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SEMINAR ON

CENTO

agricultural aspects of arid and semi-arid zones

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held in TEHRAN, IRAN, September 19-23 1971

CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones

Tehran, Iran
September 19-23, 1971

CENTRAL TREATY ORGANIZATION
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FOREWORD

The prosperity and future development of any nation depend largely on its land and water resources. These determine the level of human sustenance and, to a considerable degree, a nation's economic viability. With population on the increase throughout the world, it becomes increasingly important to improve and intensify agricultural production.

The pressures brought upon each nation to feed more people have gradually shifted the significance of food production to the arid and semi-arid lands. The limiting factor for any intensive agricultural production of these drylands is the scarcity of available water. Thus the delicate balance which exists between limited resources of water, soil and vegetation in arid zones makes necessary the development of priorities for research in developing dryland crops.

With the exception of a few isolated projects that are being developed in the Middle East, research efforts devoted to the problems and prospects of arid zone agriculture have been sadly inadequate.

Since one of the main objectives of the Central Treaty Organization is the economic development of the regional countries, the CENTO Economic Experts in January 1971 recommended that a seminar on the agricultural aspects of arid and semi-arid zones be included in the annual schedule of events. The recommendation was approved by the Eighteenth Meeting of the Economic Committee, held in London in March.

The Government of Iran offered conference facilities at the Soil Institute of Iran, and the four-day seminar took place in Tehran from September 19 to 23, 1971. Organizational and financial support were provided by the Office of the United States Economic Coordinator for CENTO Affairs.

Forty-six delegates from Iran, Turkey, the United Kingdom and the United States attended the seminar. Last minute administrative problems prevented the Pakistan delegation from attending the seminar.

The purposes of the seminar were to:

* Review the resources development and research results of the cooperating countries

* Exchange information on the management of arid and semi-arid lands of the CENTO countries

* Identify the most urgent research needs

* Encourage cooperative research on problems of mutual concern and exchange information gained from such endeavors.

This seminar is the first in its own series. It is hoped that through the sharing of not only similar problems but research and educational programs, these countries can achieve a forward step in improving the well-being of their peoples.

All the papers presented at the seminar are included at least in part, although portions of some of them have been deleted or edited to meet printing requirements.

TABLE OF CONTENTS

Foreword 1

Address of Welcome 6
by H. E. Mr. Hossain Mir Haidar, Ministry of Agriculture

Opening Remarks 8
by H. E. Mr. Turgut Menemencioğlu, Secretary General, CENTO, deli vered by Mr. Mostafa Modjtahedi

Opening Addresses
by Dr. Şahap Elçi, Ankara University 9

Dr. C. E. Johnson, Middle East Development Division 10

Dr. Howard B. Peterson, University of Utah 11

KEYNOTE ADDRESS:
Improving Farm Production in Regions of Limited Rainfall 12
by Dr. Omer J. Kelley, USAID/Washington, D.C.

CENTO Report on the Seminar 25

COUNTRY REPORTS

The Arid Zone Problems in Turkey 45
by Dr. Şahap Elçi, Ankara University

Agricultural Aspects of Arid and Semi-Arid Zones in Iran 52
by Mr. A. F. Mahdavi, Ministry of Agriculture

Measures for Better Utilization of Irrigation Potential in the Arid and Semi-Arid Zones of West Pakistan 61
by Mr. Syed Mohammad Ayoob and Mr. Irshad Ahmad, Irrigation Institute, Lahore

PAPERS PRESENTED BY THE DELEGATES

The Summer Fallow System 91
by Mr. Thomas G. Zinn, USAID/Turkey

Vegetation of Central Anatolia and Its Ecology 109
by Professor Rıza Çetik, Ankara University

Problems in Natural Resources Administration in Iran 129
by Mr. Fereidoon Niknam and Mr. Nowzar Seraj, Ministry of Natural Resources

Land and Water Resource Development for Crop Production in Turkey 138
by Dr. Ali Balaban, Ankara University

The Distribution, Value and Management of the Natural Vegetation of Iran 151
by Mr. M. J. Meimandi-Nejad, University of Tehran

Erosion Control and Vegetative Cover Under Dryland Conditions in Turkey 159
by Dr. Selman Uslu, University of Istanbul

Soil and Water Conservation on Arable Lands 164
by Mr. A. Ganjini and Mr. B. Azimi, Soil Institute, Tehran

Wheat Production Problems and Potentials on Drylands 172
by Dr. Ahmet Demirliçakmak, Wheat Research and Training Center, Ankara

Systematic Land Resources Inventories as a Tool for Agricultural Development and Proper Land Uses 179
by Mr. M. Bordbar, Soil Institute, Tehran

Water Requirements of Various Crops in Arid and Semi-Arid Zones of Turkey 191
by Mr. Özdemir Beyce, Soil Conservation Research Institute, Ankara

Possibilities of Supply and Proper Use of Water in the Garmsar Area 212
by Mr. B. Yazdani, Ministry of Water and Power, Tehran

Evaluation of the Hydrological Aspects of the Agricultural Studies in Arid and Semi-Arid Zones of Turkey 225
by Dr. Osman Tekinel, University of Ankara

General Report on Development and Utilization of Saline Soils in Iran 248
by Mr. A. Ghobadian and Mr. H. Siadat, Jondi Shahpour University

Effect of Rate and Time of Application of Nitrogenous Fertilizer on the Efficiency of Nitrogen Uptake by Wheat 258
by Dr. Nazmi Ülgen, Soil and Fertilizer Research Institute, Ankara

Systems Analysis: a Decision-Making Tool for Arid Land Development 268
by Dr. Martin M. Fogel, University of Arizona

Irrigation Waters of the Indus Plains and Their Salt Load 278
by Mr. S. B. Hasan and Mr. M. A. Hafeez Khan, West Pakistan

List of Delegates 296

List of U.S.-Sponsored Economic Publications 302

ADDRESS OF WELCOME

by H.E. Mr. Hossain Mir Haidar,

Undersecretary, Ministry of Agriculture

for Research and Technical Affairs, Tehran

It is my pleasure to extend a warm welcome to all of you who have gathered here to participate in the deliberations of the Seminar on Agricultural Aspects of Arid and Semi-Arid Zones. We are honoured that Iran has been selected as the host country.

The prosperity and future development of any nation depend largely on its land and water resources. These determine the level of human sustenance and, to a considerable degree, a nation's economic viability. With increasing population pressures throughout the world, it becomes increasingly important to improve and intensify agricultural production if a world food shortage and human malnutrition are to be avoided.

In this context, therefore, His Imperial Majesty Shahanshah Aryamehr has allocated an ever-increasing priority to the agricultural development of Iran. In areas of the country which are well endowed with soil and water resources progress has been rapid and productivity has shown a consistent annual improvement with improved methods of soil and water management. However, by far the larger part of Iran's land surface is of an arid or semi-arid nature with inadequate water resources; productivity within such areas is unsatisfactory and highly variable from year to year.

With the exception of a project launched some years ago by UNESCO the research effort devoted to the problems and prospects of arid zone agriculture has been sadly inadequate. It is in this context that your deliberations will have real and meaningful significance to us in Iran and adjoining countries.

I would request you to give special consideration to some of the following aspects:

Water being the most scarce factor in arid areas, methods for optimizing its use must receive the highest priority. It is not only a matter of quantity of water, but also its quality that needs attention.

Water frequently available in arid zones cannot be used for con-

ventional cropping regimes because of its high salt content. In such cases, emphasis could be placed on a search for salt-tolerant forage crops suitable as food for sheep and cattle production. Views on the feasibility of such projects, especially in terms of economic return, would be a matter of great interest.

It is also well known that the pistachio tree has a high degree of tolerance to saline irrigation water, but little has been done to quantify this crop's tolerance limits and its nutrient requirements. Attention needs to be focused on this lucrative crop, so eminently suited to arid zone culture, as well as on other later introductions such as olives which show great promise in some parts of Iran.

Soil surveys, land resource inventories and land classification are essential for assessment of the capability of arid lands to increase and sustain agricultural productivity. Development of suitable cropping patterns for different land classes is needed for economic and efficient land use planning. At the same time there is a concurrent need to assess the usefulness of such land classification in economic development; presently used criteria may be inadequate and may need to be modified in the light of practical experience.

Wheat is the most important crop of Iran, but nearly two-thirds of the area under this crop is dry farmed. Improvement in the productivity of dry farmed wheat by suitable soil and moisture conservation methods is required. The possibility of growing drought resistant or drought escaping forage and legume catch crops should be more intensively explored with the intention of obtaining a greater economic stability in many areas now regarded as marginal.

The delicate balance which exists between the limited resources of water, soil and vegetation in arid zones makes it necessary to develop well considered strategies in terms of soil and moisture conservation. To do this, a more detailed evaluation is needed of actual soil and water losses and integrated regional measures are desirable to quantify the various factors involved. Special factors which merit consideration are better watershed management, storage of water and the measurement of the rate of soil erosion in certain key areas.

My colleagues and I hope to benefit greatly from the discussions to be held at this seminar and we are ready to cooperate in joint programmes for the development of agriculture within the arid zones of the region. I hope that due consideration will be given not only to the technical aspects of the development of agriculture in the arid zones, but also its economic feasibility and integration with the development of agriculture in the countries of the region as a whole.

OPENING REMARKS

by Mr. Mostafa Modjtahedi,

Assistant Economic Secretary,

on behalf of

H.E. Mr. Turgut Menemencioğlu,
Secretary General, CENTO

We just heard the enlightening address by His Excellency, Mr.Hossain Mir Haidar, Undersecretary of the Ministry of Agriculture, and now on behalf of His Excellency, Mr. Turgut Menemencioğlu, the Secretary General of the Central Treaty Organization and myself, I would like to welcome you to this very first Seminar on Agricultural Aspects of Arid and Semi-Arid Zones. I would like to take this opportunity to thank the Government of Iran for having facilitated us with their kind and generous help for this meeting. At the same time our appreciation should go to the Office of the United States Economic Coordinator for CENTO Affairs in Ankara for their assistance in the formation of this seminar.

As we all know, one of the main objectives of CENTO is the economic development of the region. For achieving that objective, our organization has brought about many programs in various fields with a wide variety of aims. In many aspects of our economic development programmes we have been successful in forming seminars, symposia, workshops and training programmes, all with satisfactory results.

The scope of CENTO economic development projects, for instance, includes the railway, the highways, microwave, civil aviation, improvement of ports, geological development, various agricultural projects and animal husbandry, health projects and scientific and educational programmes.

As we gather here as the representatives of the member governments of the Central Treaty Organization, we feel confident that this seminar in this aspect of the field of agriculture which is the first of a series, will be another success for us and will bring us a step closer to our objectives--the improvement of the lot of our peoples and the creation of a good life through international cooperation.

OPENING ADDRESS

by Dr. Şahap Elçi,

Professor,

Faculty of Agriculture,

Ankara University

I do not know how I can explain the feeling that I have this morning, because all of us who are here came in order to discuss a problem of the CENTO countries; this problem really concerns the economic aspects of these countries, especially the possibility of advancing our economy. Then we have to think about what the problems are and how we can solve them, and after this what we will do as a people, and the people have to think how they should help each other. In this seminar I hope we will discuss different aspects of our different problems.

I am sure in this seminar there are many people who know better one side of their own problem, but whenever you get them together thus you will have a kind of effort from which you can get better economical and agricultural production. Finally you could help not only your country, but you may have a possibility of helping all of the world. This is why I think this kind of meeting is very important from the viewpoint of world population, not simply individual countries. This is my own belief, that whenever you have one person you can do one thing. On the other hand, whenever you have several, then you can make a huge beneficial improvement in your problems. This is why I give very high credit to these meetings which are always fruitful for the people who are enrolled in them.

In my opinion the host country is having a very difficult and important task when it organizes this kind of meeting. That is why I am thankful to the Government of Iran and to other responsible people who prepared this very fine meeting and provided facilities for us. On the other hand, I am grateful to the Central Treaty Organization and the United States of America in that they prepared this meeting to get us together to explain our problems and discuss them in detail.

OPENING ADDRESS

by Mr. C.E. Johnson, CBE,

Adviser on Agriculture,

Middle East Development Division,

Beirut

On behalf of the Government of the United Kingdom, may I say how pleased we are to be here in Tehran at this very pleasant time of year. Your dry climate which provides the theme for our discussions also gives us a very pleasant environment, especially at this time of year, and we are very glad to be here. It is a different climate from our own country. This is also a time when the people of Iran are remembering their very long history. Twenty-five hundred years ago when the Iranian civilization was first being developed the agricultural conditions for many of the farmers in the arid and semi-arid zones that stretch across this whole region were not very much different from what they are today. In many ways these people have missed out on the Green Revolution that has made such a big impact in other parts of the area. The new varieties and the new agricultural technologies that have resulted from the brilliant research work that has been carried out over a number of years by people like Dr. Norman Borlang and his many associates has so far had less impact than the area where there is a good rainfall or irrigation and the arid and semi-arid zones are still waiting for their green revolution. It is to the problems and the possibilities of bringing new technologies to these areas that we shall be giving our attention in the next few days.

We are very pleased, as I say, to take part in this. We would like to express our appreciation to the Government of Iran as our hosts for the meeting, to the Government of the United States of America for sponsoring and accomodating this conference and to the Central Treaty Organization Secretariat for making all the administrative arrangements. We hope for a very pleasant and successful meeting.

OPENING ADDRESS

by Dr. Howard B. Peterson,

Professor of Irrigation,

University of Utah

It is my pleasure to represent the delegates of the United States in expressing our appreciation and reiterating the excellent expressions of the delegates from Turkey and the United Kingdom. We appreciate the many efforts that have gone into arranging for and conducting this seminar.

We realize that scientists universally appreciate the opportunity of getting together and exchanging ideas. You have made this possible in bringing us together where we will discuss problems related to the complicated life in the arid and semi-arid zones. It is our hope and dedication that we will make the best use of all these facilities and arrangements that the host country and the members of the Secretariat have provided for us. We also hope we will justify the confidence that you have placed in us by going to this effort of bringing this conference to production. I express our hearty appreciation for these delightful surroundings, and all of the very nice things that you have done and will continue to do throughout this conference.

KEYNOTE ADDRESS

IMPROVING FARM PRODUCTION IN REGIONS OF LIMITED RAINFALL

by Dr. Omer J. Kelley,
Director, Office of Agriculture and Fisheries,
Bureau for Technical Assistance,
Agency for International Development, Washington, D. C.

INTRODUCTION

Many of the agricultural lands of the CENTO countries have limited annual precipitation and farming systems should be oriented toward making the most effective use of the available moisture. In recent decades a great deal has been learned about moisture conservation in dryland farming regions around the world, but only partial application of this modern technology has been made in a majority of the areas where moisture supply is the dominant factor in agricultural productivity. There is a natural tendency to resort to irrigation in dry regions, wherever water can be provided at reasonable cost, on lands suited to irrigation. However, the CENTO countries have vast areas of lands that are arable but must be farmed with natural rainfall. The extent of these lands is indicated in Table 1.

TABLE 1. LAND USE IN CENTO COUNTRIES
(Data from 1969 FAO Yearbook)
(in 1,000 hectares)

Land Use	Iran	Pakistan	Turkey
Total land area	163,600	94,672	77,076
Permanent grasslands	6,741	(not reported)	26,135
Arable lands and perennial crops	11,593	28,214	26,601
Irrigated lands	4,651	12,043	1,549
Lands farmed without irrigation	6,942	26,171	25,052

Notes: (1) Semi-arid and arid lands are not included in the above areas.
(2) The permanent grasslands are usually associated with cropped areas and these grasslands should be recognized as integral components of dryland farming systems.

ECOLOGICAL ZONES OF LIMITED RAINFALL

Rainfall amount and distribution through the year are fairly reliable guides to the potential productivity of arable lands in regions of limited rainfall. Average rainfall must be considered in conjunction with the nature of the soils, their moisture retention and supplying properties in each region or locality. Soil types with inferior moisture retention and supplying power should not be cropped, and are best utilized as permanent grasslands or woodlands. The rainfall zones may be described as follows:

Ecological Categories	Annual Precipitation
Wet/dry humid	1,000 - 2,000 mm. (40-80 inches)
Subhumid	500 - 1,000 mm. (20-40 inches)
Semi-arid	250 - 500 mm. (10-20 inches)

It is characteristic of low rainfall areas that the lower the total amount, the more erratic and less dependable is the occurrence of the rainfall. Within each ecological zone, the quality of the soil in retaining rainfall for plant use becomes more important as the total rainfall declines in amount. It is clear that effective application of modern technology to dryland farming requires *first*, reliable data on precipitation, and *second*, reasonably accurate soil mapping to delineate the soil types that are responsive to moisture conservation practices. In the CENTO countries, the season when precipitation occurs is important. Precipitation in the cool season is less likely to be lost by evaporation from the soil, and transpiration losses by leaves of crop plants are reduced because of lower temperatures, so that plant responses are more efficient than with the same amount of moisture at higher temperatures. Efforts should be made to capitalize on such advantages by growing cool season crops when feasible.

PRINCIPLES OF DRYLAND FARMING

The basic researches in other dryland farming regions of the world have resulted in a body of principles and practices that warrant rather intensely applied research in individual countries, to determine how best to capitalize on these recent advances in our knowledge.

Wherever the total amount of the distribution of rainfall is a principal limiting factor in crop production, farming practices should emphasize two objectives:

1) Conserve rainfall by reducing runoff losses, and by storing as much as possible in the soil profile for use by crop roots.

2) Invoke farm practices to make the most efficient use of the soil moisture by crop plants.

In meeting both objectives, adjustments in land and crop management should be made: a) to the predicted or normal seasonal occurrence and amounts of rainfall, b) to the characteristics of local soils and their water storing capability, c)to the kinds of crops that are adapted to climate and soil conditions, and d) to feasible changes in local cultural practices. Although moisture supply is the basic constraint in farming in the drier regions, and little can be done to increase rainfall, there are real opportunities to more effectively use the rainfall that occurs. The following illustrations deal with research findings believed to have applicability to CENTO countries.

Conserving Rainfall

Protect against runoff losses

The onset of seasonal rains is often characterized by heavy showers, with rains falling faster than the soil can absorb it, resulting in substantial runoff losses, as well as erosion losses of topsoil. Steeper slopes and impervious soils accentuate runoff losses. Practical ways must be found for slowing down surface water movement and for increasing the infiltration rates into the soil. Contour plantings of crops in rows that run across field slopes, instead of up and down, is helpful. Contour strips of different kinds of crops, with different dates of planting, will reduce runoff losses. If farming systems can be devised, with alternating strips of solid plantings of such species as alfalfa and grass, with tilled annual crops, very substantial control of runoff losses can be achieved. The sod crops may be harvested and sold as hay in some localities, or used as feed for farm livestock. After two or more seasons the sod land is returned to tilled crops, usually leaving greatly improved soil structure, increased permeability to rainfall and substantially deeper rooting of the subsequent annual tilled crop.

Storing water in the soil

The objective in drier regions is to store as much water as possible in the soil profile. Crop residues, manure applications, or mulches have been used to improve the rate at which water will enter the soil in bare fields, and in new plantings when young plants provide little cover. These surface treatments also reduce evaporation from the soil surface. However, the inherent physical characteristics of the soil are very important; which is the reason for reasonably accurate

mapping of the kinds of soils present in every important farming region. Soil texture, soil depth as it relates to the rooting zone, and the soil structure all affect water storage in the soil profile. Silt loam and other loamy soils may store the equivalent of 25 to 75 mm. of rain per 30 centimeters of depth. Thus soils with 60 centimeters of rooting depth may store as much as 150 mm. (6 inches) of rainfall. When such soils are filled with moisture following rains, this moisture may be a major factor in successfully maturing a growing crop. In subhumid areas where rainfall occurrence is irregular at best, the capacity of soils to admit and store intermittent rains is a crucial factor in sustaining crop growth and enhancing final yields.

Crop yields with increased soil moisture

The benefits of increased soil moisture were measured in the Great Plains of the United States, with the following results. With grain sorghum as the test crop, 230 mm. of water were required before any grain was produced on the plants. The next 25 mm. of water(1 inch) produced 190-250 kg/ha. Increasing the water supply produced greater and greater yields.

Available water	Total Average Sorghum Grain Yield
230 mm.	- kg./ha.
255 "	120 " "
305 "	900 " "
355 "	2,000 " "
405 "	3,750 " "
455 "	5,800 " "

These results were obtained on soils of moderate to good fertility, using an improved variety, grown without weeds, at a season when temperatures permitted good response to increasing amounts of available water.

Further mention should be made of perennial grasses and legumes for improving soil permeability to rainfall, and for deepening the zone for moisture storage and subsequent rooting by annual crops. The beneficial effects on soil structure of grass and legume sods (alfalfa and/or clovers) usually persist for several years after the sod is plowed for annual crop production. During the time the sod crop occupies the land, the rainfall losses are reduced or completely stopped, and moisture is stored in the soil. Not only is there an important place for such sod crops in rotation with tilled crops, but on some soil types that are too erosive, too shallow, or too stony for tillage, these sod crops may be substantially more productive than tilled crops. Sod fields may be used as pasture to support livestock, produce hay for sale, or provide feed for dry seasons. As feed for livestock,

sod lands can diversify farming systems and increase total farm incomes.

Snow conservation

Snow conservation should be given attention at higher altitudes where appreciable amounts of snow occur. Snow is effectively held in place on arable lands despite strong winds, on lands occupied by standing crop stubble, and by dormant sods of grass-legume forages. The plant roots, both living and dead, are effective in keeping the soil profile permeable to water penetration from snow melts, even though soils are frozen. Holding the snow in place depends largely on the presence of stubble or other plant cover, tall enough to hold the snowfall, instead of permitting winds to blow it off lands into gullies or other depressions where it cannot benefit subsequent crops on the fields.

Wind erosion

Maintaining stubble or other types of mulch during the cold seasons has another great benefit; this vegetative cover effectively prevents wind erosion during the periods when land is not occupied by crops. Wind erosion is a constant hazard at all seasons in regions of limited rainfall, and the long-time effects are losses of top soil and reduction in soil fertility. These losses have been well documented in various world regions, and a variety of measures, in addition to vegetative cover, have been proven useful. Tillage to provide cloddy, rough soil surfaces, planting windbreaks, and alternating strips of different types of crops have all been used effectively.

Terracing tilled lands

Terracing of lands has been used by the ancients to control undesired water and soil movement in humid regions where there is intensive cultivation. Terracing of lands in regions of limited rainfall is a more recent practice, but it has now been used quite widely and with great benefit where farm power is available. Movement of relatively large amounts of soil at low cost is possible with appropriate tractor power. Usually, government subsidies are a necessary stimulus to terracing on a large enough scale to affect farm productivity in a region. The design of terraces has proved to be very important. The "conservation bench terrace" developed and widely used in the United States is locally modified to adjust to the average annual precipitation, the observed runoff, the local soil characteristics, the temperatures in crop growing seasons, and the types of crops grown. The results of 10 years of tests (Hauser, 1968) indicated that well planned conservation bench terraces increased crop production one and one-half times that of level terraces, which in turn had greatly increased yields over lands not terraced but with the same total rainfall. On one long-term experiment

the underterraced land produced 350 kg./ha. of grain sorghum, fallowing the land without terracing increased yields to 1,390 kg./ha., and properly terraced land produced 2,830 kg./ha. Similar increases were obtained from alfalfa and from forage sorghum. For alfalfa, yields of cured forage averaged 1,980 kg./ha. on untreated lands, in contrast to 7,010 kg./ha. on terraced lands. Obviously, the amount of increase in any given year or specific location varied with the intensity and timing of the rainstorms and the ability of the soil to store the water that fell.

Fallowing

Fallowing farm lands in alternate years is widely used in regions of limited rainfall. Careful long-term experiments in the subhumid regions of the United States have shown that not more than 30 percent of the rainfall occurring during the year of fallowing can be stored in the soil for the succeeding crop. Sometimes, as little as 10 percent was conserved. Evaporation losses, dissipation of soil moisture by weeds, and runoff losses from bare soil, are largely responsible for the limited storage of moisture in the soil. "Stubble mulching" instead of bare fallow has proved to be a major improvement in storing moisture. However, there are situations where total crop production on a farm may be increased by omitting the fallow and producing a crop every year by choice of suitable crops, by correcting soil fertility deficiencies with appropriate fertilizers, by adequate weed control in the crops, and by adjustment of all cultural practices to capitalize on moisture conservation and use. This is a further illustration of how the application of modern knowledge and technology can mitigate the effects of the limited moisture supply. Adaptive research in each major region is needed to determine the best practices for local farmers. The results should be substantial advances that are unlikely to be discovered by farmers without this external assistance.

