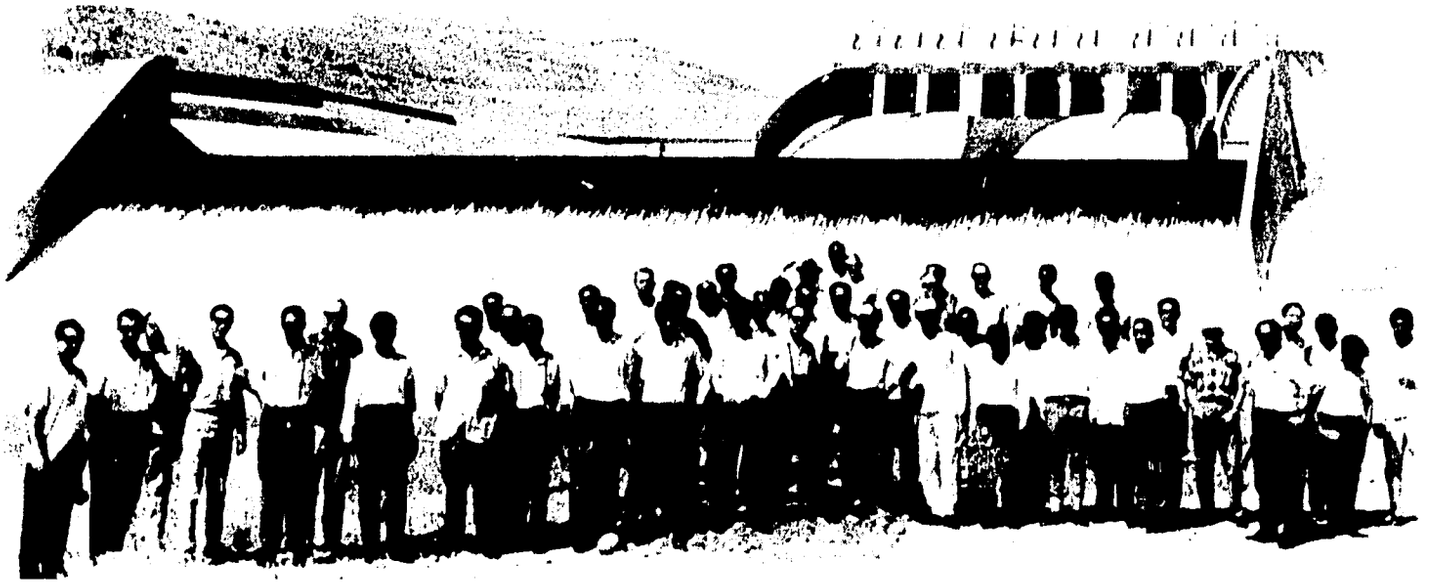
The farmer explained how he had reclaimed his entire farm from a salt flat, and quoted yield data that was over double the national average. The agricultural staff further explained that over 425,000 acres in the project area were out of cultivation at the beginning of the project (1962), and



that in six years about 250,000 acres had been returned to profitable production. It was also pointed out that in the same six years the area food production has increased threefold. Some excellent fields of *basmati* rice were to be seen on this private farm.

The third stop was at the Chakanwali reclamation experiment station, which is located a few miles northeast of the SCARP. This station exists for the primary purpose of determining how to live with water-logging and salinity. Excellent crops were being grown on lands with water tables less than three feet from the surface. Much has been learned at this station that can be used in the interim period before more expensive means of controlling water-logging can be established. A hearty lunch completed our stay at Chakanwali, compliments of the Reclamation Directorate.

Mangla Dam

The trip to Mangla dam was of special interest as it is the largest hydro-electric and irrigation storage project in Pakistan. It was officially completed this past year nearly two years ahead of schedule.

The delegates were shown all of the structures involved and given an excellent tour of the powerhouse, where three generators are "on the line" and a fourth generator is being installed.