Water Harvesting in Arid Regions

The previous discussion has dealt with water conservation in wet/dry ecological zones, and in subhumid regions. An entirely different practice, that of water harvesting, has been evaluated for arid and semi-arid regions. Various forms of this practice were used in ancient desert cultures, as long as 4,000 years ago. Water harvesting is the process of collecting and storing, or harvesting, the precipitation from areas that have been treated to *increase* the runoff of rainfall or snow melt. The collected mositure is led to adjoining plots of land, and spread by flooding or ditching. Whenever rains of sufficient amounts occur so that the moisture stored in the soil is believed sufficient to grow a crop, the opportunity is seized to plant a crop type, usually of short growing period, that will make full growth and ripen by the time moisture supply is exhausted. Whereas the ancients were limited to selection of suitable impervious slopes, and

the clearing of stones and other obstacles so as to increase runoff for harvest of water, modern farmers have a range of materials that may be used to make the collecting areas impervious to water, and thus increase the water harvest. These materials include certain calcium salts, sodium rosinate, quaternary ammonium chloride, and silicone compounds, and their proper use will render even sands relatively impermeable. In one series of experiments by Myers in Arizona (1964) 70 percent of the rainfall was harvested over a three and a half year period in a region with an annual rainfall of 250 mm. at an acceptable cost in relation to the benefits. For farming enterprises, the amounts of collected water must be compatible with the storage capacity of available adjoining croplands. The techniques of applying the collected waters to obtain maximum results from selected types of crop plants under local conditions have been found to be very important. While the entire modern process of water harvesting and use is quite sophisticated, when a workable system is perfected it may be practiced by average farmers with only nominal guidance.

Effective Use of Rainfall Stored in the Soil

Some indications of effective use of moisture stored in the soil have been provided in the foregoing discussion. However, the applications of new knowledge and technology to actual crop production offer very substantial benefits. These benefits fall into the following categories:

Selecting adapted crop species, and improved varieties of the crop

The crop species chosen for growth in regions of limited rainfall must be adapted to the general climatic conditions (including temperatures, evaporation rates) and to specific soil conditions. The differences in performance of improved varieties and/or hybrids within any crop species are often as great as the differences between crop types.

Some of the adaptation of crop types and improved varieties is that of the normal length of the growing period between germination and maturity. Normal growth and ripening should be completed before the available soil moisture is exhausted. Short-season crop types and varieties tend to evade the hazards from fluctuations in the occurrence of rains. Fortunately, there are now available a wide range of varieties and types with shorter life periods, and it is important to use those that have been tested and found to be best suited to available moisture supplies. An adapted variety or hybrid may yield 20 to 50 percent more than local unselected types of the crop species. In the Pacific Northwest wheat growing regions of the U.S., the new short-strawed, early maturing winter varieties have yielded 2,700-3,400 kg./ha., with only 400 mm. of winter rainfall.

Among annual crop species, there are pronounced differences in tolerance to droughts, or evasion of drought damage. Maize is probably the most sensitive to drought of the warm season cereals, sorghum is less sensitive than maize, and millet is the most dependable of these species. However, great differences are found in adaptation to drier regions of the varieties or hybrids within each species. Winter growing types of crops are particularly useful in regions with predominantly winter rainfall. Barley is somewhat more tolerant of heat and drought after heading than is wheat, and wheat is more tolerant than oats. However, short-season varieties become increasingly important as the total rainfall diminishes. Rye varieties of similar length of growing season have drought tolerance equal to wheat, but rye has inferior food acceptance.

Food grain legumes (pulses), root and tuber crops, and vegetables are more vulnerable to moisture shortage than cereals, but may be grown by using short-growing season varieties, with prompt planting at the beginning of period when moisture supply is generally the greatest. With these crop types also, there are great differences between varieties, and adaptative research to disclose the most productive varieties for specific regions is quite important. With world collections of germ plasm resources of each species now available, there is great opportunity to test strains or varieties for local adaptation and performance, and to multiply seed of superior varieties for farmer use in regions where these are adapted. This is an important means of compensating for limited rainfall.

Rooting depth and soil moisture use

Moisture stored in the soil profile is useful to crops only if the moist soil horizons are actually occupied by roots. Great differences in rooting depth occur between crop species, as well as between varieties and strains within a species. As moisture is stored to greater depths in the soil, plant types should be grown that will fully occupy the moist horizons.

In comparisons between crop types, the perennial legumes and grasses generally have more extensive root systems than the annual crops. If these perennials (such as alfalfa and adapted grasses) are capable of surviving periods of drought by becoming dormant, they are more dependable than annual crops. However, forages generally must be used by livestock, to contribute to farm income. Exceptions may be those situations where the forage is harvested as a cash crop. Because of their deeper rooting, the perennial sod crops improve soil structure and thus make land more productive for annuals than follow in the rotation.

Rooting depth may be curtailed by other factors than lack of moisture in the soil. Among these factors are impermeable layers of so-called "hardpan," or the presence of toxic materials, such as excessive

salinity, or highly alkaline substances that occur in dry regions. Impermeable layers and concentrations of alkali or salinity in the soil should be revealed by good soil mapping, and such areas avoided in dryland farming.

In some soils there are deficiencies of essential mineral elements such as *boron* or *zinc* that prevent root development occupation of the soil profile. The supplies of available *nitrogen* and *phosphate* are characteristically deficient in soils of drier regions. Rapid laboratory soil testing should provide indications of such nutrient deficiencies; and field trials will be necessary to determine practical means of correcting these deficiencies.

Whenever a physical examination of the rooting depth of mature plants indicates failure to occupy all of the soil horizons in which moisture is present, the need to search for the existing barriers to root penetration is evident. It is amazing how seldom such a simple exploratory measure as examining root systems is practiced.

Effect of soil fertility on drought tolerance

In general, rooting depth and growth of all crops are strongly responsive to soil fertility. Whenever plants are limited in development by any nutrient deficiency, there is continued transpiration of moisture without corresponding growth, resulting in very poor efficiency in use of available water. Plants with balanced mineral nutrition make growth and mature so as to efficiently use moisture within the limits of the environment (temperature, low humidity and high evaporation). Soil conditions which do not permit full occupation of the moist soil profile, and also restrict plant growth because of deficient fertility, produce low yields.

Fertilizers should be used in many (perhaps most) regions to supply *nitrogen* and *phosphates* for healthy growth. Rapid laboratory soil tests combined with field trials are needed to determine the most economic use of such fertilizers. *Calcium* is usually adequate in dryland soils, but some areas are seriously deficient in *magnesium*. These deficiencies must be identified and corrected so as to derive full crop response to available moisture.

Particular emphasis should be given to phosphate supply in the soil, since phosphorus is highly essential for strong root growth, for normal vegetative top growth, and for fruiting and ripening. Phosphate fertilization very often must accompany nitrogen fertilization to produce substantial benefits from either nutrient. Phosphate fertilizers must be placed within the soil before planting, preferably as bands or pockets near the seed, for early use by seedlings. Phosphates do not move into the soil with water, when spread on the soil surface.

Deficiencies in sulfur occur in some dryland regions that have

very highly weathered soils, and in other regions where soils are derived from volcanic deposits. Plant symptoms of sulfur deficiency closely resemble nitrogen deficiency symptoms, in that plants are abnormally light green and unthrifty, and have weak root development. Plant tissue tests will readily confirm any deficiencies in the sulfur supplying power of the soil. Correction of the deficiencies is easily accomplished by applications of gypsum (calcium sulfate), or flowers of sulfur, both of which are inexpensive.

Deficiencies in "trace" elements essential for crop growth

Land that has long been cropped may have become deficient in other essential mineral nutrients, such as *boron*, *zinc*, *copper*, *manganese* *iron* and *molybdenum*. These "trace" elements are needed by plants in very small amounts, and one of the most practical methods of correcting these deficiencies may be the incorporation into the soil of animal dung or other decaying plant or animal wastes, during land preparation for a crop. These organic sources usually carry the trace elements in a chemical form that is readily available to plants. Zinc and boron appear to be the trace elements most often found to be deficient in dryland soils. Tissue tests of unthrifty crop plants can detect any actual deficiencies.

Where trace element deficiencies occur, they constitute limiting factors in effective use of soil moisture for crop production. Because of limited supplies of dung, it may be most useful to apply it to those areas where food crops are grown most intensively. The deficient trace elements may easily be applied to most crop lands, as additions to chemical fertilizers; the costs are usually quite low, and the benefits from correcting the deficiencies are quite handsome.

Crop cultural practices to increase effective use of limited rainfall

It is essential to use crop species suited to the rainfall zone, to the temperature pattern, evaporation losses, and to local soil conditions. However, all cultural practices should be selected to make the best possible use of the rains that occur. Research on the most effective cultural practices to use, and the reasons for their superiority, is proceeding in many countries where agriculture is practiced with limited rainfall. New information is being continuously acquired in developed countries, so it is not surprising that much of the recently reported technology has not yet reached the farmers of less developed regions.

In general, the most useful cultural practices with wide application include the following:

1) Practice early preparation of the seed bed, including application of fertilizers as needed.

2) Plant at the most propitious time when both soil moisture and temperature favor prompt germination. The earliest feasible planting dates usually produce the highest yields, since the crop has the greatest opportunity to fully use all available moisture. However, in the wet/dry humid regions, planting dates should be chosen so that crop ripening occurs in a relatively dry period to avoid spoilage losses.

3) Plant the highest quality seed that is available, of the improved varieties or hybrids known to be adapted to the region. Seed viability can readily be tested, and planting weak or dead seed is completely futile. Government assistance is usually needed to insure commercial seed quality.

4) With the possible exception of small grains (wheat, barley, rye, oats), crops should be planted in rows, across the land slope, and not up and down slopes. Row plantings greatly facilitate any necessary practices to control weeds and combat insect pests and diseases when needed.

5) Planting enough seed to produce a plant population *no thicker* than can be supported by the expected rainfall. Excessive plant populations exhaust soil moisture before grain is matured. The most suitable and productive rates of planting under local conditions must be established by research.

6) Control weeds from the earliest growth stages, to prevent the weeds from exhausting soil moisture needed by crops. Avoid deep hoeing or tillage that damages the root system of the planted crop. Crop plants have quite limited ability to regenerate damaged root systems under conditions of limited soil moisture.

7) When necessary, combat serious insect pests with appropriate pesticides as soon as they become evident, and before serious damage occurs. Do not neglect insect invasions that may spread and become established for attacks in subsequent years.

8) Harvest the ripened crop promptly to avoid field losses from birds, insect pests, weathering and rots.

Use of forages and permanent grasslands in dryland farming

Dryland farming has the greatest potential for supporting farm families and contributing to the national economy, where the croplands are managed in conjunction with grasslands. The grasslands are complementary to the croplands in several different ways; they should add to the stability of production and income, and provide some protection against the impacts of severe and unpredictable droughts that afflict drier regions. There are two main types of grasslands: those that are part of the cropland rotation, and those that are permanently in grass on land not suited to cropping.

1. Use of forages in cropland rotations

Ruminant livestock (cattle, buffalo, sheep, goats) provide a practical means of utilizing the byproducts of crops (stalks and stems of harvested crops, leaves, chaff, vines, etc.). The ruminants not only contribute live animals for sale, as well as meat, milk and animal power, but also supply dung for use as fuel or as fertilizer on croplands, as noted previously.

However, crop wastes are not sufficient either in sustained supply or in feed quality for year-round support of livestock. Further, sustained cropping, year after year, even when fallowing the land in alternate years, tends to deplete soil fertility and the moisture supplying capacity of field soils. Both of these weaknesses are effectively corrected by the periodic growing of perennial forages (such as alfalfa-grass mixtures in CENTO countries), in rotation with tilled crops. These forage crops improve soil structure and fertility while they are growing, and this improvement persists for several years after the land is returned to annual cropping, thus improving crop yields. The legumes (alfalfa, clovers, etc.) in the sod crop mixture provide protein which livestock need to balance the low-protein crop byproducts that are available as feed. In addition, the perennial forage plants are far less susceptible to droughts that severely damage annual crops, and under normal rainfall may actually yield a greater productivity per hectare than the grain crops provide.

To achieve the full benefits of perennial forage crops, it is essential to plant adapted species and improved varieties; use fertilizers as needed, particularly phosphates for the alfalfa or clover; plant when soil moisture supply is the most favorable for establishment of seedlings; and graze or harvest the crop in a manner that will maintain the vigor of the stand. Plowing of these forage fields should occur as far in advance as feasible of the following annual crop, to provide time for breakdown of the sod into a mellow seedbed. One rather important requirement for successful use of perennial forages is the use of tractor power and machinery for land preparation. If such power can be made available to individual farmers, for handling the forage crop only, the full value of perennial forages can be made accessible to crop farmers.

2. Use of permanent grasslands in conjunction with cropland farming

Wherever permanent grasslands are available to cropland farmers in regions of limited rainfall, there are increased opportunities for stabilizing yearly production by combining the management of crop enterprises and grasslands into coordinated systems. The combination of grasslands and cropping provides a much stronger economic base than either of the components operating alone. Permanent grasslands in dry farming regions usually occur on land that is too steep, or stony or shallow for productive cropping; but such lands may be managed to pro-

duce important amounts of forage for grazing, or harvest as hay. Since grasslands need not ripen a seed crop (as is required of crops) to yield an income, these grasslands are more dependable in production than crops under limited rainfall. Any vegetative growth that is made may be used, so that there is rarely a complete failure due to droughts on permanent grasslands.

The principal effective use of grasslands is support of ruminant livestock. The permanent grasslands may provide the principal source of feed for livestock during the growing season, but these herds and flocks may be moved to croplands whenever desired to utilize crop wastes and byproducts, or to consume forage grown in rotation with harvested crops on arable lands. The dual sources of feed from the combined crop and range farming systems provide a far more stable and adequate feed support for livestock enterprises than permanent grasslands alone, or croplands alone. The livestock enterprises may become more productive as they become more stable, with reproduction, growth, and yields of milk (or power), when continuously supported by adequate feed throughout the year. The ruinous cycle of feed abundance followed by near starvation that commonly occurs with livestock on either grasslands or croplands managed separately, can be largely corrected by joint management of both cropland and grasslands. This is a logical and effective way of making dryland farming more productive, even though there is no change in total rainfall.

The application of new knowledge and technology in using the natural resources at hand has only begun. The transfer of established techniques and knowledge to people on the land in drier regions should receive the sustained support of governments and of the agencies serving dryland farming. In addition, it is apparent that there are great opportunities to develop new knowledge and techniques by strong research programs. Research may be the key to still further advancement in making dryland farming productive.

CENTO REPORT ON THE SEMINAR ON AGRICULTURAL ASPECTS OF ARID AND SEMI-ARID ZONES

INTRODUCTION

Under the auspices of the Central Treaty Organization a Seminar on Agricultural Aspects of Arid and Semi-Arid Zones was held in Tehran, Iran, for the first time in September 1971. It was felt necessary, informative and helpful to have an exchange of information among the member countries since, in the regional countries, agricultural programs, especially in Iran, are to a large extent involved in arid or semi-arid zones. Consequently the Economic Committee welcomed the idea of having such a seminar and the United States decided to give the scheme their organizational and financial support.

OBJECTIVES OF THE SEMINAR

The seminar dealt with the following objectives:

1) Reviewing the resources, development achieved and research results of the cooperating countries

2) Exchanging information on the management of arid and semi-arid regions of the CENTO countries

3) Identifying the most urgent research needs

4) Encouraging cooperative research on problems of mutual concern and exchange of information gained from such endeavors.

INAUGURAL SESSION

The seminar was opened on behalf of His Excellency Mr. Turgut Menemencioğlu, the Secretary General of the Central Treaty Organization, by Mr. Mostafa Modjtahedi, Assistant Economic Secretary of the Central Treaty Organization.

The inauguration address was delivered by His Excellency Mr. Hossain Mir Haidar, Undersecretary, Ministry of Agriculture of Iran.

The welcoming address of the Secretary General was delivered by the Secretariat's representative.

The heads of delegations of Turkey, the United Kingdom and the United States responded to the address of the Undersecretary.

Mr. M. Modjtahedi, the Secretariat's representative introduced the keynote speaker, Dr. Omer J. Kelley, Director, Office of Agriculture and Fisheries, Bureau of Technical Assistance, Agency for International Development, Washington, D.C., who delivered an address.

Installation of Chairman

In accordance with the customary CENTO procedures, Mr. A.F. Mahdavi, the head of the host country delegation (Iran) was chosen as permanent chairman of the seminar.

Special Commentary

In addition to the Undersecretary of the Ministry of Agriculture, the inaugural session was attended by other prominent officials and personalities, such as the Undersecretary of the Ministry of Natural Resources, the President of the College of Agriculture, the Director Generals and heads of various departments of the Ministry of Agriculture, Iran, and some experts from the State Plan Organization of Iran. There was also a group of experts from Colorado State University, USA, who attended the inaugural session and part of the seminar.

Discussion of Dr. Omer J. Kelley's Speech

Before assumption of the chair by the permanent chairman, discussion of the keynote speech took place. The speech was entitled "Improving Farm Production in Regions of Limited Rainfall." The highlights of the discussion on Dr. Kelley's speech were as follows:

Delegates from Iran and Turkey asked about the conditions of fallowing.

In response, Dr. Kelley emphasized that the purpose of fallowing

must be to get as much water as possible into the soil to be retained for use by the following crop. The physical condition of the soil is important to permit maximum infiltration and storage of water, and plant growth during the fallow must be eliminated to cut down losses of water by transpiration. Cultural operations must be carried out at the proper time.

The Delegate of Turkey asked about applying the recommendations made by Dr. Kelley. (For Dr. Kelley's recommendations see the keynote address, which is included in this publication.)

The keynote speaker pointed out that a lot is known about the principles of dryland farming, though much has still to be learned and the application of these principles must be conditioned by site characteristics.

The Delegate from Iran asked about the management of fallow, cultivation practices, and whether fallow could be eliminated.

Dr. Kelley emphasized that much depends on soil type, the amount and seasonal distribution of precipitation and the purposes the fallow is intended to achieve. He believed that the main purpose of a fallow was moisture storage but recognized that a fallow could have important subsidiary effects in accumulating available soil nitrogen and in weed control. These subsidiary functions can be achieved by other means, and if the fallow is eliminated these other means must be employed.

The Delegate from Turkey pointed out that much land is fallowed in Anatolia and other regions for lack of machinery for cultivation.

The Delegate of Iran asked for the speaker's opinion on the two-year fallow system.

Dr. Kelley drew a distinction between this land and the true fallow intended primarily for storing moisture. He believed that in some parts of this region it would be profitable to crop the land each year if proper tools were available for land preparation, but he also emphasized the need for local investigation and for land classification to show where such a practice would be successful.

The Delegate of Iran asked a question about the kinds of crops which could be grown to replace fallow.

Dr. Kelley indicated that a choice of crops, and farm practices to make the most efficient use of limited soil moisture, are also dependent on local conditions. The possibilities for planting leguminous forage crops in place of fallows were mentioned. He went on to say that much research on legumes for dryland agriculture has been done in Australia.

The Delegate from Iran asked about the conditions and the materials used for water harvesting.

Dr. Kelley responded by saying that considering the methods of water harvesting, these conditions depend on the seasonal rainfall pattern and the catchment areas designed to yield runoff for use on adjoining lands. The lands must be managed so as to increase runoff and should not themselves be cropped or grazed by animals.

The speaker continued, saying that in dryland farming the variability of the seasonal precipitation is as important as the total amount, and it was pointed out that farm practice must be based on the possible amount that could be expected.

The Delegate from the United States asked about the fertility problems related to fallow and indicated that the maintenance of an adequate level of soil fertility was recognized to be important to insure the most efficient use of water.

Dr. Kelley said in response that a small overapplication of nitrogen might be preferable to underapplication and would carry little risk of deleterious effects on the crop. He indicated a large excess application would be wasteful and might affect the crop adversely in dry conditions. Research results from the United States indicate that a stubble mulch may increase or decrease the yield of the following crop. When moisture is high and a large quantity of straw is produced and later ploughed down, the yield of the following crop may be reduced slightly. The usual quantity of straw ploughed down has no effect or slightly increases the yield of the following crop. The reasons for the adverse effect were not fully understood, but it was thought likely that the larger quantity of stubble produced with a good moisture supply would make heavier demands on available nitrogen and thus reduce the supply to the young growing crop.

Adoption of the Agenda

The agenda was adopted after some rearrangement of the order of presentation of papers.

COUNTRY SITUATION PAPERS

Turkey

The Delegate of Turkey, Dr. Şahap Elçi, Professor of the Faculty of Agriculture, University of Ankara, presented a paper entitled "Arid Zone Problems in Turkey." In this paper Dr. Elçi stressed the need for improved agricultural production methods to meet the demands of the rapidly rising population.

Discussion highlighted the fact that the average annual rainfall in the interior of Turkey over the last 30 years was 355.6 mm., of which a large proportion fell in winter when plants were not actively growing. It was suggested that an arid zone research unit could make important contributions to the solution of the agricultural problems of the region.

It was pointed out that there was insufficient production of forage crops for the needs of the large livestock population and that there was a great need for improvement of the natural pastures.

It was noted that cooperation with international organizations and exchange of material and knowledge with other regions would be beneficial.

Discussion continued mainly about the question of preventing cultivation of land which, because of steep slopes and other unfavorable factors, would best be left under its natural vegetation, and of the social problems involved in encouraging sound land use in arid and semi-arid areas.

It was generally agreed that the social problems were of crucial importance and that a comprehensive approach is necessary, integrating technical, social and economic factors.

There was also a discussion in regard to the question of relations between water and vegetation, of the possibilities of assessing the reliability of rainfall and especially of defining those areas where reliable crop production is possible. There appear to be rainfall statistics covering a large number of recording stations in the region, but no statistical studies have yet been made with a view to assessing rainfall reliability.

Iran

"Agricultural Aspects of Arid and Semi-Arid Zones" was presented by Mr. A.F. Mahdavi, Director of the Soil Institute, Ministry of Agriculture. The Delegate of Iran, upon presenting his paper, defined arid regions as those receiving less than 100 mm. of rain annually, and these cover about 13 percent of the country, while 60 percent is semi-arid with a mean annual rainfall of 100 to 350 mm. A further 17 percent of mostly mountainous country was described as dry but humid, with 350 to 500 mm. rainfall. Only a small proportion of the country has a rainfall exceeding 500 mm. The rainfall of the arid and semi-arid zones is extremely variable and this variability is the most important factor in determining the yield of dryland wheat and barley. About half the cropped area of some 7 million hectares is irrigated annually and most of the dryland cropped area is under wheat and barley cultivation.

Mr. Mahdavi reviewed research bearing on the arid and semi-arid areas of Iran. Land resource surveys occupied a prominent place. The delegate continued, saying that investigations in the field of soil and water management give priority to irrigation, the consumptive use of water by crops and the interaction of soil fertility with soil moisture supply. He said the establishment of dry farming research stations in different regions of Iran is under consideration. The delegate spoke of the need for a national center for practical research on the reclamation of saline soils and for more investigation of water quality and fertilizers and minor elements. He ended his presentation by mentioning the problems of conserving natural resources and emphasizing the need for a well formulated research and extension policy covering the coordination of research at a national level, reinforcement of research institutions, integration of all development activities at farm level and exchange of experience within the country and at an international level.

The discussion on the above paper was pursued by the seminar on the definition of arid and semi-arid areas. There was a consensus that average annual precipitation figures provide an inadequate guide as many factors are involved, including seasonal distribution of precipitation and its variability from one season to another, temperature and soil type.

It was suggested to the seminar that all the relevant factors were integrated by the vegetation and that an ecological approach might provide a basis.

It was also pointed out that from the agricultural point of view a crucial factor is the rainfall during the period of the year when, given a sufficient amount of soil moisture, a crop could be grown.

Questions were brought up about the extent of farm mechanization in Iran, and of experience with large irrigation projects. It was reported that mechanization was advancing on the larger farm units and that an increase in production on irrigation projects was due to the increased use of fertilizers, improved seeds and other inputs, as well as the provision of water.

DRYLAND TILLAGE

The Delegate of the United States, Mr. Thomas Zinn, Summer Fallow Specialist, USAID/Ankara, presented a paper entitled "Dryland Tillage."

The representative of Turkey, during the ensuing discussion, asked whether results or information include an estimate of tillage costs.

The representative of the United States replied that he expects

that equipment similar to that which is now being used by the Oregon State University team can be manufactured in Turkey. That should bring the cost down. The equipment being tested would be economical for large farms. Small units would have to form cooperatives.

The representative of Iran commented that in Iran some cooperatives involve as many as 2,000 hectares, and for them the use of large machinery may be economical.

The Delegate of the United States replied that cooperatives can be an answer for mechanization of dryland farming.

The Delegate of Turkey asked whether the United States Delegate could tell them how much straw is needed for the mulch.

The United States Delegate responded that the straw is used for animal feed and a dust mulch can be used without straw. It is important to have some of the straw returned to the soil to maintain a desirable organic matter content.

The representative of Turkey commented that he doubts that straw mulch can be used in Turkey since they get 1.2 tons of wheat and 2 tons of straw per hectare. The straw is worth about as much as the wheat. Straw replacement represents too high a cost.

The representative of the United States replied that the new varieties of wheat in the summer fallow system can double wheat yield and increase the quantity of straw. The value of straw may go down as wheat production increases. The area in permanent pasture could also increase.

The Delegate of Turkey commented that the custom of using straw for livestock feed needs to change. The total social and economic aspects of human nutrition need to be developed. For example, wheat is now an important human food. The Turkish people also need to change their diet to include more protein and less bread.

THE VEGETATION OF CENTRAL ANATOLIA AND ITS ECOLOGY

Professor Rıza Çetik, Faculty of Science, Ankara University, presented a paper entitled "Vegetation of Central Anatolia and its Ecology." Upon the pursuance of the discussion of this paper the representative of Iran asked whether Turkey developed range management plans based on ecological studies.

The Delegate of Turkey responded that some grazing experiments were completed on fencing overgrazed areas. We concluded that reseeding

was essential. He stated that the Range Management Institute is selecting plants for forage in arid climates.

The Delegate of Iran commented that in the Middle East countries research and execution are far apart. Research results are taken to the library, not to the field. Iran is focusing research on immediate problems.

The representative from Turkey commented that they have had some pilot reseeding plots with good results.

In this respect the Delegate of the United States asked whether they have a comparative value figure for cropland and rangeland production in Turkey.

The Delegate of Turkey replied: "No." He believes that rangeland has to be kept as rangeland, otherwise erosion will be the result. The Delegate of Turkey commented that they have not completed their soil and plant surveys.

PROBLEMS IN NATURAL RESOURCES ADMINISTRATION IN IRAN

The Delegate of Iran presented a paper entitled "Natural Resources Administration in Iran" by Mr. N. Seraj and Mr. F. Niknam, of the Technical Bureau of Pastures, Ministry of Natural Resources, Tehran.

In pursuing the discussion that followed, the Delegate of Turkey asked what percentage of Iran's forest lands is productive. What is the average timber yield? Is the timber used in Iran? What is the relationship between forest and rangeland? Are they doing research on erosion problems behind dams in Iran? What species are best for the various habitats?

The Delegate of Iran replied that the Caspian Sea hardwood forests contain about 1.4 million hectares in commercial production.The forests in northern Iran are not presently accessible for commercial production. The production per hectare varies. The timber is used in Iran.

Livestock grazes forest land. One solution is to transfer stock from productive forests to the degraded forests. Another is to have forest contractors plant forage crops in forest clearings. Goat grazing is limited in some forests, or they may graze at a higher tax rate. We hope to get goats out of forests eventually.

The research on reservoir watersheds is done by the Ministry of Natural Resources.

The Delegate of Turkey asked whether Iran is planning to restrict tractor use according to land classification.

The Delegate of Iran replied that range and forest lands are not allowed to be cultivated. Land classification is essential.

The Delegate of the United Kingdom commented that they obviously need a more comprehensive approach to planning. The first need is a reduction in the duplication of effort.

The Delegate of Turkey asked what they use for range reseeding in Iran.

The Delegate of Iran replied that near Tehran with 200 mm. annual rainfall they started with Atriplex species, Kochia and Agropyron cristatum. Protection of the reseeded area from grazing for two years is important, then controlled grazing may be permitted. Fencing is not economical. Our transitory management plan is proving successful. Secondary stages will be based on data developed during the early stages. Iran is short of technical capability in this field.

The Delegate of Iran, in pursuing his comments, said that they must recognize the conflicts involved between agriculture and flocks. Rangelands are being cultivated and it will take 15 to 20 years to restore them. Rangelands around villages are being cultivated. Goats may be the only animal that can utilize higher areas. Total planning to include all factors is required.

LAND AND WATER RESOURCE DEVELOPMENT FOR CROP PRODUCTION UNDER DRYLAND CONDITIONS

Professor Dr. Ali Balaban, Faculty of Agriculture, Ankara University, presented a paper entitled "Land and Water Resource Development for Crop Production Under Dryland Conditions."

The ensuing discussion of this paper brought a question from the Delegate of Iran about how people can be educated to implement programs.

The Delegate of Turkey replied that if the answer were known there would be no problem. Extension personnel can make a program successful. The human factors, including education, must be a part of any program. In Turkey, major reforms in land and education are planned.

The Delegate of the United Kingdom commented that at the Seyhan project the devoted extension man has put all the production services into operation. How can this program be extended to other areas, even if less spectacular?

The Delegate from the United States stated that first successes can proliferate. This case should be a justification for optimism.

The Delegate of Iran stated that the marketing aspects must be included in a program. Purchasing power must be expanded as production increases.

The Delegate of the United States commented that irrigation allows more diversification than does rainfed agriculture. Marketing cooperatives may develop markets further afield as surpluses develop.

The Delegate of the United Kingdom replied that diversification is also possible with rainfed agriculture: for example, a shift from monoculture to mixed farming, including stock and grains.

The Delegate of Iran commented that large irrigated areas and small, irrigated, mixed dryland areas have different problems.

The Delegate of the United Kingdom stated that small units are more difficult to organize and service. Large projects, with relocation of people, are sometimes easier to manage, although the capital costs may be high and the suitable areas are fairly limited.

THE DISTRIBUTION, VALUE AND MANAGEMENT OF THE NATURAL VEGETATION OF IRAN

The Delegate of Iran, Mr. M. Meimandi-Nejad, Professor of Ecology, Agricultural College, University of Tehran, presented a paper entitled "The Distribution, Value and Management of the Natural Vegetation of Iran."

In pursuing the discussion on this paper the Delegate of Iran stated that ranges around villages need more protection than distant areas. There are 60,000 villages in Iran. The stock grazing on fallow land and crop residue leads to erosion after overgrazing.

The Delegate of Turkey stated that uncontrolled grazing depletes plant cover in the vicinity of the villages. This is very difficult to control in Turkey. Then he asked whether in Iran they have experiments in village areas to stop overgrazing and erosion?

The Delegate of Iran replied that they need a subsidy plan to inhibit too early and too late grazing in Iran. The social factors may be important obstacles. The discussion was pursued by the Delegate of Iran who said that the range carrying capacity should receive prime consideration. Marketing facilities may be limiting and lead to overgrazing.

The Delegate of Turkey stated that controlled grazing on payment has been used effectively in some pilot areas, but good stock is required.

The Delegate of Iran replied that each area must be considered according to its use capability. The starting point is land capability maps. He said that in Australia and the U.S.A., rangeland is largely private. Then he asked whether Iran's rangeland should be privately owned.

The Delegate of Turkey replied that community owned land can also be managed properly.

The Delegate of Iran stated that their village councils will issue grazing permits. Fencing may be needed to insure that the carrying capacity is not exceeded.

EROSION CONTROL AND VEGETATIVE COVER UNDER DRYLAND CONDITIONS IN TURKEY

The Delegate of Turkey, Professor Dr. Selman Uslu, presented a paper entitled "Erosion Control and Vegetative Cover Under Dryland Conditions in Turkey." During the discussion of this paper the Delegate of the United Kingdom asked: "Was fertilizer applied during the establishment of shelter belts?"

The Delegate of Turkey gave a negative answer to the above question.

The Delegate from the United Kingdom asked whether there has been any work done on soil fertility and shelter belt establishment.

The Delegate of Turkey responded that considerable work has been done in Europe.

The Delegate of the United Kingdom commented that it is important to give emphasis to a water-fertility relationship.

SOIL AND WATER CONSERVATION ON ARABLE LANDS

The Delegate of Iran presented a paper entitled "Soil and Water Conservation on Arable Lands," coauthored by Mr. A. Ganjini, Chief of the Soil and Water Conservation Division, Soil Institute of Tehran, and Mr. B. Azimi, Deputy Chief, Soil and Water Conservation Division, Soil Institute of Tehran.

After presentation of the paper the Delegate of Turkey asked: "In the reported experiment, why did block C yield best?"

The Delegate of Iran replied: "Due to weed control."

The Delegate of Turkey asked: "How was silt accumulation measured?"

The Delegate of Iran replied that figures were developed both by calculating reservoir volume and by monitoring the silt load of incoming water. The figures agree well.

The Delegate of Iran commented that the figures on silt accumulation are total, not annual.

The Delegate of the United States asked in this respect: "When were plots seeded?"

The Delegate of Iran stated: "Probably in the late fall."

The Delegate of the United States asked if an herbicide was used to control weeds during crop growth.

The Delegate of Iran replied that it was not.

WHEAT PRODUCTION PROBLEMS AND POTENTIALS ON DRYLANDS

The Delegate of Turkey, Dr. A. Demirliçakmak, Director, Wheat Research and Training Center, Ankara, presented a paper entitled "Wheat Production Problems and Potentials on Drylands."

The Delegate of Iran asked whether Turkey has improved varieties of wheat for rainfed areas. The Delegate of Turkey answered that several local varieties are adapted. Last year Bestalotia was introduced, but the bread quality is down. On the coastal plain, with 500 mm. of rain, Penjamo does well.

The Delegate of the United Kingdom commented that there seems to be a lack of credit available to farmers in Turkey. Research must be followed by other input availabilities.

FIELD TRIP

The seminar participated in a well planned field trip to Esfahan and vicinity. A visit was made to the site of the new Shah Abbas, the great dam located about 110 km. southwest of Esfahan. This dam project was developed to provide water for irrigation, for flood control and for power development. It will also furnish power and water for the new steel plant.

Enroute, the delegates had an opportunity to observe intensive irrigation agriculture, a limited amount of dryland tillage and consider-

able rangeland. There was ample evidence of drought and overgrazing of the range. Many herds of goats were observed grazing throughout the area.

The delegates observed modern equipment in operation in the fields alongside of some of the primitive tools being utilized.

After returning from the dam, the group assembled at the Soil Research Institute, from which they were given a brief tour of the city of Esfahan before returning to Tehran.

SYSTEMATIC LAND RESOURCE INVENTORIES AS A TOOL FOR AGRICULTURAL DEVELOPMENT AND PROPER LAND USE

Mr. M. Bordbar, Deputy Chief of the Soil and Land Evaluation Division, Tehran, presented a paper entitled "Systematic Land Resource Inventories as a Tool for Agricultural Development and Proper Land Use."

In pursuance of the discussion on this paper, the Delegate of Turkey asked how information about future development potential was determined in arriving at a classification of potentiality classes. This is a factor which is often not known and further research was required to arrive at universally accepted standards.

The Delegate from Iran agreed with the comment of the Delegate of Turkey and said that work was in progress to obtain information which would allow the adoption of satisfactory standards for future development potential. At the present time, however, the practice in Iranian land resource inventories was to relegate land for which this information was lacking to a temporary low category.

WATER REQUIREMENTS OF VARIOUS CROPS IN THE ARID AND SEMI-ARID ZONES OF TURKEY

Mr. Özdemir Beyce, Soil and Water Works, Central Research Institute, Ankara, presented a paper entitled "Water Requirements of Various Crops in the Arid and Semi-Arid Zones of Turkey."

Upon discussion of this paper the Delegate of Iran inquired whether the United States could report any work on the simplification of the complicated formulas hitherto in use for the calculation of evapotranspiration.

The Delegate of the United States replied that the complicated formulas referred to had been developed to meet conditions in specific areas and pointed out that care should be exercised in adapting them for use in other areas. He agreed on the need to find simple formulas

for assessing evapotranspiration losses. He further said that he believed the evaporation pan method of obtaining evaporation readings was still the most practical.

The Delegate of Iran referred to figures for evapotranspiration losses by alfalfa and sugar beet quoted in the paper and pointed out that work in the field in parts of Iran had given higher values. He further thought that insufficient consideration for deep percolation losses was perhaps given in the results reported.

The Delegate of Turkey agreed that it was necessary to assume a figure for deep percolation loss of water in calculating field irrigation requirements, but pointed out that as this was an unpredictable figure, it could not be easily assumed for exact experimental purposes. In the experimental results quoted moisture depletion losses in the soil had been obtained by measuring moisture depletion at different depths throughout the course of the experiments.

The Delegate of the United States pointed out that measurement of loss of water by deep percolation was only necessary in calculating irrigation requirements and was not a factor in the calculation of evapotranspiration.

The Delegate of the United Kingdom pointed out that the discussion had so far only taken into consideration the physical requirements of the crop. But the physiological requirements of crops were also of vital importance in the context of irrigation practice, particularly under circumstances where the available water supply is insufficient to provide the total requirements of the crop. Research has shown different reactions to water stress depending on the state of crop growth,and that patterns of such stress varied from crop to crop. Increased research on the water stress reactions of crops was essential if maximum economic production was to be obtained from irrigated agriculture.

POSSIBILITIES OF SUPPLY AND PROPER USE OF WATER IN THE GARMSAR AREA

The Delegate of Iran, Mr. B. Yazdani, Expert at the Research Center and Laboratory, Ministry of Water and Power, Tehran, presented a paper entitled "Possibilities of Supply and Proper Use of Water in the Garmsar Area."

The Delegate of Turkey asked whether it would be desirable to increase the percentage of land under fodder crops. At the same time he suggested that the inclusion of only 3 percent alfalfa in the cropping pattern might be too low.

The Delegate of Iran replied that the 3 percent alfalfa in the

cropping pattern could be increased if necessary, but the planned percentage was in fact sufficient to supply the requirements of livestock in the area.

The Delegate of Turkey asked whether any work had been done to develop particularly salt-tolerant crop varieties.

The Delegate of Iran responded that no such work had been done in the Garmsar area and the selection of crops was based on long local experience.

The Delegate of Iran pointed out that the irrigation rates were particularly high, and so too was the percentage of crops such as wheat which have a high demand for water. He thought that these rates of water use would be uneconomical for the ordinary farmer. The discussion went further to stress that a high water application rate was necessary to provide a degree of leaching -- 27 percent of the recommended water use was provided for a leaching effect in addition to the normal crop requirements.

The Delegate of the United Kingdom was concerned about the apparent discrepancy in the pattern figures quoted for actual evaporation and calculated evapotranspiration, and brought out the need to establish well tested relationships between these two groups of figures for general use.

The Delegate of Turkey pointed out that sprinkler irrigation methods could achieve unsaturated leaching with the resultant benefit of reduced water use and lower drainage load.

EVALUATION OF THE HYDROLOGICAL ASPECTS OF THE AGRICULTURAL STUDIES IN THE ARID AND SEMI-ARID ZONES OF TURKEY

Dr. Osman Tekinel, Assistant Professor, Faculty of Agriculture, Adana, presented a paper entitled "Evaluation of the Hydrological Aspects of the Agricultural Studies in the Arid and Semi-Arid Zones of Turkey."

In regard to the above paper, the Delegate of the United States pointed out the need to relate evapotranspiration figures quoted in reports of agricultural studies to units of crop production or to some other factor with a practical significance.

The Delegate of the United Kingdom inquired whether the proposals for arid zone research also included provision for agricultural research.

The Delegate of Turkey confirmed that the proposed arid zone research unit would be built up gradually, and that its role would be to coordinate the whole range of arid zone research in Turkey, including the agricultural sector.

GENERAL REPORT ON DEVELOPMENT AND UTILIZATION OF SALINE SOILS IN IRAN

The representative of Iran presented a paper entitled "General Report on Development and Utilization of Saline Soils in Iran," by Mr. A. Ghobadian, Member of the Scientific Council, Jondi Shahpour University and Mr. H. Siadat.

Opening the discussion on this paper, the Delegate of Turkey inquired whether any new crops resistant to salinity had yet been developed in Iran.

The Delegate of Iran said that although some work is proceeding no results had yet been obtained.

The Delegate of the United States made a general comment about water use in relation to salinity. He suggested that the commonly accepted implication that an increase in water efficiency is good should be regarded with caution. In order to make a true assessment in this context, it is first necessary to define efficiency in terms of how well success is being attained in achieving what is intended.It is necessary to know what happens to drainage water, to the salt it may carry when it leaves one locality, as it is not necessarily lost to the system, and may move on to accumulate elsewhere. As a result the problem may be only transferred from one unit of land to another. These factors have to be taken into consideration in assessing the overall advantages of any proposals to employ leaching and drainage techniques. This emphasizes the need to consider land reclamation and amelioration procedures in the context of the benefit that may accrue to a territory as a whole.

The Delegate of Turkey emphasized the importance of what the United States Delegate had said and quoted experience from a site near Ankara where even the act of drainage, without any addition of water by irrigation, resulted in a considerable decrease in salinity.

EFFECT OF RATE AND TIME OF APPLICATION OF NITROGENOUS FERTILIZER ON THE EFFICIENCY OF NITROGEN UPTAKE BY WHEAT

Dr. N. Ulgen, Assistant Director, Soil and Fertilizer Research Institute, Dışkapı, Ankara, presented a paper entitled "Effect of Rate and Time of Application of Nitrogenous Fertilizer on the Efficiency of

Nitrogen Uptake by Wheat." As the discussion began on the above paper the FAO representative commented that to his konwledge there was no experimental evidence in Iran to confirm the production of a significantly increased quantity of wheat by split application of nitrogen. He also doubted whether the results quoted confirmed that any real benefit was likely to accrue from this type of application of nitrogen. For this reason he thought that in practice it would always be more economical for the farmer to apply nitrogen to his wheat only at seeding. He thought that it was possible that in certain very cold areas there might be some benefit from a split application of nitrogen to wheat at seeding and tillering, but even so he knew of no experimental evidence to confirm that this was so.

The Delegate of Turkey thought that the split application of nitrogen in his experiment had in fact had a positively favorable result by increasing the uptake of nitrogen in wheat by 10 to 15 percent.

The Delegate of the United States referred to work carried out in the colder parts of his country which confirmed that a split application of fertilizer was sometimes beneficial. Using this technique it was possible to slow down the growth of young wheat in the early part of the season until climatic conditions were suitable for its further development. Furthermore, this technique allowed for a more economical use of nitrogen as the second application could be related to the thickness of the stand obtained after seeding and the amount of rainfall subsequently received up to the tillering stage. It was also frequently worthwhile incurring extra expenditure on the split application technique in order to obtain a high protein wheat which was likely to obtain a premium price for milling.

SYSTEMS ANALYSIS: A DECISION-MAKING TOOL FOR ARID LAND DEVELOPMENT

The Delegate of the United States, Dr. Martin M. Fogel, Professor of Watershed Management, University of Arizona, presented a paper entitled "Systems Analysis: a Decision-Making Tool for Arid Land Development."

During discussion on this paper the Delegate of Turkey inquired what steps could be taken by developing countries to implement systems analysis in circumstances where data are deficient.

The Delegate of the United States replied that much could be achieved, even with insufficient data, through simultaneous procedures which could be used to build up a useful model.

The Delegate of the United Kingdom pointed out that in fact a large amount of data does exist in many developing countries but is not made use of.

The Delegate of Turkey commented that in many countries social and political factors play an important role in project planning. He further inquired whether these factors might be incorporated in methods of systems analysis.

The Delegate of the United States confirmed that it was quite possible to take account of such considerations.

The Delegate of Iran asked how the differing interests of the public as a whole and the individual farmer could be reconciled in systems analysis.

The Delegate of the United States replied that the system reconciles these factors through the application of constraints which have an effect on final decisions.

RECOMMENDATIONS

1) The Committee, noting the large extent of land in the arid and semi-arid zones of the region and the large population dependent on dryland farming, recommends greater emphasis on research and development directed to the problems of dryland farming.

2) The Committee noted that a great store of knowledge has been accumulated by the various research organizations in the region and that much of this knowledge is not yet being applied, and recommends that urgent action should be taken to identify the problems that are impeding the application of research and practice.

3) The Committee noted the different problems that are encountered in the different parts of the region and recommends that greater resources should be allocated to the task of developing agriculture by the application of known scientific principles.

4) The Committee noted the valuable work which is being done in the region in the survey and evaluation of land capability, and recommends that this information should always be fully utilized as a basis for planning and implementation of land use.

5) The Committee was struck by the amount of high grade research that is being carried out by various institutions in the region and noted a lack of coordination between these institutions, and recommends that urgent steps should be taken to improve coordination of research activities within and between the countries of the region in order to avoid duplication and insure maximum efficiency of the research.

6) The Committee noted that arrangements for the interchange of in-

formation between research institutions are still inadequate despite the attention given to this matter at various CENTO meetings in the past, and recommends that urgent attention should be given to the improvement of these facilities.

7) The Committee noted with approval the efforts that are being made by CENTO to bring together specialists in different fields of agricultural research and development, and recommends that these efforts should continue and, insofar as possible, be strengthened.

8) The Committee noted the need for a center for the collection, storage, processing and dissemination of data and research information that are available at scattered places throughout the region, and invites the attention of CENTO to this requirement.

9) The Committee noted the complex problems of management of the communal pastures and development of livestock in the arid and semi-arid zones of the region and urges that active steps be taken to follow up the recommendations of the CENTO Working Party on Range Management and the CENTO Conference on Livestock Policy held last year.

10) The Committee noted that 65 percent of the population of the two regional countries represented at the seminar is engaged in agriculture and recommends that the allocation of greater budget support to the agricultural sector should be seriously considered by the region countries.

COUNTRY

REPORTS

THE ARID ZONE PROBLEMS IN TURKEY

by Dr. Şahap Elçi,
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BACKGROUND

The population increase in Turkey is about 3 percent per year. In other words the population of Turkey is increasing by 900,000 people every year. This rapid population increase exploits the resources that are available within the limited boundaries of Turkey. Therefore an increase parallel to that of the population in the production of agricultural produce ought to be secured. Otherwise, the nutrition of the increasing population will be a great problem. Even today it is possible to admit that there exists such a problem in Turkey. On the other hand, it is not easy to try to reach the modern standards of the advanced countries in connection with the expanding requirements of the population. So, there is no other remedy but to effect agricultural developments in a way that will provide adequate nutritional requirements by making use of modern technical advances in this field.

The agricultural methods applied in Turkey greatly need such innovations. In other words, unless the present production methods in Turkey are improved, it will not be possible to exploit the soil to the benefit of utmost yield of agricultural produce.

In Turkey there are many factors limiting the yield of agricultural produce. Therefore a solution towards the increase of agricultural produce and methods to bring this about are a highly significant problem.

Generally areas without sufficient irrigation facilities may be considered as arid zones. However, the annual rainfall in the typical arid zones is about 300-350 mm. If it is taken into account that the rainfall occurs partly in winter, not coinciding with the growth period of the plants, then it becomes clear that water is indeed a very limiting factor. Then the distribution of rainfall plays an important part, rather than the total amount of it, for the growth of plants. The interior of Anatolia is in principle the representative case for the arid zones in Turkey.

In the interior regions of Turkey the average annual rainfall during a period of 30 years was 355.6 mm. Of this rainfall 33.8 percent, i. e. 120.2 mm., took place in winter. On the other hand, the number of summer days in the region, that is when the daily maximum temperature was +25°C or more, was 114.2 days. The first frosts occur around 10 September; the last ones are encountered around 28 April. In this way, it is evident that the rainfall during a cultivation period of 132 days is extremely important. On the other hand, the areas with similar ecological factors should be considered within the arid zones. For example, Iğdır, which has had an average annual rainfall of 256.0 mm. for the last 30 years, Erzincan with a rainfall of 364.8 mm., Malatya suburbs with 368.2 mm. rainfall and other similar areas ought to be considered in the same light. Thus it is clear that the arid zones cover an extensive area of Turkey. As a result, consideration of the agricultural problems of such an extensive area should from the economic point of view be of a highly significant nature.

ASSIGNMENT OF PRIORITIES

It is essential that immediate priority should be given to this case and various measures taken towards the solution of the problems. But it is necessary to determine the beginning in such an endeavour. An Arid Zone Research Unit which undoubtedly can play a most effective role can work towards the solution of these significant problems which are of vital importance to the economic development of Turkey.

Research to be carried out in this field will deal with agricultural problems according to priority and will solve the regional problems thus securing their economic development. Should the incomes from the arid zones of today be made to reach a higher standard on account of taking various agricultural measures, the economic welfare of the country will surely not be limited only to the arid zones, but will affect Turkey as a whole.

The classification and cultivation of the soil in the arid zones within the framework of the recent technical advances will enable the concerned to derive maximum benefit from these natural resources. It will also be impossible to prevent the growing erosion caused by wind and water and thus reduce the loss brought about by the same.

The protection of the soil against erosion should call for other agricultural systems than the monocultural implementations fully applied in Turkey thus far.

In this region half of the land is ploughed and cultivated and the other half fallowed. This monocultural system is not only used in lands classified as fields. It is unfortunately also applied to areas undergoing erosion, for example on steep or sloping sites. Field ploughing is also being carried out in areas which by their characteristics are and should be left as pastures or meadows since no economic production activity may be exploited through their use. As a result, this monocultural system is causing extensive harm to the economy of Turkey.

The exploitation of the pasture lands in an unmethodical manner is destroying the vegetation and flora, reducing the animal feed and speeding up erosion. The production methods in areas suitable for field cropping should also be improved. Advanced cultivation techniques, high quality seeds and rapidly developing fertilizers may also be developed in order to obtain higher agricultural yield than that of today.

FORAGE CROPS

As a result of studies made in the arid zones, it has been observed that the distribution of the annual rainfall is insufficient for cultivation of plants or vegetative development during their rapid growth. It will be possible to make a most economical use of the annual rainfall in plant production through the use of various technical methods in agriculture.

It is essential to make use of forage crops in order to make the agricultural sector supply a higher yield of produce. In this way, animal feed and hay will be put at the disposal of stock farming and its provision will surely lessen the loss of animals reared. In Turkey only a few species of forage crops are being cultivated, such as alfalfa, sainfoin, vetch and bitter vetch. The methods used in the cultivation of these are, however, not sufficient. The area for cultivation of these species can in no way be compared with those in foreign countries.

It is a bitter fact that many species cultivated in other countries are not grown in Turkey. As a paradox, the origin and gene centre of most of these various and invaluable forage crops can be traced back to Turkey. It is possible to observe these plants in the natural vegetation of Turkey. Some are extremely valuable plants from the point of view of forage crop production.

The cultivation of plants for optimal produce should be based on rotation, soil and climatic conditions for plant production in the region. Towards this end, the following points should be determined:

1) Determination of plant species under soil conditions in a most economic manner

2) Identification of plants for cultivation under such climatic conditions

3) Determination of a policy as to what kinds of species may be cultivated in various regions of the area under various soil and climatic conditions. In this way the prevention of erosion by wind and water must be sought.

4) Selection of the most suitable wheat in the region for macaroni and bread

5) Reseeding of pastures and the yield to be obtained by way of proper grazing

6) Improvement of barley for beer and feed

7) Adaptation of high quality forage crop plants

8) Determination of high quality vineyard and orchard plants adaptable to the region

9) Relations between water and vegetation, water supply for irrigation and drainage problems

10) Evaluation of saline lands

11) Possibilities of the improvement of regional stock farming in relation to the development of forage crop production

12) Relations between high quality and regular feeding and animal production

13) Determination of animal species having an influence on these relations and improvement of the same

14) Determination of appropriate tools for soil cultivation in the region

15) Marketing problems of the produce in arid zones

16) Crop rotation system

17) Relation between various plants and fertilizers in fertilization

18) Significant problems for the region in plant protection

19) Research to be conducted on the determination of suitable trees and

shrubs for the purpose of arboriculture and animal feeding in the region

20) Study of the fuel problem of the region

21) Possibility of better management of forestry

22) Development of the food industry and the identification of the agricultural industrial branches which are economic under the regional conditions

23) Seed improvement research of various cultures most suitable to regional conditions

24) Determination of the flora cover and other measures to be taken in the prevention of erosion by water and wind.

RESEARCH

It is essential that required long-range and more extensive research projects should be considered and undertaken for regional development. These may be summarized as follows:

1) Arid zone flora

2) Vegetation maps

3) Soil maps

4) Capacity of underground and surface water resources for the purpose of irrigation, the underground water reserves and the possibility of making use of the same in agriculture

5) Possibility of adaptation and cultivation of plants grown in other countries in arid zones

6) Water balance in regional plants and factors affecting the same

7) Reasons for resistance against drought and cold in plants

8) Soil microflora

9) Erosion and plant succession

10) Effects of the ecological factors in the region on the flora cover

11) History of the flora cover

12) Factors limiting crop yield

13) Study of the region as gene centre of the plant cultures

14) Identification and preservation of the significant gene materials in the region (in cooperation with the Agricultural Research and Introduction Centre in Izmir)

15) Distribution of the annual rainfall in the region and its relation to cultivation of plants

16) Transpiration and evaporation in the region.

A unit will be established by the National Scientific and Technical Research Council of Turkey in order to solve some of the problems mentioned above. This unit will serve at the beginning as a research group to help the researchers who are working on their own. This help may include new techniques and methods of coordinating different research activities into one goal. There is of course the possibility of conducting research in the region when necessary. There are already several institutions working on arid zone problems, but in some areas of the research there is a lack of cooperation or effective techniques. The unit will give more emphasis to that point in order to make the research more beneficial and fruitful. Later on, the unit will act as an institution working on the problems of the arid zones. The practical result of the research should be applied by the producers, but for this purpose we need an efficient extension service to work in the arid zones. Today, we need a very efficient program on agricultural extension as well.

CONCLUSIONS

There are some other important and useful ecological characteristics of the region that help produce better quality seeds of legumes and grasses and the other cultivated crops during the flowering period of most of the cultivated plants. The weather is bright, sunshine is prevelant and the humidity of the air is always low; this enables insects to pollinate the allogamous flowers. Wind pollination also occurs easily. It is a great advantage to our agriculture to be able to obtain good quality and prolific seeds from crop plants in this manner. In the coastal areas we advise the use of seeds obtained under these conditions in the central plateau. We could derive more benefit from these natural conditions, if we could use water for irrigation in some part of the region.

It is obvious that if we want rapid development in the arid zone we will have to cooperate with the international organizations. I believe, from the viewpoint of exchange of material and knowledge, that we can benefit by their long period of experience and very rich materi-

al, and we may add some original material and experience that we have in our country.

It gives me great pleasure to be here in Iran with my colleagues who are working on some of the subjects mentioned above in the arid and semi-arid zones of Turkey.

Special thanks are due to the Government of Iran, including all the responsibility for the excellent conference arrangements.

AGRICULTURAL ASPECTS OF ARID AND SEMI - ARID ZONES

by Mr. A.F. Mahdavi,

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Tehran

INTRODUCTION

Iran is essentially an arid and semi-arid country. The relevant climatic information and data and the rainfall pattern will be given in other papers presented at this meeting.

Arid regions are characterized as those receiving less than 100 mm. of rain per year and occupying about 220,000 square kilometres, or about 13 percent of Iran's total surface. The semi-arid regions, which receive 100-350 mm. of rain, cover about one million square kilometres, or about 60 percent of the land surface of Iran. The dry subhumid areas of Iran largely comprise the mountainous areas of Alborz and Zagros, mostly around 2,000 metres elevation, with an annual precipitation of about 350-500 mm. and occupying about 280,000 square kilometres, or 17 percent of the land surface of Iran.

The moist subhumid regions, with normally 500-1,000 mm. of rain, cover about 8 percent of the land surface of Iran; the humid area with an annual precipitation of more than 1,000 mm. represents only 1 percent of the total land area. In other words 50 percent of the land surface of the country is covered by arid, semi-arid and dry subhumid areas, each one having an average annual rainfall below 500 mm.

The most important problem of arid and semi-arid areas is the variability of precipitation from year to year. Variation (in terms of rain and snow) also occurs in the annual distribution and according to the part of the country.

Rainfall distribution is characterized by the absence of rain from April until October over most of the plateau area. This variability of precipitation is the most important factor in determining the yield of dryland farming of wheat and barley.

LAND AND WATER USE IN IRAN

Of the total 1,650,000 square kilometres of land surface only 190,000 square kilometres (11.5 percent of the total area) is considered suitable for crop production. Actually about 7 million hectares (700,000 square kilometres) corresponding to 4.2 percent of the total area are annually under cultivation.

These are cropped as follows:

Winter and spring crops:	3.5 million hectares are rainfed 1.7 million hectares are irrigated
Summer crops:	0.3 million hectares are rainfed 1.0 million hectares are irrigated
Perennial crops, gardens, vineyards and orchards:	0.5 million hectares

Each year about 3.5 million hectares of land are put down to dry farmed wheat and barley, out of a total of 12 million hectares, the rest of which are normally fallow.

The total area under irrigated agriculture is around 3.5 million hectares. A rough estimate indicates that 2.0 million hectares are fairly well provided with irrigation water and 1.5 million hectares are partially irrigated.

It is not fully clear as to how much of this 3.5 million hectares is provided with good quality irrigation water, how much with medium quality and how much with poor quality.

The average precipitation in Iran is estimated to be 240 mm. per year. The total amount of water received annually by precipitation is estimated at about 400 billion cubic metres. Of this amount 240 billion cubic metres are lost by evaporation and only 100 billion cubic metres of water flow in the streams.

The amount of water which permeates the ground and joins the groundwater is estimated to be 60 billion cubic metres.

Out of a total average 400 billion cubic metres of water in Iran only about 78 billion cubic metres, or 19 percent, is utilized as follows:

* 37 billion cubic metres in agriculture

* 1 billion cubic metres for domestic and industrial consumption

* 40 billion cubic metres consumed in the form of evaporation and evapotranspiration in forests and pastures.

Assuming that the country's groundwater resources remain constant, the remainder either evaporates or flows out of the country. With high evaporation rates and relatively low average precipitation, irrigation is required for most summer crops.

The amount and quality of irrigation water are important factors in determining the yield of various crops in irrigated agriculture. The other factors which are responsible are:

1) Proper soil and water management

2) Irrigation and drainage layout

3) Cropping pattern.

AGRICULTURAL ASPECTS OF ARID AND SEMI-ARID ZONES

In this paper I shall review the research in the context of the agricultural development of the arid and semi-arid zones of Iran.

Study of Land Resources Inventory

In Iran, as well as other arid and semi-arid parts of the world, soil and water resources are limited and scattered. Therefore, planning and implementation of agricultural development projects should be directed towards areas of higher productivity and potentiality, based on information obtained from land resource inventories.

As you will see from another paper to be presented to this conference, 30 million hectares of the total 165 million hectares of land surface of Iran have been surveyed on a generalized basis with maps on a scale of 1: 250,000. These maps classify land resource in respect to:

* Agriculture
    Dry farming
    Irrigated farming

* Range

* Forests

* Recreation.

In most cases the recommended use or uses as a result of these surveys are presented. Iran is a country which is developing rapidly in response to progressive leadership and forward planning. Because progress is rapid, it is most important that the development and use of land and water resources be planned and implemented in such a way that the objective and development targets are not only attained but also that improved production, achieved from development, can be maintained indefinitely.

In case some participants to this conference wish further details I suggest you contact the Land Evaluation Division of the Soil Institute in order to understand the procedures developed to survey and evaluate our land resource potentialities.

Irrigation and Drainage

The origin of irrigation in Iran goes back to early history. The The *qanat* system, by which water is tapped from the surrounding mountains and led by gravity through subterranean canals to the lower lands, is still used in Iran in much the same way as it was 2,500 years ago.

Equally ancient must be the system of irrigation directly from mountain streams by small diversion canals. Many irrigation development schemes eventually failed. No doubt many of these failures may be attributed to lack of understanding of the problems of salinity associated with agriculture and the consequent need for drainage. Today's technology, however, makes it possible to sustain the level of economic production in many irrigated areas. However, it has been seen that frequently the production per unit of water is extremely low. This is due to poor levelling of land, also loss in conveyance by secondary and tertiary canals, as well as inadequate knowledge of water requirements of crops in different agricultural climatic regions of Iran.

The average crop yields per hectare are much below the potential.

Considering that available water resources are much more limited than land suitable for irrigation, the maximum yield per unit of water and land should be the aim when increasing agricultural production, instead of expanding the land area under cultivation. The proper use of irrigation water is of great national importance because it is one of the limiting factors in the current agricultural development in Iran.

With new development of water resources and harvesting of additional surface water by water storage dams and flood control in river

basins more irrigation water will be available. However, this alone will not guarantee higher production unless it is accompanied by an efficient management.

Efficient soil and water management will yield favourable results not only in areas of good soil and water, but also in areas where one of two factors is comparatively poor.

In the field of soil and water management the following points, on which we are working, will be of interest to you:

Organization for land and levelling and grading

The land must be prepared so that water can be applied with maximum efficiency. Land grading and levelling contributes to uniform distribution and efficient use of water on the land.

Government is considering ways and means of including public and private sectors for promoting land levelling and grading on irrigated areas in Iran.

We would be happy to exchange experiences, both on technical and organizational aspects of this important matter of water management.

Canal lining

Some estimates have been made that 50 percent or more of the water is lost during conveyance in many primary, secondary and tertiary canals in Iran.

This loss can also prove damaging to some lands which may be presently good. Such losses have to be reduced considerably by proper canal lining and related measures.

Consumptive use of water by crops

The requirements for water vary with agricultural climatic regions, with the type of crop and varieties, soil type and condition, etc. The consumptive use of water by a crop includes its physiological requirement for transpiration as well as the evaporation from adjacent soil and water surfaces. This information is of basic importance for evaluation of existing irrigation practices and as a means of suggesting future improvements.

Water allocation to irrigation projects and individual farmers can be based on these data.

Several studies have been made by the Soil Institute to determine the water requirements of agricultural crops. The water allocation for these crops should be based as far as possible on such studies.

Fertility--Irrigation--Interaction

The efficiency of both fertilizer and water and other yield-increasing factors increases considerably if research on the interaction is conducted properly.

Such studies have been carried out by the Soil Institute at Marvedasht and other areas in Iran and use will be made of these findings and similar studies for improved and more efficient agricultural practices.

Dryland Farming -- Techniques for Improvement

The dry farmed cereal area amounts to about 3.5 million hectares. Including the fallow land, the area is about 12 million hectares. This is the largest land use of the total cultivated land.

The cropping system practiced in many or most regions is still primitive. Under the specific climatic conditions, the present yield of dry farmed winter cereals is about 600-800 kg. per hectare.

Improved varieties, fertilizers and improved tillage methods are capable of increasing the yields above 1,000 kg. per hectare.

Some preliminary study has been made in respect to soil and moisture conservation.

Significant improvements have been observed in the yield of crops in the pilot and demonstration areas, especially in East and West Azarbaijan, as well as Kermanshah and the Kurdistan areas which normally receive rainfall in excess of 350 mm.

However, it is our considered opinion that we should establish dry farming research stations in at least two or three regions of Iran to work on all aspects of dry farming research and development. This will also include study of suitable machinery and equipment, breeding of drought-resistant varieties of wheat and barley, as well as bringing into rotation systems drought-resistant legumes which can do fairly well under semi-arid conditions, and other techniques of soil and moisture conservation.

The selection of such stations is in progress and it is expected that the Ministry of Agriculture will undertake such a study, possibly in collaboration with FAO.

Soil Salinity and Reclamation of Saline Soils in Iran

It has been estimated that the total surface of saline and alkaline soils in Iran is about 25 million hectares, which is about 15 percent of the total surface of Iran. In relation to the surface of the

plain land and flat sloping land, this amounts to approximately 30 percent and in relation to irrigable land, present and potential, as much or more than 50 percent is affected by salinity and alkalinity to a varying degree, followed by corresponding and growing losses in production. Because of the seriousness of salinity problems, research on soil salinity and alkalinity must be reinforced.

A national center for practical research on reclamation needs to be created with a few subcenters.

More reclamation and drainage work needs to be carried out on a large scale in Khuzestan, Fars and Esfahan.

Water Quality Research

As was mentioned earlier, water is a limiting factor in agricultural development in Iran. Because of this limitation, and besides efficient use and management of good quality water, there is an urgent need for research on the use of saline water in irrigation. According to international criteria, water with a conductivity of 2,250 micromhos/cm. or more are unsuitable for irrigation.

Such waters are only suitable for the more salt-tolerant crops and only when the subsoil drainage is good and adequate irrigation water is available, to meet the leaching requirements.

In Iran these waters are generally being used without any restriction, provided that enough rain falls in the winter.

The experimental work reveals that groundwaters with up to 3,000 p.p.m. salt are commonly used through the country on medium to heavy textured soils.

Although a tentative classification for the use of well waters has been set up, the water quality research work should attempt to define in greater detail the salt tolerance of different crops to varying salinity levels.

Fertilizer and Minor Elements

As a result of nearly 15 years of experimentation in different parts of the country with different crops, sound fertilizer recommendations have been established. It is proved that fertilizer alone can increase the yield of most agricultural crops on an average between 25 and 40 percent on irrigated land.

Studies on minor elements and trace element deficiencies and toxicities in arid zones, where salinity is often very high and where occurrence of high calcium carbonate concentration is very common, should be recognized as an important part of arid zone research activities.

Conservation of Natural Resources

There has been much environmental destruction, soil erosion, forest destruction, loss of wildlife habitat, water and to some extent air pollution in many parts of the country.

Thousands of years of wrong use of land has produced instability and deterioration which will continue to occur at increasing rates unless positive action is taken to correct these conditions. To stop the deterioration and to recreate soil, forest and rangeland resources will not be easy; in some places it will take a long time.

Achievement of conservation ultimately depends on the individuals who use and manage land and they must be educated to accept the responsibility of adapting modern conservation technology such as:

* Contour ploughing

* Contour banking

* Conservation agriculture

* Water harvesting

* Efficient soil and water management

* Regeneration of rangelands.

It is the overall responsibility of the Government to protect the natural resources of the country and to see that they are developed and used properly in the long-term interest of the community.

CONCLUSION

Iran is developing rapidly in response to progressive leadership and planning. If the rate of agriculture development is to keep pace with social and industrial progress and development, it should be realized that modern agriculture needs financial aid and a farming community motivated by a desire for progress. Any potential increase in agricultural production depends on a well formulated research and extension policy. These imply:

* Coordination of research on a national basis

* Reinforcement of research institutions in terms of staff equipment and improved quality of work

* Integration and coordination of all development activities at the farm level

* Exchange of experience within the country and region as well as on the international level.

I strongly hope that this and similar seminars will serve to stimulate international interest in the complex technical and social problems related to utilization of land and water in the arid and semi-arid zones of the world and will contribute to their eventual solution.

MEASURES FOR BETTER UTILIZATION OF IRRIGATION POTENTIAL IN THE ARID AND SEMI-ARID ZONES OF WEST PAKISTAN

AND A PROPOSAL FOR FUTURE COORDINATED RESEARCH ACTIVITIES IN THIS FIELD SUITED TO THE CENTO REGION *

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Senior Research Officer,
Irrigation Research Institute, Lahore

INTRODUCTION

Pakistan emerged in 1947 in two blocks--East Pakistan and West Pakistan, separated from each other by over a thousand miles of Indian

* This paper was prepared for the seminar, but not read, as last minute administrative problems prevented the Pakistani delegation from attending. It is included in this publication in order to present a complete evaluation of the situation in the regional countries.

territory. These two wings of the country are differently gifted as regards area, resources, population and climatic conditions. Thus West Pakistan, with 84.9 percent of the area, has 45.8 percent of the population, and East Pakistan, with only 15.1 percent of the total area of the country, contains 54.2 percent of its population.

West Pakistan lies between parallels 61° E and 75° E and latitude 24° N and 37° N. This wing has a common frontier with India on the east, with Afghanistan and Iran on the west. To the southwest lies the Arabian Sea which provides access to Iraq and Arabia through the Persian Gulf, and to Egypt and beyond through the Arabian Sea and the Red Sea.

Through West Pakistan flows the mighty Indus river with its tributaries, the Beas, Sutlej, Ravi, Chenab and Jhelum rivers. Before entering Pakistan the tributary rivers flow either through Indian territory or through the disputed territory of Jammu and Kashmir State.

Climatically, West Pakistan is dry and much of it is barren. The temperature in May and June exceeds 120° F in some places. In winter, on the other hand, the minimum temperature in some places, even in the plains, is several degrees below freezing point. In this wing of the country the average rainfall is only 20 inches (508 mm.) and in large areas of the South and the East less than 5 inches (127 mm.) per annum. Thus West Pakistan depends mainly on artificial canal irrigation.

The total area of Pakistan is about 366,000 square miles, of which 55,000 square miles constitute the eastern wing and 311,000 square miles the western wing. In terms of acres the total area of Pakistan is 233.8 million acres, of which 35.4 million acres are in East Pakistan and 198.4 million acres are in West Pakistan. Nearly 65 percent of the total area of East Pakistan is under cultivation, but in West Pakistan the cultivated area forms only 20 percent of the total.

PRESSURE ON RESOURCES

For a developing country two measures may be used to get an idea of the pressure on resources: a) population density, i.e. the average number of persons per square mile and b) cultivated area per head of population or per worker engaged in agriculture.

According to the latest census, taken in 1961, the overall density of population in Pakistan is 256 per square mile. The degree of variation of density in West Pakistan is much larger. The highest density is shown in Lahore, both as a division and as a district, and the lowest in Kalat. The average density for Lahore Division is 726 while in Quetta and Kalat Divisions the density is 14 and 7 respectively.

In agricultural countries like Pakistan, density of population is

mainly determined by the fertility of the soil, coupled with water resources. The low density area in West Pakistan contains a high proportion of barren land with very scanty water resources which produces very little to support human life. The high densities of Lahore and Sargodha Divisions are due to high agricultural fertility with adequate water resources resulting mainly from canal irrigation which has made high concentration of population possible.

Cultivated area per head of population is the index of population pressure. The cropped area per head according to 1951 and 1961 censuses was as follows:

Table 1. PER CAPITA CROPPED AREA

(Reported Area Only)

	Total Population (thousands)		Total Area (Million Acres)	Per Capita Cropped Area (Acres)	
Area	1951	1961		1951	1961
East Pakistan	41,930	50,840	35.4	0.61	0.52
West Pakistan	31,060	42,880	198.4	0.97	.0.81
Total	72,990	93,720	233.8	0.76	0.65

Table 1 indicates that the cropped area per head is less than one acre and is hardly sufficient for reasonable subsistence under conditions of agriculture like ours. The table further reveals that due to the increase in population and failure of expansion of the cropped area, per capita cropped area is considerably lower in 1961 than it was in 1951.

The agricultural yield per acre in West Pakistan is very low. One of the reasons for this low yield is the scarcity of water. West Pakistan has limited water potential and a lot of water is lost as seepage through canal and water courses and evaporation as discussed in the following paragraphs.

WATER POTENTIAL OF WEST PAKISTAN AND ITS LOSSES AT VARIOUS STAGES

West Pakistan surface water resources were estimated to be 133.8 million acre feet in 1969-70, and the average of the last five years (1965-66 to 1969-70) was 139.3 million acre feet. The abstract of river flow availability is put forth in Table 2.

Table 2. INDUS BASIN IRRIGATION SYSTEM--ABSTRACT OF RIVER FLOW AVAILABILITY

Year	Jhelum	Chenab	Indus	Total (Million acre feet)
1965-66	26.4	22.6	89.3	138.3
1966-67	23.1	25.9	91.3	140.3
1967-68	23.8	25.2	96.5	145.5
1968-69	21.6	23.9	93.1	138.6
1969-70	24.2	22.4	87.2	133.8

It is further estimated that for the five years ending in 1969-70, the annual diversion from the rivers into irrigation canals averaged 95.69 million acre feet. The annual canal diversions varied from year to year, e.g. in 1969-70, the last year of the five-year period, the diversion to West Pakistan canals totalled 98.26 million acre feet, compared with the average of 95.69 million acre feet during the last five years. The abstract of provincial canal withdrawals during the five years mentioned above is given in Table 3.

Table 3. ABSTRACT OF PROVINCIAL CANAL WITHDRAWALS

Year	Punjab	Sind and Baluchistan	Northwest Frontier Province	Total (Million acre feet)
1965-66	47.26	39.38	4.61	91.25
1966-67	50.08	40.97	4.91	95.96
1967-68	52.20	37.51	4.99	94.70
1968-69	52.66	40.74	4.91	98.31
1969-70	51.46	41.78	5.02	98.26

Harzint has estimated the water potential of West Pakistan and its losses at various stages. According to their estimates 60 percent of

the diverted water is lost as seepage, evaporation, etc., and so only 40 percent of it is used for the production of crops.

Estimates of water losses were also made in the past by different approaches by various experts: Kennedy, Benton, Blench and Khungar. Their estimates show that about 45 percent of the water let into a canal system was wasted during the delivery. The farm losses at the field were estimated separately, and these amounted to 20 to 25 percent, so that hardly 35 percent of the water diverted at the head of a canal was usefully consumed by crops. The estimates are put forth in Table 4.

Table 4. ESTIMATES OF FARM LOSSES AT THE FIELD

Canal System	Kennedy	Benton	Blench	Khungar
Main canals	5	16.4[1]	5	15.5[1]
Branches	15		15	
Distributaries	6	6.1	7	5.4
Watercourses	21	20.2	20	16.5
Total	47	42.7	47	37.4
Farm Losses	25	19.1	-	-

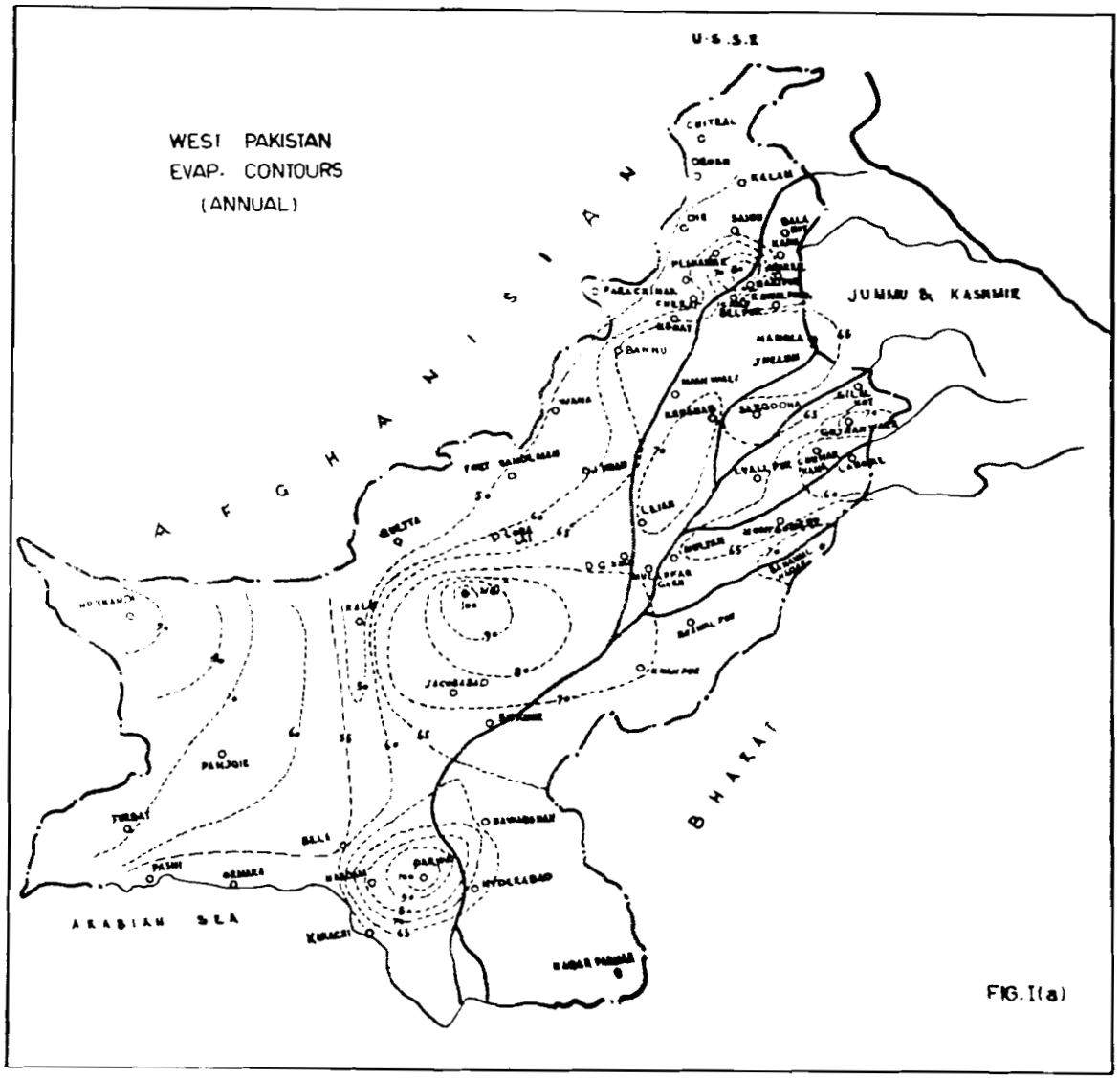
1. Main canals and branches combined.

The water losses calculated by different experts vary, but they are appreciable.

The table indicates that out of total losses, maximum losses are from watercourses. From these, water enters a field or farm. Here again losses are mainly by seepage and evaporation. The moisture taken up by soil is also lost by evaporation from the soil surface before transpiration from the plants.

Evaporation Losses

A large volume of available water is being wasted through evaporation from free water surface. It is estimated that in West Pakistan water lost from free water surface is in the range of 3.7 to 8.0 cusecs per square mile of free water surface. An estimation of free water surface evaporation from West Pakistan is shown in Figures I a, b, c with contours giving water intensity lost annually and biannually. An estimation of evaporation losses from reservoirs has been made as discussed below.



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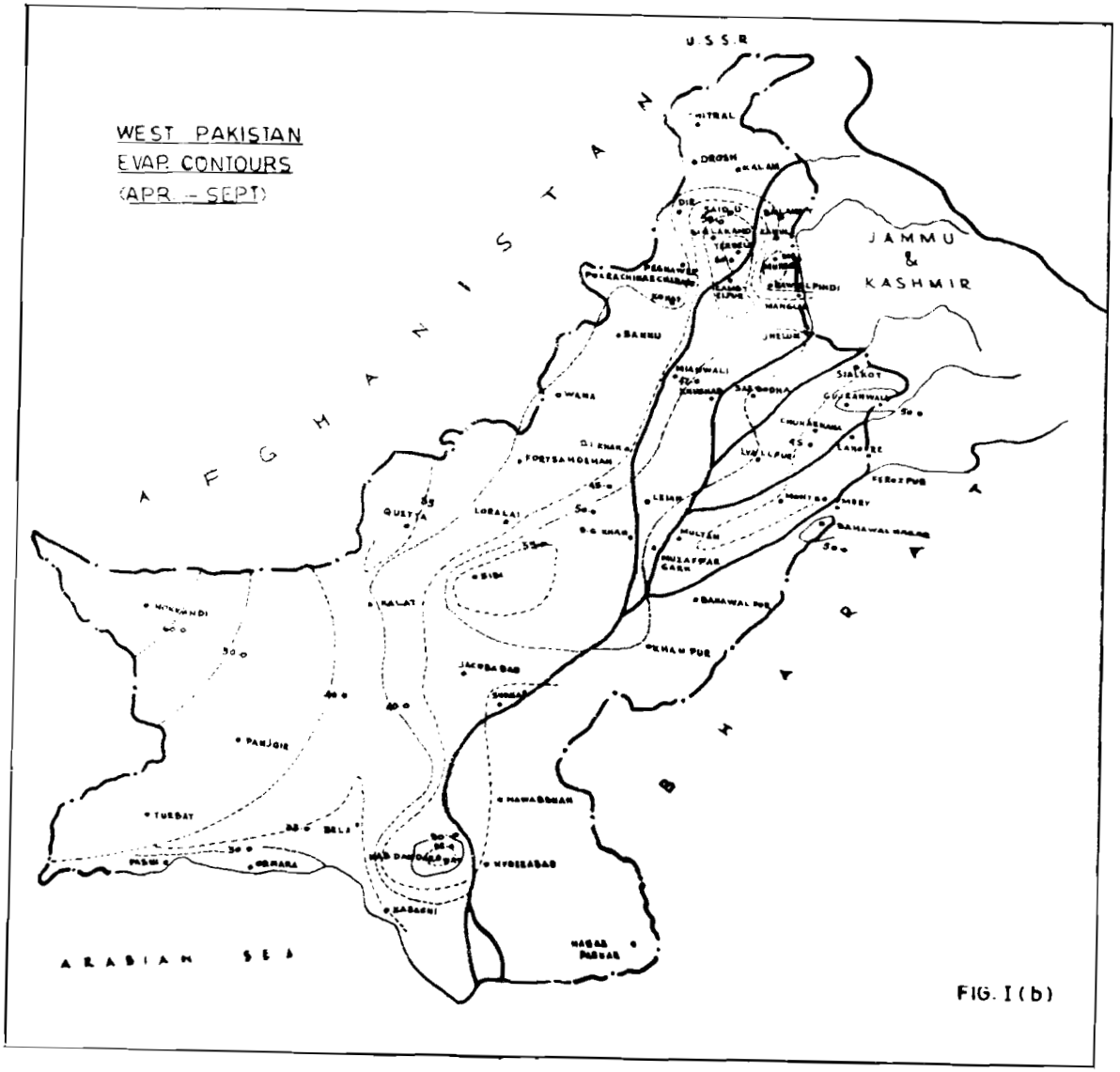

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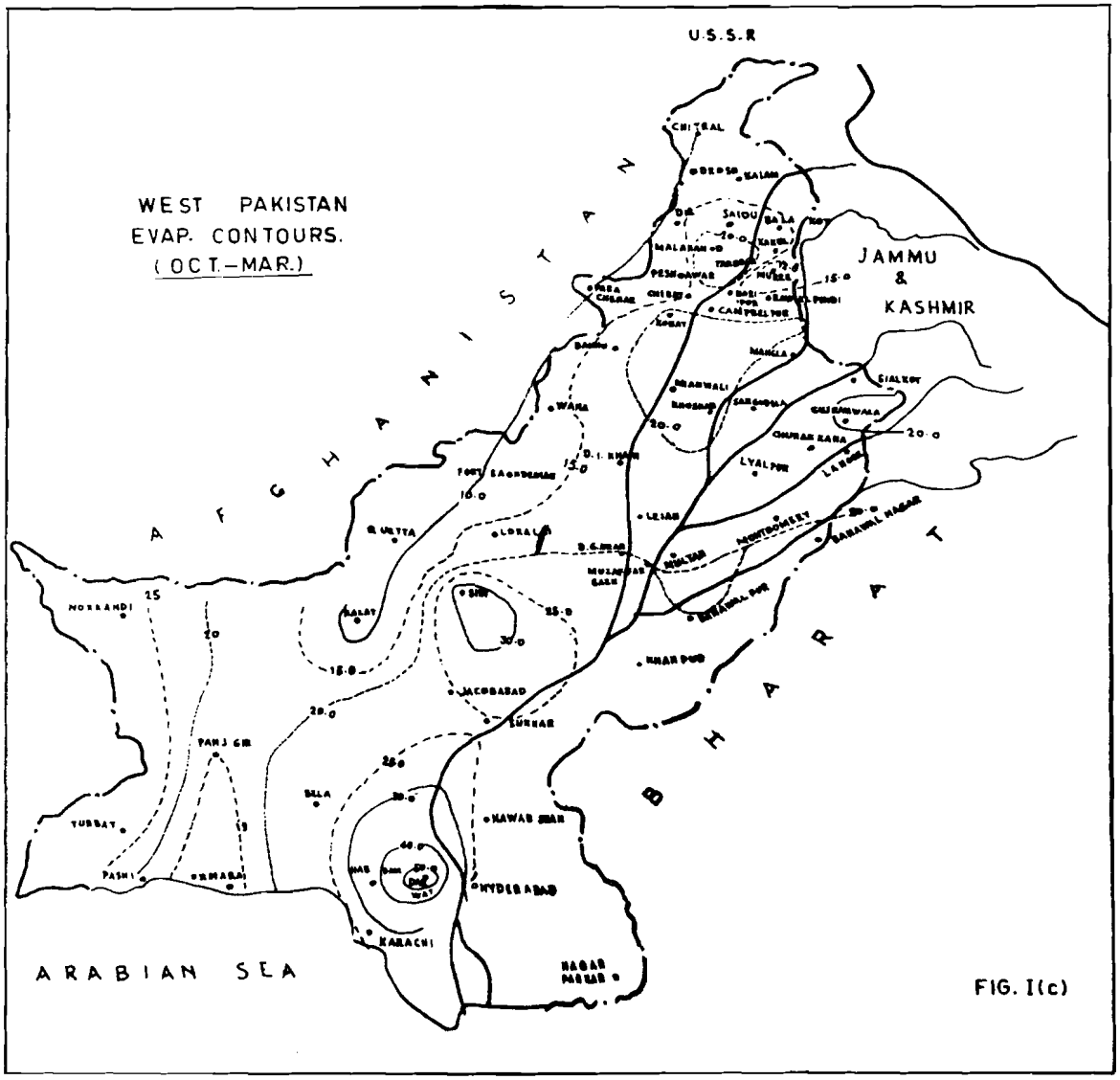

WEST PAKISTAN
EVAP. CONTOURS.
(OCT.–MAR.)
U.S.S.R
AFGHANISTAN
JAMMU
&
KASHMIR
BHARAT
ARABIAN SEA
CHITRAL
SAIDU
PESHAWAR
CAMPBELLPUR
MANGLA
SIALKOT
WARA
D.I. KHAN
LYALPUR
LAHORE
LEIAH
MONTGOMERY
BAHAWAL NAGAR
MULTAN
BAHAWAL PUR
KHAIRPUR
LORALAI
QUETTA
KALAT
SIBI
JACOBABAD
SUKKUR
NOKKUNDI
PANJGUR
TURBAT
PASNI
SALA
NAWAB SHAH
HYDERABAD
KARACHI
NAGAR PARKAR
15
20
15.0
20.0
25.0
30.0
40.0
10.0
FIG. I(c)

Reservoir Losses

These losses are also the outcome of evaporation from the surface area of reservoirs created behind the dams. There are many big and small dams in West Pakistan.

Big reservoirs

Mangla

The surface area of the Mangla and Tarbela reservoirs at maximum pool elevations is on the order of about 65,000 acres each. An exercise was made to compute the evaporation losses from the water surface area of Mangla reservoir. For this a reasonable reservoir operation pattern around the year was assumed for computing the surface area at monthly intervals to which were applied mean evaporation figures over the period 1960-67. This indicated an average loss of about 0.3 million acre feet as shown in Table 5.

Table 5. EVAPORATION LOSSES FROM MANGLA RESERVOIR

Month	Reservoir Level (Feet)	Water Surface (Acres)	Mean Evaporation Losses (Inches)	Water Surface Evaporation (Acre feet)
October	1202.0	63,506	7.26	38,421.13
November	1182.0	53,966	4.50	20,237.20
December	1165.6	50,103	3.35	16,987.10
January	1154.6	42,058	3.20	11,215.46
February	1140.1	38,757	3.96	12,789.80
March	1104.4	23,570	6.62	13,002.78
April	1040.0	9,772	9.61	7,825.74
May	1085.4	17,530	14.20	20,862.17
June	1123.0	30,598	13.97	35,621.17
July	1155.0	42,058	9.80	34,347.37
August	1193.3	58,170	7.73	37,471.18
September	1202.0	63,506	7.22	38,209.46
Total				286,790.56
			Approximately:	0.3 million acre feet

Tarbela

The extent of Tarbela reservoir is almost the same as Mangla, but its operational pattern would be such that its draw down period would be about three months longer than Mangla. Though this operation pattern would tend to enhance the evaporation losses in the case of Tarbela, for the sake of conservation the value of 0.3 million acre feet is also suggested in this case.

Chashma

The area of this reservoir at maximum conservation level of 649.0 is about 90,000 acres. This reservoir is located in an area where the evaporation losses are relatively more than Mangla and Tarbela. Furthermore, the losses would be enhanced if the reservoir draw down is prolonged over the whole of the Rabi season. Assuming this sort of inefficient reservoir operation, losses from this vast and shallow reservoir are estimated at about 0.1 million acre feet. Almost the same approach was adopted by the World Bank Study Group which assumed a loss of the equivalent of 14 percent of the capacity.

Small reservoirs, dams and ponds

Besides the big reservoirs, there are a number of small reservoirs, dams and ponds, and their total surface is also quite appreciable, consequently their total evaporation losses are very high.

It is estimated that on the completion of small dams and Tarbela dam in 1975 the total loss of water from free water surface will be approximately 2,000 cusecs.

Loss of water from bare soil

A large amount of water is wasted owing to the present high water tables in various regions of West Pakistan. This loss has been estimated to be next to losses from free water surface. The rise of the groundwater table is due to enormous seepage from unlined canals, distribution systems and watercourses in West Pakistan.

With the water table between 0 and 5 feet, the loss of water by evaporation is about 50 percent of that which takes place from the free water surface. In the case of a water table between 5 and 10 feet the loss by evaporation is about 15 to 20 percent.

Losses by plants (evapotranspiration)

A major portion of the water absorbed by the roots of plants is lost by evaporation into the air. The loss of water in the form of water vapours from the aerial parts of the plants is called transpiration. Although the loss of water takes place from all the exposed parts

of a plant, the leaves are the chief transpiring organs.

Transpiration is not merely a physical process of evaporation, but is a vital process which is controlled by the activity of the living protoplasm. The following are principal factors which affect transpiration:

1) Humidity of the air

2) Wind movement

3) Temperature of the air

4) Intensity of light

5) Barometric pressure

6) Chemical nature of the soil

7) Number and position of stomata

8) Water table conditions.

Transpiration is essential for plants as it keeps the plant cool and prevents overheating even when it is exposed to strong sunshine. It is absolutely necessary for nutrition, for, by maintaining the transpiration of ascending currents, it brings the supply of water and dissolved mineral salts to the leaves. Some plants show an excess transpiration to that required for their proper growth. So actually, excessive evapotranspiration is taking place mainly in waterlogged soils. Figures II a, b, c show the effect of different water tables on evapotranspiration in the case of sugarcane and cotton L.S.S.

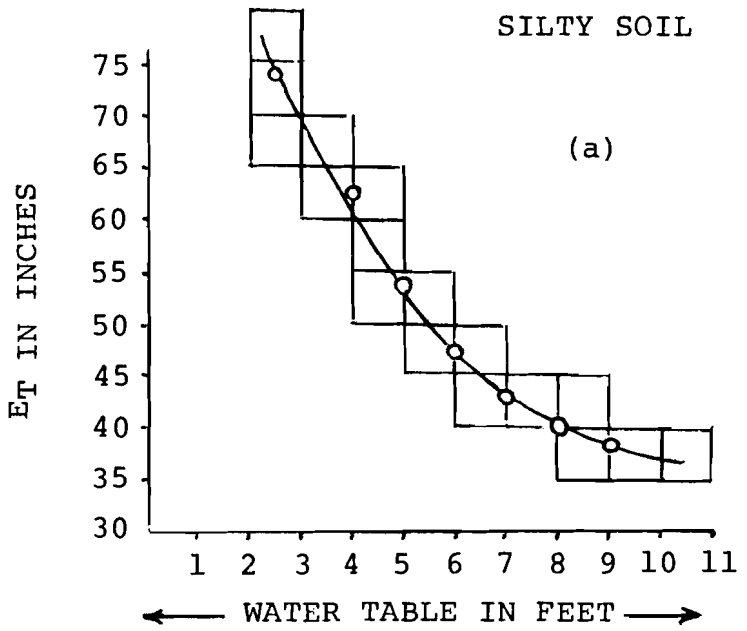
Water is also lost by weeds and trees growing in an excessively moist area, i.e. on the banks of canals and watercourses.

Water losses by conventional irrigation practices

It has been determined by experiments that crops under different water table conditions require different quantities of water but within normal irrigation practices this point is not taken into consideration. Moreover, the cropping pattern, if not selected in accordance with water table and climatic conditions of a region, will cause excessive evapotranspiration to take place.

Through old surface irrigation practices more water is lost than through modern techniques, e.g. dividing fields into small compartments and using sprinkling techniques. Surface irregularities and surface gradients also cause loss of water.

EVAPOTRANSPIRATION BY COTTON
L. S. S. AT DIFFERENT DEPTHS



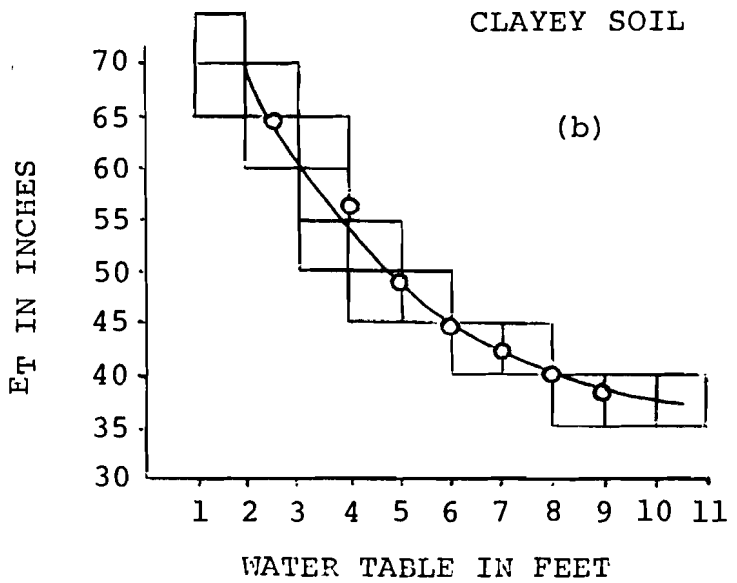
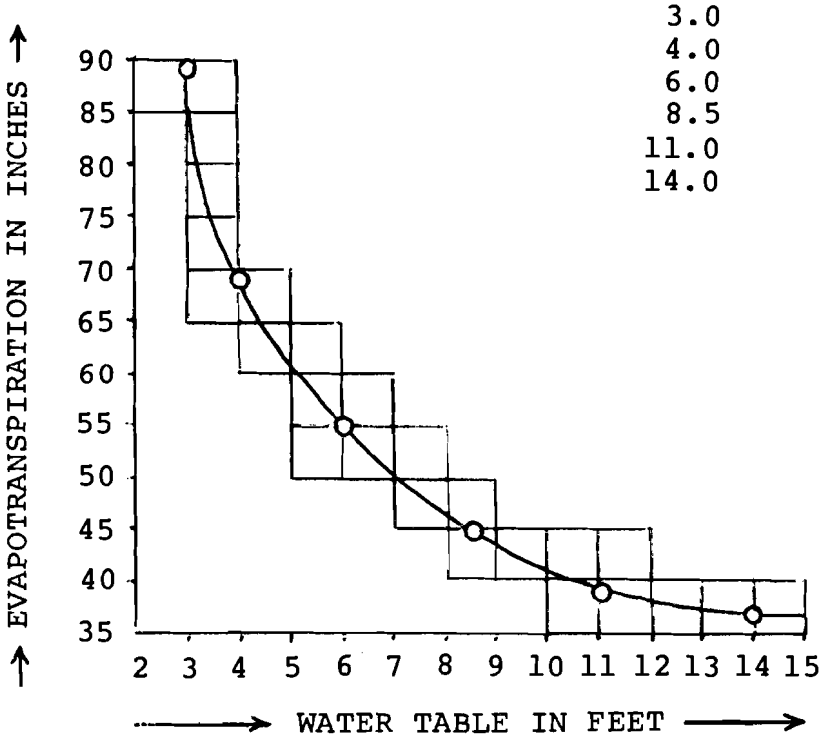


FIG. II (a-b)

EVAPOTRANSPIRATION BY SUGARCANE AT DIFFERENT DEPTHS



DATA

W.T. IN FT.	ET
3.0	89.52
4.0	69.06
6.0	34.97
8.5	44.91
11.0	39.15
14.0	36.86

FIG. II (c)

The colossal water losses discussed above need serious consideration owing to the increasing demand for water in areas under canal irrigation.

The surface water potential of West Pakistan neither varied much during the last 20 years, nor is any substantial increase in the future anticipated as most of the potential has been consumed in replacing the supplies of the three eastern rivers allocated to India under the Water Treaty of 1960. On the other hand, the annual increase in the population of Pakistan is approaching 3 percent, and in order to meet the food and fibre requirements of this rapidly increasing population, intensive and extensive cultivation is a must. To achieve this, water is the basic requirement. Despite the fact that the irrigated area in West Pakistan is about 30 million acres, the yield per acre is very low as compared with that of other countries. The main reason for this low yield is that the total water availability per unit of land is less than actually required.

To increase yield per acre, additional water is needed to meet consumptive uses of crops and leaching requirements of soils, plus good quality seeds and fertilizer. Actually, countries with climates similar to ours use three to four times more water on their land than we do.

The surface water potential is limited and out of that about 60 percent is lost as evaporation or seepage. If efforts are made to conserve even 50 percent of this amount, along with efforts to cultivate and irrigate with recently developed water conservation techniques, we will not only be in a position to meet the entire food and fibre requirements of our own country, but may have a surplus for export.

In the following paragraphs an effort will be made to elucidate some water conservation measures and their suitability for West Pakistan.

WATER CONSERVATION MEASURES

Losses from canals

Maximum water losses occur through seepage in canals and the distribution system as shown in Table 4. Seepage losses from canal beds can be effectively reduced by lining the canals. The total length of canals in West Pakistan is about 40,000 miles, including major and minor distributaries. To line such a length with concrete or tile work would be very costly and not practical because operating canals are closed only two or three weeks in a year. The result is that 98 percent of the canals in this country are unlined.

With the advancement of science and technology, cheaper methods are being developed to line canals. Use of soil sealants is a new method of lining the operating canals. During the last few years research has been directed to developing materials in the form of emulsions, the

ingredients of which are normally insoluble in water, but in emulsified form can be diluted with water. When these emulsions come in contact with soil particles, they break into their original components, which are insoluble in water and generally have the property of sticking to the soil particles thus blocking their pores. The emulsions presently being developed have a basis of asphalt, wax and some mineral oils.

Several organizations in the world are conducting intensive research to produce a suitable type of soil sealant. The Irrigation Research Institute of Lahore is also trying to develop a bitumen emulsion for canal lining. Laboratory results are very encouraging. The soil sealants have been found to be effective under water and reduce the percolation by 30 to 90 percent.

The approximate costs of various lining materials are given below for comparison.

* Concrete lining	Rs. 150 per sq. ft.
* Tile lining (double layer)	Rs. 138 per sq. ft.
* Tile lining (single layer)	Rs. 133 per sq. ft.
* Emulsion lining	Rs. 20-75 per sq. ft.

The comparative costs of different types of lining indicate that emulsion lining is the cheapest.

The test results and cost of treatment of various types of emulsion are shown in Table 6. Complete reduction of seepage losses from canals is a controversial point, but a reduction of even 50 percent will conserve a huge quantity of water.

The water which seeps into groundwater loses its original good quality, and if pumped out, apart from the excessive cost of pumping, is more saline and is liable to create sodium hazards and salinity in soils. By lining canals, good quality water can be conserved and utilized.

Table 6. DEVELOPMENT OF SOIL SEALANTS FOR LINING EARTHERN CANALS

No.	Name of Sealant	Penetration (Inches)	Efficiency (Percent)		Durability	Cost (100 sq. ft.)
			Lab Test	Field Test		
1.	Catonic Asphalt Emulsion	1/2-2	60-70	50	Effective for two years	Rs. 20
2.	S.S. 13	1/16-1/4	42-80	78-90	Destroyed due to wetting and drying cycles	Rs. 15
3.	Chevron Soil Sealant (Wax emulsion)	6-12	80-90	70	Not effective with high water head	Rs. 40
4.	Oil Emulsion of P.C.S.I.R. Laboratory, Lahore	2-11	60	-	Destroyed due to wetting and drying cycles	Rs. 15
5.	i) Esso Low Cost Sealant	1/2-10	35-85	60-80	Marked 2/2 sealant was found suitable	Rs. 20-80
	ii) Esso 2/2 Marked Sealant	3-5	-	75	Quite effective up to now	Rs. 35-80
6.	Sealants produced by I.R.I., Lahore	1/8-20	30-70	-	Under study	Rs. 20-75

Losses from Watercourses

There are nearly 60,000 watercourses and the average length of each watercourse is assumed to be two miles, thus the total length of the watercourses works out to be 120,000 miles. The average wetted parameter can be taken as 4 feet.

Various durable and economical lining materials, e.g. plastic films, soil cement mixture and emulsion of various types, are under study at the Irrigation Research Institute, Lahore. A reduction of 50 to 100 percent in seepage has been recorded so far. The durability and other aspects of these lining materials are still being studied.

Water losses from watercourses can also be greatly reduced by:

* Proper alignment of watercourses

* Keeping the watercourses free from weeds.

Losses from Free Water Surface

It is estimated that by 1975 the total loss of water from free water surface in West Pakistan will be about 2,000 cusecs. Water loss from a reservoir causes its salt content or conductivity to increase. Hence evaporation reduces both the quantity and quality of the water during storage. Important work is being done to reduce water losses in many countries of the world such as America, Canada, Australia, and Russia. It has been observed that when films of chemicals are spread on the water, they reduce evaporation. Physical methods have also been tried; floating plants and plastic flakes are worth mentioning. Encouraging results have been achieved with various types of alcohols. Mansfield saved 200 million gallons of water at Broken Hill using cetyl alcohol dissolved in volatile petroleum. At the Rio Tinto Mines in Spain a solution of cetyl alcohol spread with two large floating dispensers saved 35 percent of the total evaporation. Some countries have tried various vegetable oils and have obtained good results.

The Irrigation Research Institute is also conducting research in this direction. Various alcohols, oils and emulsions of mineral and vegetable oils have been tried under local conditions and the results obtained so far are put forth in Table 7.

Table 7. REDUCTION OF LOSSES FROM FREE WATER SURFACE

No.	Evaporation Retardant	Average Reduction (Percent)
1.	Wax in turpentine oil	60.0
2.	Cottonseed oil	58.0
3.	Groundnut oil	43.0
4.	Linseed oil	38.0
5.	Rape seed oil	35.0
6.	Cetyl alcohol in kerosene oil	33.0
7.	Paraffin oil	32.0
8.	Mustard oil	28.0
9.	Cetyl alcohol (solid)	28.0
10.	Coconut oil	27.4
11.	Stearyl alcohol	25.0
12.	Emulsions of vegetable and mineral oils marked ERI-ER 13 (under study)	20-70

Loss of Water from Bare Soil

As mentioned earlier, with the rising water table, water losses from the soil continue to increase. With proper drainage water tables can be maintained at an appropriate depth, and so the water loss from bare soil can be minimized. Some countries have started experimenting with certain chemicals spread on the soil to reduce water losses, and encouraging results have been obtained. Some studies are being planned at the Irrigation Research Institute to reduce water loss from the soil with certain chemicals, particularly with bitumen emulsions.

Excessive Evapotranspiration

In the majority of cases excessive evapotranspiration is of no advantage to plants. It has been learned that if the water table is taken

down beyond 10 feet evapotranspiration is appreciably reduced. Generally a high water table reduces the yield with the exception of sugarcane. The yield of cotton falls greatly with the water table brought to 3 feet. It has been observed that the water table kept at an average level of 15 to 20 feet is suitable for almost all crops, with the exception of crops like sugarcane.

Chemicals are also being used in an attempt to reduce evapotranspiration. If suitable chemicals, e.g. some alcohols, are spread on the body of the plant, its transpiration can be controlled. If chemicals are spread on a rice field in standing water its evaporation is reduced; a side benefit is also achieved as water temperature increases, which proves beneficial at a certain stage in the growth of plants.

Water Conservation with Improved Irrigation Practices

a) *Cultivation in Blocks:* If crops are cultivated in blocks, the watercourses are aligned properly, and the losses in transportation of water to different parts of a chak or farm are kept to a minimum.

b) *Basin and Furrow Irrigation Methods:* The basin method has been found suitable for wheat and cotton, while the furrow method is suitable for potatoes and other vegetables. In the basin method small size basins are more economical, but in actual practice it has been observed that a maximum of eight basins per acre is found suitable in the case of wheat and four basins in the case of cotton. In the furrow method, the frequency of water application is increased and despite that there is overall economy as a full head of water for the required application is used, starting from the upper end and filling to the lower end quickly. This prevents overirrigation of upper reaches and underirrigation of lower reaches.

c) *Sprinkling technique:* Irrigation by sprinkling is an improvement over the conventional gravity irrigation system. The two systems are analogous to a racing cyclist versus any fast runner. In spite of the fact that the efficiency of any machine is less than one, the glorious victory of the cyclist over the runner is attributed to a well planned and careful application of the energy so that all losses are reduced to a minimum. In a similar manner, the gravity irrigation system involves huge percolation losses to deeper soil zones beyond the root zones of the plants. This in turn develops waterlogging and salinity, whereas a well designed sprinkler system enjoys the benefit of a uniform application of water to the entire area in question, to such an extent that almost no percolation takes place beyond the root zones of the plant and the entire amount of applied

water is usefully consumed by the crops.

It has been estimated that with the same available quantity of canal water, about 50 percent more area can be irrigated with a sprinkler system in comparison to the gravity system. Crop production, however, is also expected to be doubled on account of other advantages of this system, such as washing harmful germs and dust particles off the plants, thus developing a better respiration system.

The Irrigation Research Institute is planning some experiments in sprinkler irrigation, keeping in mind the conditions prevailing in Pakistan, and determining if this system can be adopted within the present distribution system.

d) *Water Conservation with Underground Asphalt Barrier Technology:* Agriculture with asphalt barrier technology in arid, semi-arid and saline lands has given highly encouraging results in some countries of the world. The available information on this technology is summarized below:

1) Asphalt barriers are laid 2 to 3 feet deep in the desert in order to prevent infiltration and rising up of water from below.

2) Asphalt is spread in a layer of 1 mm. thickness.

3) A tractor and trailer combination that can lay 10 to 20 acres of asphalt per day is being manufactured in the USA.

4) The technology requires one-half to one-fifth of the ordinary quantity of water and the crop increases by 40 to 300 percent.

5) The new technology has been found successful in the USA, France, the United Arab Republic and the Republic of China.

6) The problem of waterlogging and salinity can also be tackled with the new technology.

7) Asphalt layers and VS vinyl films can be used. Asphalt costs less and is more durable than vinyl film which has been in use for cultivation of rice in Japan. It takes less time to apply than vinyl film.

To study this technology, a start was made in 1970 at Niazbeg Research Station, Lahore, by cultivating a rice crop (Basmati 198) in lysimeters set up with bitumen barriers. The experiments are briefly described in the following paragraphs.

Experimental setup

Twenty lysimeters of 3 feet in diameter were selected. One lysimeter contained a packing of clay while in the rest the top 3-foot layer was clay followed by silt. The lysimeters with uniform clay formation were divided into three sets as A, B and C, each containing three lysimeters. Set A was kept untreated while in sets B and C bitumen layers of 4 mm. thickness were applied at depths of 2 and 3 feet respectively. In the remaining one lysimeter plastic film was laid. Similarly the lysimeter with stratified soil formation, i.e. the top 3 feet of uniform clay and the rest silt, the sets were divided as D, E and F. D was kept untreated while in E and F bitumen layers at 2 and 3 feet respectively were applied and in the remaining lysimeter plastic film at a depth of 2 feet was laid. A new variety of rice, Basmati 198, was planted in these lysimeters. Evapotranspiration and drainage surplus were observed.

The experimental setup is given in Figure III and the detail is put forth in Table 8.

Table 8. WATER CONSERVATION USING BITUMEN BARRIERS AT DIFFERENT DEPTHS

No.	Soil Conditions in Lysimeters and Their Depth	Total No. of Lysimeters	Depth at Which Bitumen Layer is Applied (in ft.)	Thickness of Bitumen Layer (in mm.)
A	8-ft. uniform clay	3	Untreated	Nil
B	8-ft. uniform clay	3	2	4
C	8-ft. uniform clay		3	4
D	3-ft. clay at the top with silt underneath	3	Untreated	4
E	3-ft. clay at the top with silt underneath	3	2	4
F	3-ft. clay at the top with silt underneath	3	3	4
G	3-ft. clay at the top with silt underneath	1	2	Vinyl film (Plastic cloth)
H	3-ft. clay at the top with silt underneath	1	3	Vinyl film

EXPERIMENTAL SET-UP OF LYSIMETERS AT NIAZ BEG

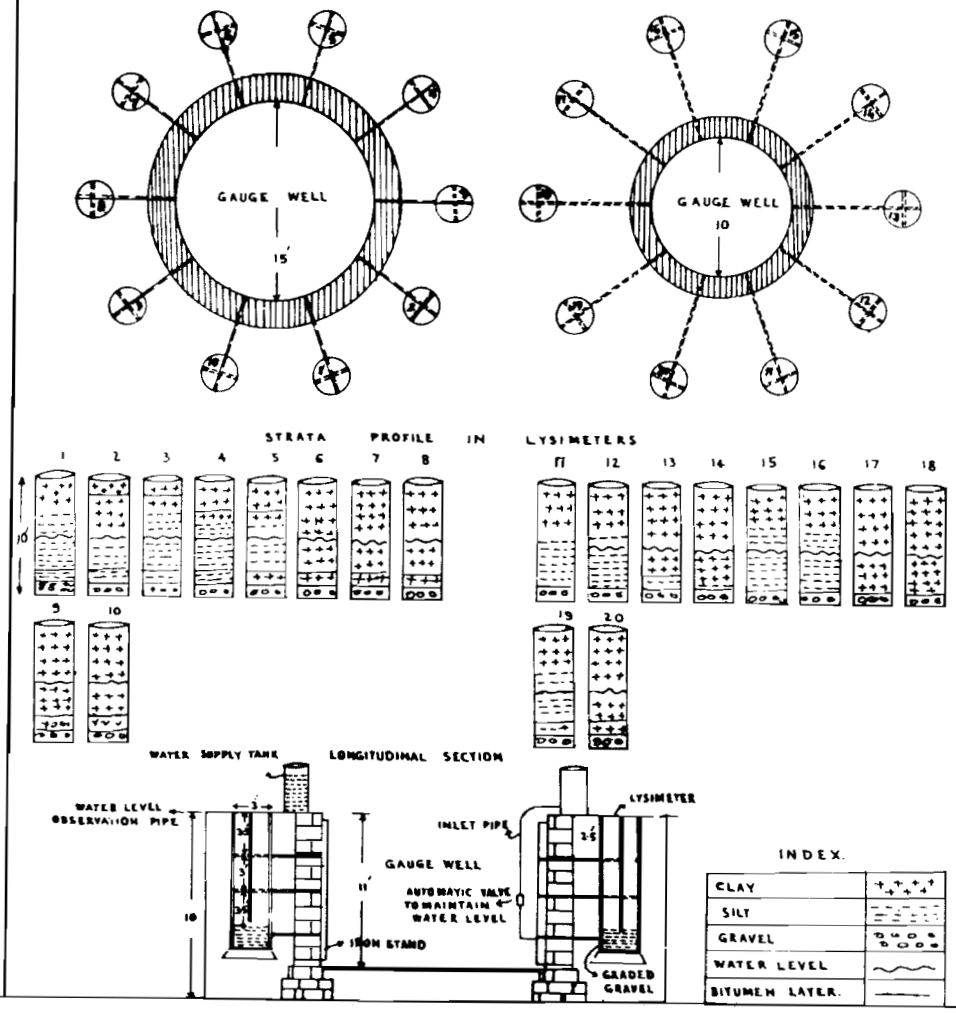


FIG. III

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Unfortunately there had been a countryside disease called leaf hopper on rice crops and the crop under study was also greatly affected. Consequently varied yields were recorded even from those lysimeters where the experiments were maintained under almost identical conditions. Owing to this hazard to the crop, it was very difficult to learn the effects of the technology on the crop yield. However, the technology clearly indicated its usefulness in water conservation in the case of the rice crop.

The experiment is being repeated this year and some bigger lysimeters measuring 20 ft. x 15 ft. x 10 ft. are also being constructed so that the effect of the technology on other crops under controlled conditions can be studied.

SUMMARY AND SUGGESTIONS

The summary of information on the water potential of West Pakistan along with the suggested measures for their better utilization are given below:

1) West Pakistan surface water resources were estimated to be 133.8 million acre feet (1969-70) and out of this 98.26 million acre feet were diverted to irrigation canals.

2) Surface water potential did not vary much during the last 20 years and no substantial increase is anticipated in the near future.

3) Out of the diverted water, about 60 percent is lost as evaporation or seepage.

4) The surface water potential is limited. Countries with climates similar to that of Pakistan use three to four times more water for cultivation.

In order to meet the food and fibre requirements of a rapidly increasing population, measures can be adopted for better utilization of the limited irrigation potential of West Pakistan by conserving the colossal wastage of water. The following steps can be taken to conserve water:

1) Chemical soil sealants can be used as cheap canal lining materials. Laboratory studies with bitumen emulsions gave a 30 to 70 percent reduction in seepage. Their other aspects and economics are still under investigation.

2) In the case of watercourses, water losses can be minimized by lining them with soil sealants, laying plastic cloths, proper

alignment, replacing Kacha Nakka with Pacca Nakka and killing weeds.

3) In the field a lot of water can be conserved by the leveling of land, spraying land surfaces with chemicals, using the compartment technique and furrow methods for irrigation.

   Water can also be conserved by introducing modern technologies developed for water conservation, e.g. the sprinkling technique and asphalt barrier technology.

Water conservation problems concern not only Pakistan but member countries of the CENTO region as well, so in this field a collective effort, in the interests of the whole region, may be made. The following proposal for a joint venture is put forth.

Proposal for Future Coordinated Research

Considerable research on water conservation techniques is being conducted in many countries under their local conditions and preferably with locally available materials. These water conservation technologies can be studied for their suitability to local conditions and the socio-economic setup of the CENTO region as well.

The prospects of using asphalt as canal lining material, an underground moisture barrier and moisture preservation material on the surface of the ground, are very bright for the arid and semi-arid zones of the region.

The setting up of an agro-chemical complex is a prerequisite for making asphalt barrier technology a success. Such an industry is a cheap source of asphalt. Its byproducts are also useful for agricultural development. However, before introducing the use of asphalt on a large scale for water conservation purposes a detailed study and a survey of local conditions and all other relevant factors are essential.

In 1970 a Japanese Arid Land Studies Mission carried out a survey on the feasibility of the use of asphalt for agricultural development in West Pakistan. Some members of the mission, after the survey, visited international organizations, including FAO, UNESCO, UNDP and the World Bank. They explained the arid land reclamation and development projects and exchanged views with them. Later in the year the mission submitted to the Government of Pakistan a report titled "Preliminary Study of the Use of Asphalt in Arid Land Reclamation and Development Projects in West Pakistan."

The report gives a summary of the findings of the mission. It describes local climatic and soil conditions, the socio-economic setup and the potential of asphalt production, prospects of constructing

agro-chemical complexes and the use of asphalt as water conservation material on a large scale, etc. It also points out that to obtain regular and large quantities of asphalt at a low cost, the setting up of agro-chemical complexes is essential and such complexes might be feasible in Iraq, Iran, West Pakistan and Saudi Arabia. Asphalt produced from agro-chemical complexes would be useful for construction works and development projects in these countries. In addition they would produce byproducts that could be used successfully for purposes other than water conservation.

Benefits of an Agro-Chemical Complex

1) *Production of asphalt:* A refinery built for this purpose should have a capacity of processing over 150,000 barrels of crude oil per day. The naptha proceeded as a byproduct could be exported to Japan and elsewhere. The asphalt would be used in the development projects of the country in which the refinery is located.

2) *Manufacture of fertilizer:* Ammonium sulphate and urea can be readily manufactured from asphalt. The asphalt can be turned to hydrogen by a partial combustion process and then converted to ammonia.

3) *Pavement of roads:* The use of asphalt in the development of a network of roads and their maintenance is of great importance in developing countries.

4) *Development of harbours:* Development of harbour facilities is necessary for developing countries. Asphaltic concrete is the most durable and suitable construction material for harbours.

5) *Lining of canals:* Asphalt can be used for the lining of canals, watercourses and reservoirs to prevent the seepage of water. The lining can be asphalt concrete, asphaltic membrane or asphaltic mattress. It can also be used for lining drainage channels and ponds containing water of high salt content.

6) *Preservation of moisture:* An emulsion of water and asphalt can be used for spreading on the surface of the soil for the preservation of moisture in the ground.

7) *Stabilization of sand dunes:* Sand dunes can be stabilized by spreading emulsion on them, prepared from water and asphalt, etc.

8) *Asphalt barrier for water conservation:* When asphalt is laid in a continuous thin film 60 to 90 cm. below the surface of the ground in arid lands, it acts as a moisture barrier, saving 20 to 50 percent of the water. This technology also helps in increasing the yield of crops through its other benefits.

9) *Production of sulfur and gypsum:* The sulfur and gypsum produced by the hydro-desulfurization of heavy fuel oil can be used to improve alkaline soils.

West Pakistan has such alkaline soils as can be reclaimed by using sulfur and gypsum. In West Pakistan the salinity-alkalinity survey carried out during 1968-69 by the Directorate of Land Reclamation indicates that out of 38 million acres, 5.5 million acres are saline-alkaline. This is 14.2 percent of the total area surveyed. No specific categorization of alkaline classes has been made so far. A tentative estimate, however, indicates that nearly 90 percent of the entire salt-affected land is saline-alkaline.

Reclamation of alkaline soils can be effectively achieved through the use of chemical additives like gypsum and sulfur. The requirement of gypsum per acre varies with regard to the alkaline status of the soil. On an average the per acre requirement of gypsum may vary from 3 to 5 tons.

10) *Activated carbon:* Activated carbon can be made from asphalt. It is used for purifying water and its use for other purposes is also increasing.

In view of these benefits in setting up agro-chemical complexes, an economic feasibility survey may be made in the CENTO region to locate the most suitable site for the industry.

Some preliminary experiments on the use of asphalt for water conservation should be started under local conditions. Such experiments can be undertaken by countries having arid and semi-arid conditions. If results of coordinated research and experiments prove favourable in these countries, pilot farms could be established. Technical know-how available within the countries where this technique has been tried can be utilized in the form of a mutual assistance programme. As regards an underground asphalt barrier technology, some preliminary study as narrated earlier has been carried out. Further studies, as described below, will be conducted at the Irrigation Research Institute, Lahore, West Pakistan. Plans have been made to:

1) Study different types of locally available materials (particularly asphalt) to be buried in the form of layers as barriers against water losses

2) Determine suitability, permeability and durability of different types of layers spread at different depths

3) Determine seepage losses of water at different water heads through the buried layers

4) Determine the role of an asphalt barrier layer in reducing irrigation water requirements per unit of land

5) Determine crop management techniques required for growing rice, sugarcane and cotton over an asphalt barrier

6) Determine water management requirements to maintain a favourable salt balance in the soil above an asphalt barrier

7) Determine bearing capacities of the buried layers under moving loads of different types of agricultural machinery

8) Study the effectiveness of layers on different types of soil

9) Study behavior of layers in alkaline and saline soils

10) Study the rise of salts through the buried layers. (The alkalinity and salinity menace can be controlled.)

11) Determine the role of an asphalt barrier in checking the mixing of good quality water with saline water in soil

12) Study temperature movement in soil with asphalt or bitumen barrier. (Soil temperature also affects the growth of plants.)

13) Develop an efficient and economical technique for laying asphalt layers at optimum depths evolved after study

14) Determine the economy of using fertilizer in the new technology

15) Study the varying rates of soil evaporation and evapotranspiration and then suggest remedial measures to reduce the water losses

16) Study merits, demerits and economics of the two barriers: vinyl film and asphalt.

The completion of such proposals will greatly help in understanding all the possible problems which may crop up during application to different types of local soils and crops. The proposed studies for the new technology will also point out specific directions of research in which more vigorous activity is needed. The comparison of economics and feasibility of this technology with others for water conservation measures will decide its future in our country.

Some preliminary studies of water conservation are already being conducted at the Irrigation Research Institute with its meagre resources. To carry out the studies on a large scale, six projects of water conservation studies, given below, were prepared and sent to USDA

for their expert and technical advice and aid under the PL 480 programme:

1) Studies on soil sealants for lining earthen channels

2) Studies on evapotranspiration with an asphalt barrier technology

3) Studies on evaporetardents

4) Studies on evapotranspiration of crops

5) Studies on gravity and sprinkler irrigation systems

6) Studies on the economics of various water conservation techniques.

The projects, however, have not been finally approved and are under consideration.

Along similar lines other member countries can plan and study water conservation projects under their own local conditions.

A research institute, mainly dealing with asphalt research for water conservation may be established by seeking help from UNDP, UNESCO, FAO, UNIDO, the World Bank and other such agencies. The accumulation of the past experience and knowledge of these organizations can be incorporated in projects and financial grants and loans from these sources might be available. Such research organizations may also be very helpful in imparting training to engineers and other experts in the region responsible for implementing the projects involving this technology in their respective countries.

To sum up, for future coordinated research activities in the water conservation field in the CENTO region, the following main suggestions are put forth for consideration:

1) Research activities in the water conservation field should be coordinated in a proper way to benefit the whole region. In this connection frequent meetings of the scientists and experts must be held to exchange views on the subject.

2) Out of the various water conservation studies being conducted in different countries of the world, the use of asphalt for water conservation has great prospects for the CENTO region. Therefore, a joint venture is needed in its production and use.

3) To obtain a regular quantity of asphalt at low cost, the setting up of agro-chemical complexes must be studied in detail.

4) A research institute for conducting water conservation studies, preferably by the use of asphalt, can be established by seeking help from UNDP, UNESCO, FAO, UNIDO, the World Bank and other such agencies.

5) To make a start, some preliminary applied experiments are being undertaken at the Irrigation Research Institute, Lahore, West Pakistan, and such types of experiments may also be planned and conducted in other member countries under their own local conditions. If the results of these coordinated research programmes and experiments prove favourable, pilot farms could be established.

PAPERS PRESENTED BY THE DELEGATES

THE SUMMER FALLOW SYSTEM

by Mr. Thomas G. Zinn,

Soil Specialist,

Oregon State University and

USAID/Turkey

BACKGROUND

During the last few years rapidly increasing human populations have resulted in inadequate food supplies in many areas of the world which were formerly self-sufficient. Some of these areas are composed largely of semi-arid or dryland climatic conditions. Dryland regions have proven to be very productive when we apply the technological advances and developments in agriculture to these semi-arid areas. By using knowledge and practices gathered in regions where agriculture is highly developed, technical people have been able to increase food production in many other areas.

Throughout the world there are many areas with very similar climatic conditions. Central Turkey and other areas in the Middle East are climatically very much like the inland areas of the Pacific Northwest in the United States, such as Oregon and Washington. The rainfall distribution and pattern in these areas are similar. Elevations and temperatures are near the same. In both these regions wheat produced under a fallow system is the major crop. The question then arises: why are wheat yields much higher (an average of 200-300 kg./decare) for the Pacific Northwest as compared to the Anatolian Plateau of Turkey and the Middle East with an average of 80-100 kg./decare?

To find an answer to this question let us compare the farming systems being used.

WHY THE FALLOW SYSTEM?

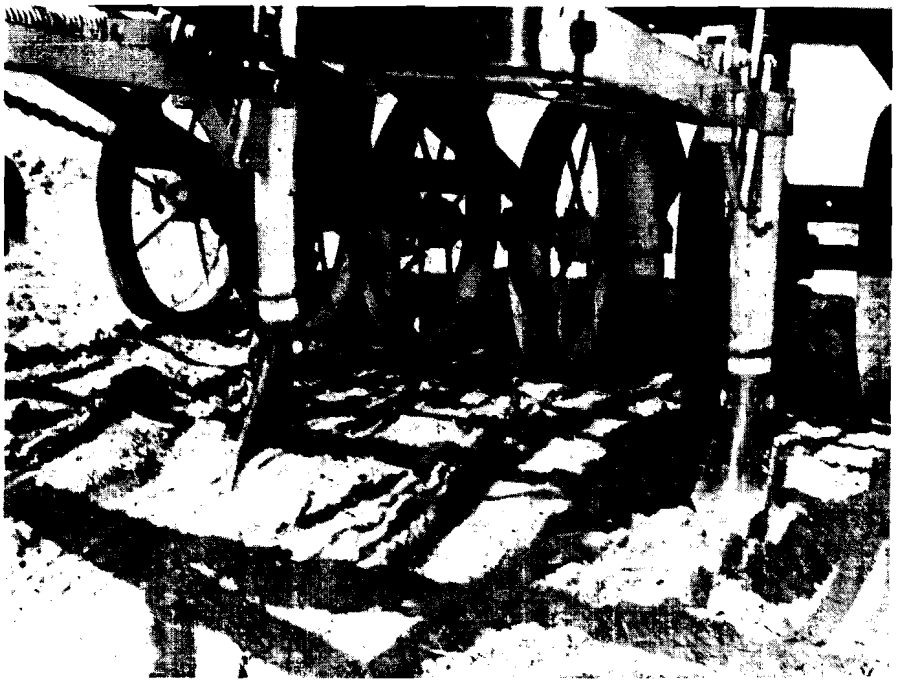
Where rainfall is too limited to permit annual cropping, as in many areas of the Middle East and the semi-arid lands of the United States, a system has been developed to keep the land free of a crop for one year. The purpose of this is to accumulate moisture in the root zone for the subsequent crop in alternate years.

This system has been more commonly used in producing winter types of small grain than spring types or summer crops such as sorghum and millet, and in areas of dominantly winter rainfall. The soil is usually dry at the time the winter wheat is harvested in July and August. Little accumulation of moisture will normally occur by planting time in September. Annual planting of winter wheat in low rainfall areas usually produces low yields and many crop failures.

Fallowing for winter wheat as compared with annual cropping has shown higher total production and greater stability of production. It tends to even out the production function curve, particularly during the years of short moisture. It also produces a lower unit cost of production, and a greater efficiency in moisture use.

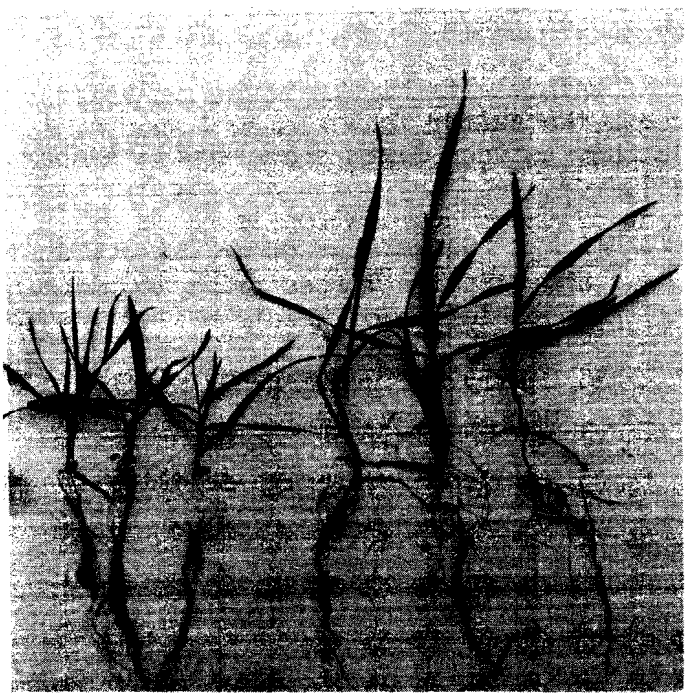
The summer fallow system makes use of a mulch which consists of fine particles of soil and straw to a depth of approximately 12 centimeters. By mid-September the soil beneath the mulch is still moist, as shown above. Wheat seed can be planted in this moist soil at a depth of approximately 15 centimeters by means of a deep furrow drill. There is normally enough moisture to germinate the seed within 7 to 10 days.

Erratum: Page 93, lower photograph. Caption should read: *"Planted in September, the plants on the right display a primary and secondary root system that is sufficiently well developed to take advantage of early spring rains and soil fertility. They will not have to depend on late spring rains for development as will the plants on the left."*



This photo shows two different types of shovels or points that can be attached to the deep furrow drill.

The point on the left is the regular point or shovel, and the point on the right is used when soils are compacted and it is difficult for the drill to penetrate to the desired depth. It is capable of drilling seed to depths of 12 to 15 centimeters.



Planted in September, the plants on the left display a primary and secondary root system that is sufficiently well developed to take advantage of early spring rains and soil fertility. They will not have to depend on late spring rains for development as will the plants on the right.

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Purpose of the Fallow System

The primary purpose of the fallow system is to accumulate moisture in the root zone. Available nitrogen and other nutrients also result from microbiological breakdown of soil humus during the fallow period.

The summer fallow operation has two distinct objectives in moisture conservation: 1) the total amount of moisture stored in the root zone that can be used by the next crop and 2) the amount of moisture that can be maintained at a depth of 10 to 12 cm. so that seed can be planted into moist soil before the fall rains start. Accomplishing this second objective is very important and requires a series of very timely tillage operations. Planting winter wheat into moist soil between September 20 and October 1 in an area like the Anatolian Plateau of Turkey allows the wheat plant to become established early enough to develop the secondary root systems before winter dormancy occurs. Many winter wheat plantings that wait for mid-November rains for germination do not develop the secondary root system before winter dormancy occurs, and sometimes never develop a good secondary root system.

This earlier germination and seeding development in the fall often advances the date of maturity from 1 to 2 weeks the following year. This means that these wheat plants might escape some hot, dry weather that could have serious effects on later maturing wheat.

Rainfall is highly variable in frequency and amount in regions where the summer fallow system is practiced. Several days of hot dry weather between light showers will evaporate most of the water from the soil surface. Many years of measurements show that only 20 to 30 percent of the precipitation is saved during the fallow period. An effective fallow system must store water when it comes, whether as rain or snow, and minimize losses prior to planting the crop. Maximum efficiency in accumulation of moisture requires the following:

1) Control of weeds since weeds act as a water pump and will use much of the water stored during the fallow cycle.

2) Maintenance of high infiltration rates so that the rain that falls enters the soil.

3) Slowing of the surface movement of water to permit infiltration and reduce water erosion.

4) Avoidance of tillage that loosens or turns up moist soil and exposes it to rapid drying.

5) A moisture barrier, or mulch, which must be established at the proper depth so that it will hold the stored soil moisture during the fallow season until seeding time.

It is very important that the mulch hold the soil water at a level in the soil so that the seed can be planted into a moist soil layer.

When a good mulch has been established, little moisture is lost from soils, if it has penetrated below a depth of 7.5-10 cm. Tillage which loosens and exposes the moist soil and weed growth will cause water loss.

Timeliness is important in cultural practices. Mechanization has improved timeliness by speeding up field operations. Efforts in developing a summer fallow system and perfecting a stubble or dust mulch were not significant in the semi-arid lands of the Pacific Northwest of the United States until the use of tractors really became available. Otherwise, mechanization has been the key to the success of this system. This work began about 25 to 30 years ago and has been very successful.

Whenever a farmer takes implements to the field, he should have important tillage objectives to accomplish. His implements should be the proper ones to do the work.

The Present System

Summer fallow and planting procedures being used in the Middle East and other dry farming areas are often inadequate. Wooden plows pulled by oxen leave the soil loose and subject to drying as deep as it is turned. Weed control during the fallow operation is often incomplete or nonexistent. Little plant residue is left on the surface to protect the soil and maintain water infiltration rates.

In this part of the world it is common practice to remove all straw from the fields at harvest. The fields are then heavily grazed by flocks. Weeds which emerge in the spring are grazed until early summer when the fallow tillage begins. At the optimum time for wheat planting, the plow zone of the fallow field is frequently very loose and dry. The farmer has to cultivate a number of times before planting, thus losing moisture that has been stored. Farmers in these areas have learned that seed planted early in the fall in dry soil may be germinated by a light rain, then dry out, and die. Thus they have adopted the practice of delaying planting until late fall when temperatures are cooler and rains more certain.

Much of the wheat is seeded by hand broadcasting. High seeding rates are used to help assure a good stand under the poor conditions. Sometimes the farmer plows the field, broadcasts his seed on the rough, loose soil, and covers it with a harrow or drag. Sometimes the seed is broadcast on the surface of the fallowed field and the wooden plow is used to cover the seed. In either case the seed is placed in loose soil, subject to rapid drying, rather than in contact with firm moist soil which would promote germination.

In Turkey research has proved that 7.5 kilograms per decare is a satisfactory seeding rate if a proper seed bed is prepared. Most of the farmers plant 12 to 15 or more kilograms of seed per decare. Based on the number of hectares of wheat grown in Turkey this excess seed used each year amounts to approximately 500,000 tons of wheat. Wheat yields in these areas are low for a number of reasons:

1) Poor summer fallow practice

2) Poor seedbed at planting time

3) Delay of planting past optimum date

4) Very poor planting methods for assuring germination and stand establishment

5) Excessive soil erosion and low fertility

Fallow System in the U.S.

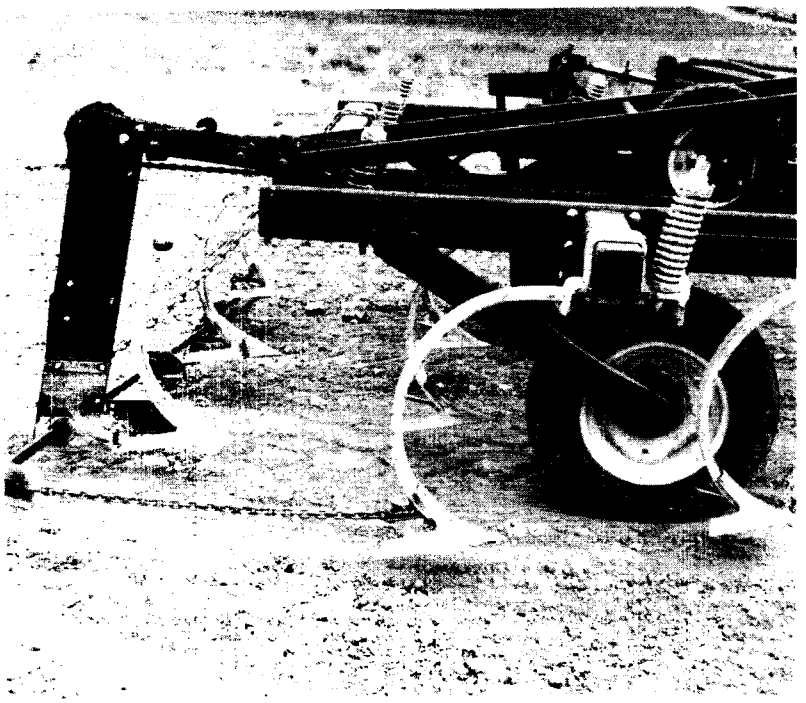
In the Pacific Northwest the production of cereals in these semi-arid regions include the following combinations of practices:

1) After harvest the land to be fallowed should be in a condition to allow maximum infiltration and penetration of moisture to reduce erosion hazards during the winter months. This may or may not need to include a fall tillage operation such as chiseling, subsoiling or sweep plowing.
   In the summer fallow system the moisture stored during the late fall, winter, and early spring is one of the most significant aspects. For it is this moisture that when successfully held in the soil profile, enables early germination of the crop. Precipitation coming in the late spring and early summer, unless in large amounts, is of little value for the maturing crop.

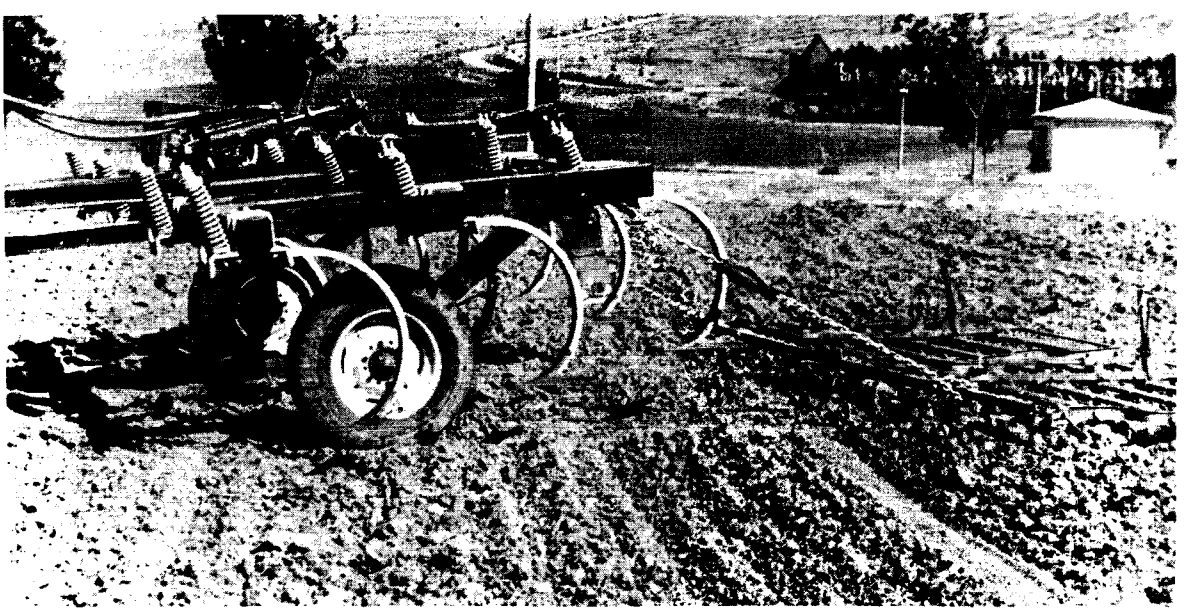
2) Initial spring tillage at the proper time and depth is essential to conserve the maximum amount of soil moisture. This is accomplished by killing the volunteer cereals that may have germinated and by controlling weed growth. In addition, the initial spring tillage operation produces a moisture barrier (mulch) for the following operations.

3) A mulch of the proper depth must be established that will hold the stored soil moisture during the fallow season until seeding time. The preparation of this moisture barrier is of primary importance.

4) Weed control and maintenance of the mulch must be practiced



The sweep or sweep chisel plow is a very useful and versatile implement for dryland wheat production. The sweep is normally used for the first spring tillage operation, but the sweeps can be replaced by chisel points and used for a fall tillage operation if necessary. Pictured above is the sweep with a rod weeder attachment, a combination that can be used throughout the summer for the summer tillage operation.



Research trials in Turkey have proven the importance of using a sweep and sweep rod weeder combination plus a set of spike tooth drag harrows. When pulled behind this combination the harrow does an excellent job of breaking down the clods and covering up any cracks that might be left from the sweep.

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during the spring and summer of the fallow season. This may require several tillage operations such as rod weeding or use of some other tool which will eliminate weed growth and produce a surface mulch.

5) Use the best available adapted variety which is capable of maximum production under such a fallow system.

6) Prepare the best seedbed possible, plant at the optimum rate, date, and row spacing to insure rapid germination and establishment of stand before cold weather begins.

7) Fertilize at the optimum rate and date (at planting and/or spring top dressing for maximum yield).

8) Control weeds during the crop growing season (fall and spring).

9) Control insects and diseases on crop where needed (this could be seed treatment prior to planting).

RESEARCH CONDUCTED IN TURKEY ON DRYLAND AREAS

The Government of Turkey, beginning in 1969, engaged in a joint effort with the Agency for International Development, through a contract with Oregon State University and the National Wheat Improvement Center, to increase cereal production on the Anatolian Plateau. These project activities are coordinated through the Ministry of Agriculture and the Ministry of Rural Affairs. The primary emphasis for increased cereals production has been directed toward the continuation of the research and adaptive research projects now underway, utilizing new and special techniques and developing an effective extension and farmer education program covering:

1) Soil moisture conservation (improved summer fallow tillage)

2) Use of new or improved tillage and seeding equipment

3) Use of fertilizers

4) Use of pesticides and herbicides

5) Improved varieties of seed.

Research has been and is continuing to be conducted cooperatively to determine the systems of soil management which will conserve the maximum amount of soil moisture. Based on observations of current tillage methods, it is apparent that higher yields are possible. Through

the use of more advanced equipment and improved and refined soil moisture management practices, it should be possible to stabilize higher yields and make it more profitable for the wheat farmer and help Turkey produce her cereal needs. The soil tillage research now being conducted is of primary importance in order to formulate a combination of tillage operations needed to conserve the maximum amount of moisture. This research is designed to determine the effectiveness of good soil moisture conservation and the most effective equipment combinations to use in the various soil types. With the establishment of the National Wheat Research Center, research is being carried out to determine the optimum fertilizer rates, seeding rates, row spacing, weed control practices and varieties of wheat that are capable of maximizing the benefits of increased moisture. It is extremely important to understand that it will require the application of a combination of these practices, rather than any one individual practice, to achieve the most significant influence on dryland cereal production on the Anatolian Plateau. Although the combination of these practices is necessary, we feel that moisture conservation is the most important single factor. Without the added moisture the other practices cannot produce the maximum benefit.

Priority needs to be given to the research work underway and to the expansion of this work to produce the data pertinent to the development of recommendations to go into the "package of practices" cited above.

As tillage combinations are tested and research data compiled recommendations will continually be refined and improved. Not only tillage, but the other combinations such as fertilizer, herbicide treatment, varieties, row spacing, date and rate of seeding will need continued research and refinement to meet the ever-changing "state of the science."

It must be remembered, however, that our research work was initiated in 1969. Research involving tillage combinations under the fallow system requires two years before yield data from the given trial are available. The first yield data were recorded in the 1971 harvest but had not been analyzed at the writing of this report.

RESEARCH

The experiments harvested this year consisted of a total of 80 different treatment combinations of fall, spring and summer tillage. The total area of each trial was over 3.2 hectares. This probably caused some variability because of the difficulty in getting uniform soil over that area. Some of the different tillage combinations are giving a different moisture situation in the seeding zone that appears significant.

Six sites at four locations are included in these trials. The sites were selected as being representative of the area in soil type, depth, topography and fertility level. In addition, these sites had been cultivated in the past in the usual manner, i.e. moldboard plow and disk, then rodweeder. None of the sites had received subsoil tillage treatments such as chisel plow or subsoil.

Soil Moisture Sampling Procedures

Soil moisture samples for determining total moisture in the profile were taken at three different times. Samples for determining depth of mulch and percent moisture at seeding depth were taken at two different times.

First Moisture Sampling Period

At the beginning of the experiment after the 1969 harvest (July 25-31) sampling pits were dug to a depth of 150 cm. except where parent rock occurred nearer to the soil surface. Disturbed bulk samples were taken from the most representative pit for physical and chemical analyses.

Undisturbed samples were taken from all three pits in each site for soil moisture determinations and bulk density values.

Sampling Procedures

Disturbed soil samples were collected from 0-10, 10-30, 30-60, 60-90 and 90-120 cm. depths. Undisturbed soil samples from the same depths were taken with a core sampler. Porosity, volume weight and moisture content of each layer in the profile at the time of sampling were calculated from the undisturbed samples. Volume weights will be used for conversion of percent moisture in mm. of water in future samplings.

GENERAL CONCLUSIONS FROM THE FIRST SAMPLING PERIOD

The moisture content in all the sites was near the wilting point or below. This was somewhat surprising because previous observations reported by consulting teams had indicated that because of late planting and the presence of dense plow-layers, the wheat plants were probably not extracting moisture from much below 1 meter in depth. The rainfall during the preceding crop period (September 1968 - June 1969) was well above average (474.3 vs 380.9 mm). Since none of the sites had previously had any subsoil tillage, dense layers at plow depth were observed in several of the soil pits. Apparently though, in spite of this the wheat plants were extracting moisture from well below the 1-meter depth.

The rainfall data indicate about average moisture conditions were present. However, by examining the distribution of the rainfall at these locations on a daily basis it becomes apparent that relatively small amounts of moisture fell on any given day. This, coupled with the fact that the winter of 1969-70 was abnormally warm, thereby increasing the evaporation potential, would account for the lack of water in the soil profile. The soil profile was well below its moisture holding capacity at the beginning of Spring, 1970.

TILLAGE AND HERBICIDE TREATMENTS

The different treatments applied at each trial site were as follows:

Fallow Tillage and Seeding Operations 1969-70
Fall 1969-Early and Late Tillage and
Chemical Fallow Treatments

August 7-20 and October 13-17

Type of Implement and Adjustment	Tillage Depth (cm.)
1. Chisel plow, 5 shanks with spike points, 40 cm. spacing	25
2. Subsoiler, single shank 110 - 120 cm. spacing	50
3. Chemical fallow treatment: Atrazine, 45 grams/decare + Amitrole, 0. 175 l/decare in 24 liters/decare water	

Spring 1970 - Initial Tillage Treatments April 7-25

Type of Implement and Adjustment	Tillage Depth (cm.)
1. Sweep plow, 7 shanks with 42-44 cm. sweeps (local manufacture), 30 cm. spacing and skewtreader (John Deere, MT8 ft.) in packing position, maximum angle, hitched to and pulled behind sweep plow.	14-16

2. Sweep plow (same as above) with spike-tooth drag harrow (2-5 foot sections) attached to and pulled behind sweep plow. Harrow spikes set at about 30° angle.	14-16
3. Chisel plow, 9 shanks with spike points, 25 cm. spacing and skewtreader (adjusted as above in No.1) attached to and pulled behind chisel plow.	14-16
4. Moldboard plow, 2-way, 3-16" bottoms. Harrow operation, with 2-5 foot sections of a spike-tooth drag harrow, with 1-25 kg. extra weight on each section, followed moldboard operation within 24 hours.	18-20
5. Moldboard plow (same as above). Moldboard control plot. All subsequent tillage operations were performed by State Farm personnel as in adjacent field.	18-20

Spring and Summer 1970 Treatments

First Treatment April 21 - May 22

Type of Implement and Adjustment	Tillage Depth (cm.)
1. Sweep plow, 9 shanks with 42 - 44 sweeps(local manufacture), 30 cm. spacing and spike-tooth drag harrow (John Deere, 2-5 foot sections)with harrow spikes set at 30° angle 1-25 kg. weight added to each harrow section. Attached to and pulled behind sweep plow.	11-13
2. Sweep plow (same as above, but without harrow), Rodweeder (Calkins 10½ foot) immediately after sweep plow.	11-13 9-11
3. Rodweeder (Calkins 10½ foot) Rodweeder only and Rodweed-Chemical plots received the same treatment initially.	9-11
4. Chemical Fallow: 1 kg./hectare: 2,4-D Amine + 0.45 kg./ha. Amitrole.	

Second Summer - 1970 Treatments
June 9 - 25

Type of Implement and Adjustment	Tillage Depth (cm.)
1. Sweep plow and harrow. Same as No. 1, above(1st Spring and Summer 1970 treatments) except new (imported) Graham Hoemo sweeps (6-40 cm. sweeps and 3-47 cm. sweeps) were used.	10-12
2. Sweep plow (same as above) and Rodweeder immediately following sweep operation.	10-12 9-11
3. Rodweeder (Calkins, 10½ foot)	8-10
4. Herbicide treatments on Rodweed and chemical fallow plots: 2.5 kg. 2,4-D/hectare as "spot-treatment" on weed patches only.	
5. Chemical fallow (no tillage plots) spot-treated with 1 kg. Amitrole/hectare.	

Third Summer 1970 Treatments
July 18 - August 4

Type of Implement and Adjustment	Tillage Depth (cm.)
1. Sweep plow and harrow (same as 2nd summer treatment).	11-13
2. Sweep plow (same as above) and Rodweeder immediately following sweep operation	11-13 9-11
3. Rodweeder	7-9
4. Rodweed-Chemical plots "spot-treated" with 2 kg. 2,4-D/hectare	

Fall 1970 Treatment September 11-18	
Type of Implement and Adjustment	Tillage Depth (cm.)
1. All trials seeded with John Deere HZ7-14 deep furrow drill. Seed rate: 8 kg./decare. Fertilizer rate: 10 kg. D. A. P./decare. Seed and fertilizer placed together in furrow.	
Depth of furrow from soil surface	10-12
Depth of soil covering seed	6-8

An attempt was made to apply each series of tillage treatments on all trial sites at about the same period so that time of tillage would not be a factor. This was generally possible except at one location where intervening rainfall caused a delay in the initial spring treatments.

GENERAL OBSERVATIONS AND CONCLUSIONS

The design of these trials did not lend itself to detailed statistical analyses. Rather, they should be viewed as exploratory trials involving a large number of treatment combinations at several locations. The data obtained to date have given some good indications of the tillage systems which appear to have the best application in the areas under consideration.

It should be recognized that the climatic conditions prevailing during the period of these trials were typical of the average or "normal" conditions. A single year s results can hardly be considered conclusive; however, these may be used to indicate the direction for future trials. Yield data are not yet analyzed. With the data collected and observations gathered throughout the trial period some general conclusions have been drawn.

1) None of the fall tillage treatments (chisel or subsoil) increased the amount of moisture stored or depth of moisture penetration. Since the rainfall was not sufficient to cause runoff

this is as expected. There was a difference in the ease and uniformity of spring tillage in the fall-tilled plots. This generally resulted in better tilth on the soil surface and the establishment of a better mulch in subsequent tillage operations.

2) In the initial spring tillage operations, the sweep-skewtreader, chisel-skewtreader and sweep-harrow treatments were generally superior to the moldboard-harrow treatment in total moisture conserved, depth of mulch, moisture in the seeding zone and tilth at the soil surface. This is probably due to the fact that the former three treatments did not destroy all the tilth established during the winter season. The sweep-harrow treatment was generally equal to or better than the sweep-skewtreader or chisel-skewtreader treatments. Although not included as a treatment in these trials, a second sweep-skewtreader or sweep-harrow operation following the initial spring tillage by about 2 to 3 weeks and in the opposite direction from the previous operation may appear to be desirable. This would give a more uniform tillage depth and further reduce the soil particle size on the surface. These two effects would make the establishment of a mulch above the seeding zone easier and more effective.

3) The sweep-harrow and sweep-rodweeder treatments were better than the rodweeder only and rodweeder-chemical treatments in establishing a mulch and holding moisture in the seeding zone during the summer. The rodweeder alone seemed to cause a compacted zone with each operation, thereby decreasing the depth of penetration until the mulch was too shallow to hold the moisture. The rodweeder used one time followed by chemical weed control was apparently not sufficient to establish a mulch to hold the moisture in the seeding zone. Chemical weed control after a second rodweed operation may be more satisfactory, based on cost compared to additional tillage operations.

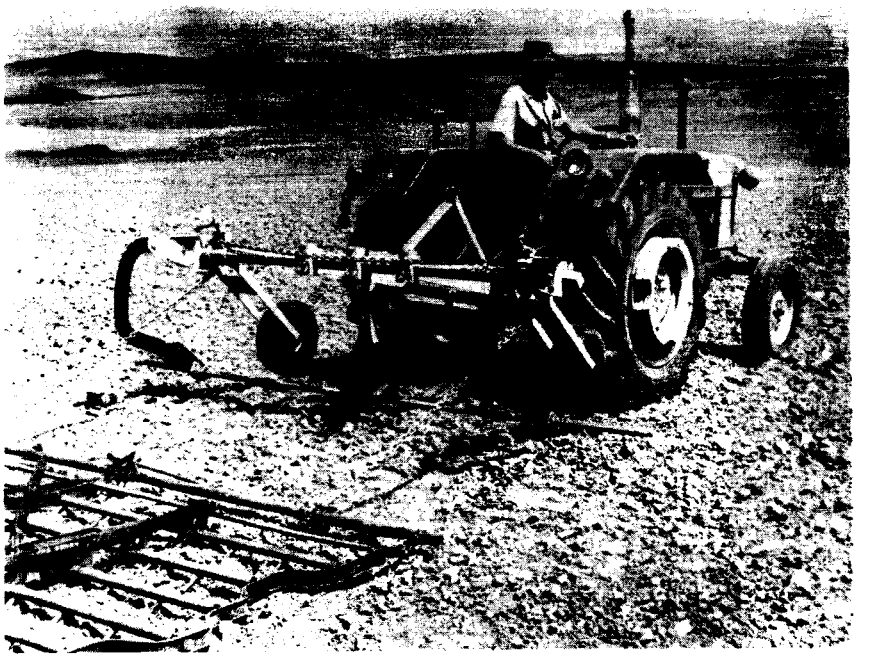
4) Time of initial tillage is very important. If the soils are worked when the moisture content is too high, the soil will be difficult to break down to a good fine mulch; a good seedbed will also be difficult to achieve. The moisture content can be determined that gives the proper tilth in the spring, but a farmer must have some visual, or "feel," test to determine when he should work his soil. Soils which are worked in the fall with a chisel, sweep or other implement, tend to be rough and reach a soil moisture situation that gives good tilth sooner than unworked soils. Physical moisture determinations of the comparison of different fall treatments will help determine the value of the fall treatment not only as a factor in soil moisture conservation but as a factor in preparing a good tilth for summer fallow.

SUMMARY

In the semi-arid areas of the world where the fallow system has been employed successfully it is now clear that early planting in autumn is giving higher yields. The early seeded wheat plant, planted in September, develops a larger root system and is able to take advantage of spring and summer rainfall when the long days permit rapid growth. Earlier maturity also allows the wheat plant to escape some hot weather that can reduce the yields of later maturing plants as they run out of moisture. Harvest usually takes place in July and August. In the dryland areas where rainfall varies between 300 and 500 mm. per year experience proves that 100 to 150 mm. of water may be stored in the soil during the fallow year under this system. The fallow system is regarded as particularly necessary because rainfall is highly variable and because in a dry year a crop can be saved with very little additional moisture stored in the soil.

By following a cereal/fallow rotation, yields far greater than can be expected from the rain falling during the crop season have been obtained; there is no doubt that under certain conditions the practice of fallowing does result in the storage of moisture in the soil. Therefore part of the rainfall of one season can be made available to crops grown in the next season. In many areas where this system is practiced the rainfall during the growing season does not generally exceed 150 mm. Using a successful fallow system, it is possible to grow crops of wheat yielding up to 1,000 kg./ha. The requirement for such a crop is estimated to be equivalent to 260 mm. of rainfall and it becomes obvious that a considerable part of the rainfall is being conserved.

The fallow system has been given great prominence in many dryland areas and is undoubtedly the most effective system of moisture conservation to date. It is not, however, necessarily the answer to all the problems of moisture conservation under all conditions of climate, soil and land use. This is particularly true in those parts of the world, as in the Middle East, where so much value is placed on straw and stubble for the feeding of livestock. However, even under these conditions, much of the equipment originally designed to control erosion and develop an effective fallow system can be used to conserve moisture. Subtillage implements such as sweeps and chisel plows can be very effectively used to prevent water and wind erosion and increase infiltration of rainwater. Subsurface sweeps and rodweeders can effectively control weeds and so reduce losses by evapotranspiration much more economically than by plowing and without producing a soil condition that is susceptible to water erosion.



A subsurface implement such as the rod weeder pictured above is used for tillage as a summer treatment, and has proved to be an effective and popular implement in weed control. It also helps in establishing the mulch and producing a firm seed bed. In the research trials in Turkey it was found most beneficial when a spike tooth drag harrow was pulled behind as pictured. This particular rod weeder, called a Calkins, has been developed to be used on a three-point hitch. It also has sweep points that can be adapted to the frame of the rod weeder to insure penetration on the heavier clay soils.

As we look back at the history of the development of the fallow system in the areas where it is now being used, we find that through the years we have been able to increase production. It is recognized that there are other factors that contribute to these increases such as fertilizers, herbicides and improved varieties. But these factors can all take advantage of the additional moisture stored in the soil. As the production has increased in these areas above the human consumption demand we note that this produces additional feed for livestock. The net result over a period of years is a substantial increase over the older systems of food for human comsumption and for livestock feed.

One very definite conclusion can be made: that is, a dryland fallow system is based on the speed and timeliness of operations. Resources of manual and animal power, even in densely populated areas, are not sufficient to carry out the speedy and timely operations that are necessary.

The operations of greatest importance in respect of timeliness are those of tillage and seeding. It is on the improvement of these operations that the development of dryland cereal production mainly depends. Mechanization is essential, but in many of the dryland farming areas the size of holdings and the economic conditions are such that alternatives to the individual ownership and operation of machinery by the farmers themselves may be necessary.

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I would like to make one other point that I feel is significant to many of you, particularly in the Middle East area. The fallow system, to be efficient and economical requires soil of adequate depth and free from large and numerous stones. These criteria should eliminate a number of areas where cereals are now being produced. Actually the poor soils will produce more feed for livestock under a permanent pasture program than they can economically produce in cereals under most types of dryland fallow systems.

By increasing cereal production on deeper soils many of the less productive soils can be returned to improved grazing lands. This results in more total animal forage, both from the cereal crops and from the pasturelands.

The improved fallow system actually produces more feed for livestock but the pattern of use by the livestock is changed.

VEGETATION OF CENTRAL ANATOLIA AND ITS ECOLOGY

by Dr. Rıza Çetik,
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GEOMORPHOLOGY

Asia Minor is a peninsula which is surrounded by the Black Sea, the Aegean Sea, and the Mediterranean Sea, and constitutes a bridge between Europe and Asia. From the point of geomorphology, climate and flora, there is a great deal of diversity between the eastern and western parts and the northern and southern parts of the peninsula.

From the West to the East the altitude gradually increases and terminates with the higher mountains such as Ararat (5,165 meters) and Suphan (4,434 meters). The altitude of the central plateau varies between 800 and 1,200 meters. The lowest area of the central plateau is occupied by the Salt Lake. In West Anatolia the mountains run perpendicular to the coast and produce some intermountain valleys with fertile soils suitable for growing crops such as cotton, olives, tobacco and grapes.

The north and south mountain chains (the North Anatolian mountains and Taurus mountains) run parallel to the seaside and produce high barriers which are responsible for the dry climate of Central Anatolia. There is a narrow coastal strip at the seaside. The elevated mountain chains, in the Taurus and North Anatolian mountains, contain a great

many higher ridges whose altitudes reach 3,585 meters in the Bolkar mountains, and 3,937 meters in the Kaşkar mountains. In both the northern and southern sides of the central plateau there are a few gaps which pass through the mountains.

From the point of geomorphology and climate the boundary of Central Anatolia was fixed in the First Geomorphological Congress, which was held in Ankara in 1941. The line between the Antalya Gulf and the lower Sakarya River forms the eastern boundary. In the south, it is naturally restricted by the foot of the Taurus mountain chain (Fig. 1). It is rather difficult to restrict the northern boundary, because a few mountain branches run through the central plateau and create complications in delimitation. However, the line running through Bozhüyük, Mihalıççık, Beypazarı, Kızılcahamam, İskilip, Merzifon, Amasya and Tokat roughly separates Central Anatolia from North Anatolia. Thus Eskişehir, Konya, Ankara, some parts of Çankırı, Amasya, Tokat, Sivas and Kayseri, Yozgat, Nevşehir, Niğde, and the Kırşehir area are located in Central Anatolia. The territory in the southern part of Central Anatolia is characterized, geomorphologically, by the basin of the old Konya Lake, Salt Lake, flattened areas of Ereğli, Karapınar and the neogen plateau between Sultan Han and Konya, where the elevation changes considerably with isolated volcanic mountains such as Karapınar and Hasan Dağ. The northern part of the plateau is rather different from the southern part, since instead of isolated mountain formations, there are large neogen plateaus, sedimentary mountains and small flattened areas. The Salt Lake, the lakes of Akşehir, Ilgın, and Eber considerably change the landscape of the plateau and produce relatively microclimatic diversities. These are some fresh water marshes such as Akşehir, Ilgın, Sultan Sazlığı, Karasaz, and salt marshes which are covered with an halophytic vegetation at Çumra, Aslım, Aksaray and Eskişehir. Central Anatolia covers about 140,000 km^2; that is roughly one-fifth of the total area of Turkey. The Konya plain is the largest flattened area which was depressed in the formation of the Taurus mountains and covered with lakes in the Pliocene and Pleistocene periods. Later these lakes dried and this large flattened area became a cuvette formation, which has no drainage outlet. The geomorphology of the area is, of course, responsible for the formation of salt marshes, and fresh water marshes which will be mentioned later in the description of the vegetation.

CLIMATE

The data used in the climatic description of the area are taken from meteorological recordings of the stations of Ankara, Çorum, Eskişehir, Kayseri, Kırşehir, Konya, Niğde, Nevşehir, and Yozgat. The number of recording years of all the stations (except Nevşehir) is more than 20. The number of recording years in Çankırı is 21, and in Ankara it is 40. In the other stations it varies between 31 and 37 years.

The climate of Central Anatolia is correlated with its geomor-

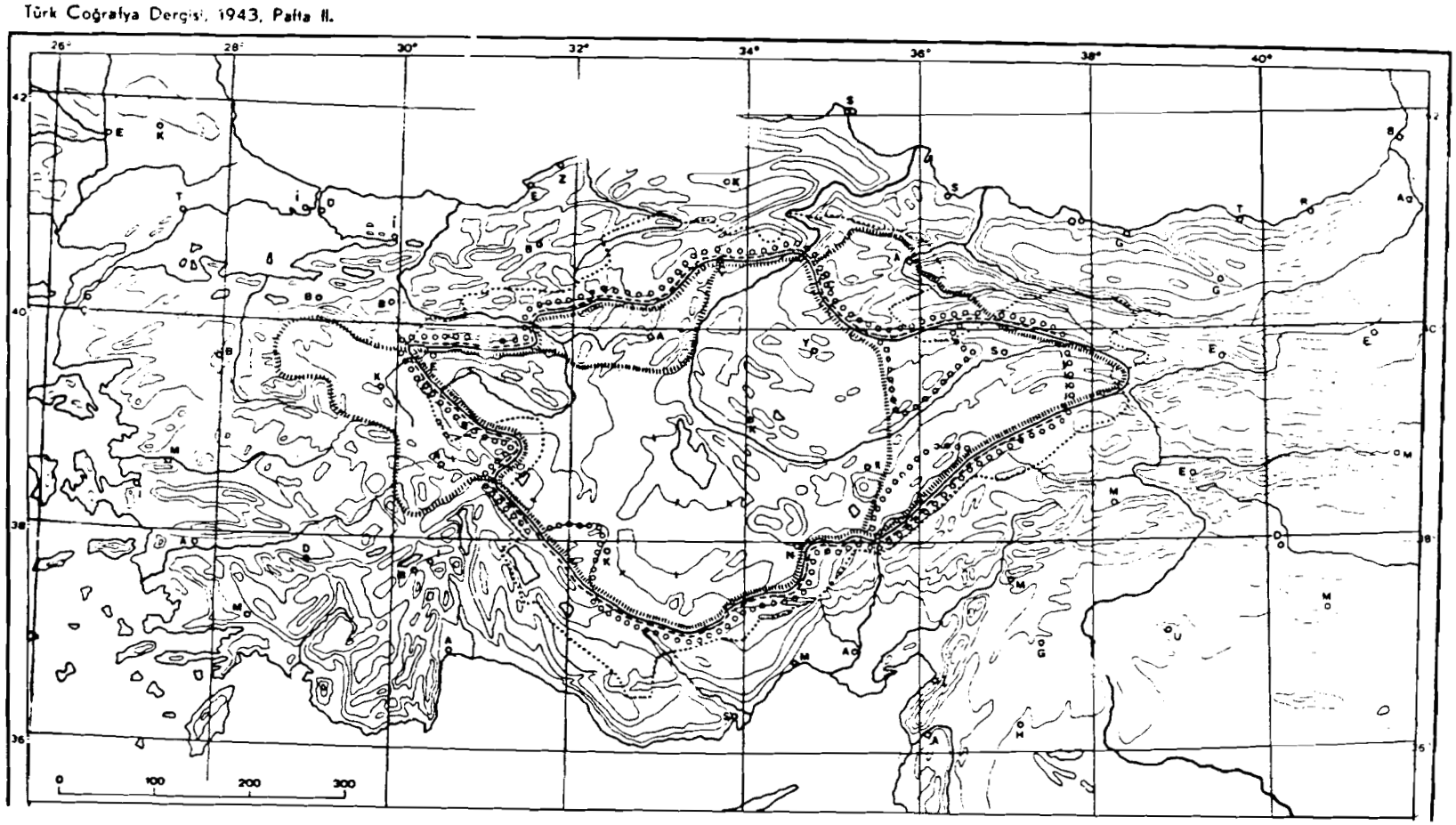

Fig.1 Geographical map showing boundary of Central Anatolia (Louis, 1941)
——— According to the proposal in the First Geographical Congress.
From the point of geomorphology

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phology. The Taurus mountains and North Anatolian mountains are mainly responsible for the arid climate of the central plateau, while most of its moisture-bearing winds come from Western Anatolia.

TEMPERATURE

According to the meteorological data which are mentioned above, the mean yearly temperatures in the region vary from 8.9 C° (Yozgat) to 11.7 C° (Ankara) while in the stations of Çorum, Eşkişehir, Kayseri and Nevşehir the mean is 10.9 C° . The recorded values in the other stations are very near 11.5 C° . The recorded monthly values of the mean annual temperatures are rather interesting. The lowest values always occurred in January and (except Çankırı with 0.2 C° and Nevşehir with 0.1 C°), they often decreased to zero or below zero.

The mean annual maximum temperature ranges between 14.3 C°(Yozgat) and 18.1 C° (Kayseri). The mean annual maximum temperatures in the following stations are: Nevşehir 16.9 C°, Eskişehir 13.3 C°, Çorum 17.5 C°, Kirşehır, Konya and Çankırı 17.9 C°. The highest values of the mean maximum temperatures (except Nevşehir in July) occurred in August (Çankırı 31.2 C°, Kırşehir 30.1 C°).

Mean minimum temperature varies from 2.8 C° (Kayseri) to 5.8 C° (Ankara), while the lowest values again occurred in January (Kayseri -6.6 C°, Nevşehir -3.1 C°).

Even extreme maximum and extreme minimum temperatures and the differences between the two extremes are rather important for the plant life and the determination of the vegetation types of an area.

The extreme maximum temperature in the region ranges between 41.8 C° (Çankırı) and 37.1 C° (Yozgat) and they often occur after the 15th of July and in August, while the extreme minimum temperature varies between -23.6 C° (Nevşehir) and -32.5 C° (Kayseri) and they occur in January. The differences between these two extremes are 23.2 C° at Yozgat and 30.6 C° at Kayseri. The values in the other stations are between these extremes.

As is shown in the preceding paragraphs, mean annual temperature, the smallest and highest values of the mean maximum and mean minimum annual temperatures are very similar in all the stations. The month of January is very cold. The lower values for mean minimum temperatures usually occur in this month and they are below zero. July and August are very hot. The highest values of the mean maximum temperatures are often realized in these months. From the standpoint of plant life, the values of different temperatures have created a hard continental climate in Central Anatolia. It is clearly shown that there is a rather big difference between extreme values of mean maximum, mean minimum

temperatures and mean annual temperatures. In fact at Ankara, the difference between the extreme value of the mean maximum temperature of August (30.4 C°) and the mean annual temperature (11.7 C°) is 18.7 C° and between the extreme value of the mean minimum temperature (-3.7 C°) and the annual mean temperature (11.7 C°) is 15.4 C°.

The differences of these kinds of temperatures at Kayseri is greater (20.1 C°, 17.5 C°) than at Ankara. Even the differences between mean annual temperatures and extreme temperatures (Ankara 36.6 C°, Kayseri 43.4 C°) is exceedingly high. These explanations mean that the climate of different sectors in Anatolia are very similar to each other and also disclose that everywhere the summer season is hot and the winter season is cold. In all of Central Anatolia there is snowfall in November, December, January and February. Snow depths reach 92 cm. at Yozgat, 84 cm. at Niğde, 60 cm., 66 cm., and 58 cm. at Kırşehir, Konya, and Çankırı respectively and 33 cm. at Ankara. Frost occurs frequently in December, January, February and March, while Konya may also have some days with frost in April. The temperature, which sometimes falls below zero in the spring months, may damage the fruit trees and the other agricultural plants.

WIND

The dominant winds and their velocities are shown in Figs. 2.1-2.6. Wind directions usually change in different stations, but the dominant ones often come from one or two directions. At Ankara, Konya, Yozgat and Niğde dominant winds come from the north and northeast, while at Niğde and Yozgat they come from the south and at Kayseri from west and south. At Eskişehir the wind blows predominantly from the west and less frequently from the east. In some stations different directions are nearly equal in dominance. The winds from the south and southwest strongly increase transpiration and often dessicate the plants, while the winds from the north and west often carry rainfall to the region. Northern and northeastern winds often occur in autumn and winter. If they come in the summer months they create a rather enjoyable atmosphere which decreases evaporation and transpiration intensities.

EVAPORATION

The yearly water loss by evaporation in the different areas of the central plateau is rather high if it is compared with the annual precipitation. The yearly water loss by evaporation (1,316.9 mm. at Ankara and 1,340.0 mm. at Kırşehir) is more than three times their yearly rainfall and it is higher than four times (1,524.5 mm.) at Niğde.

Fig. 2.1 ANKARA

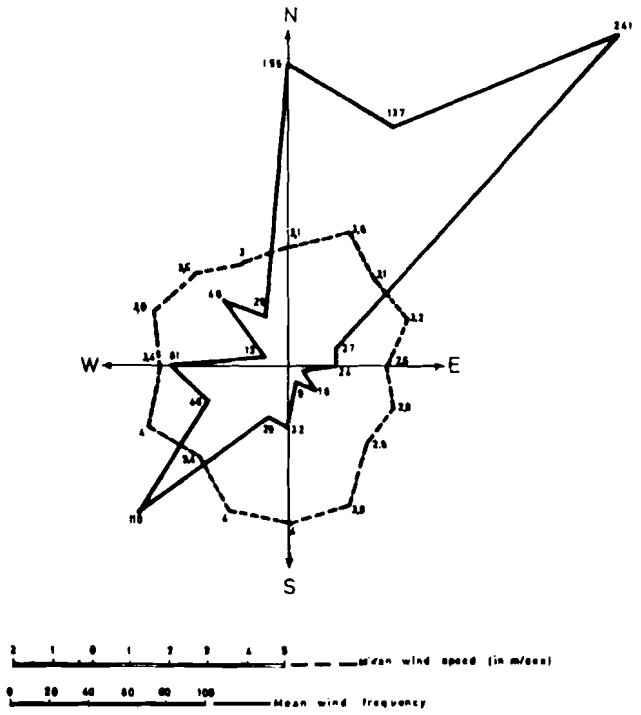

Fig. 2.2. YOZGAT

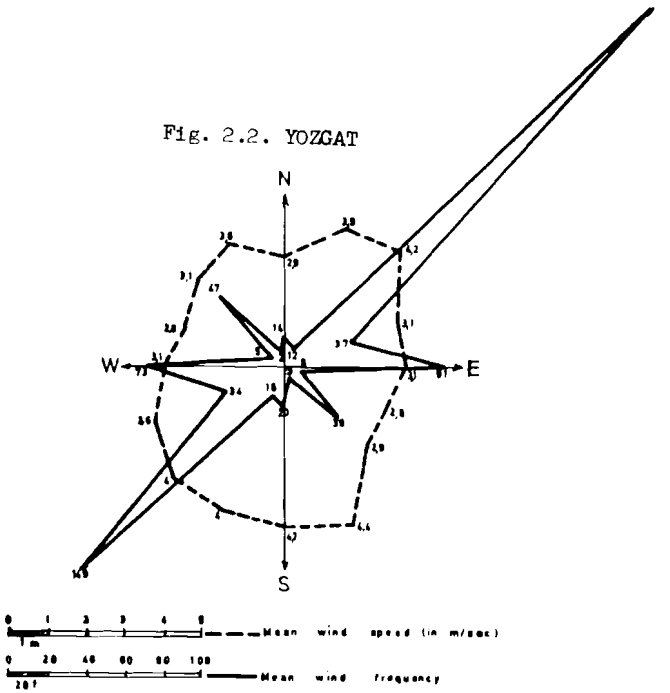

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Fig. 2.3 ESKİŞEHİR

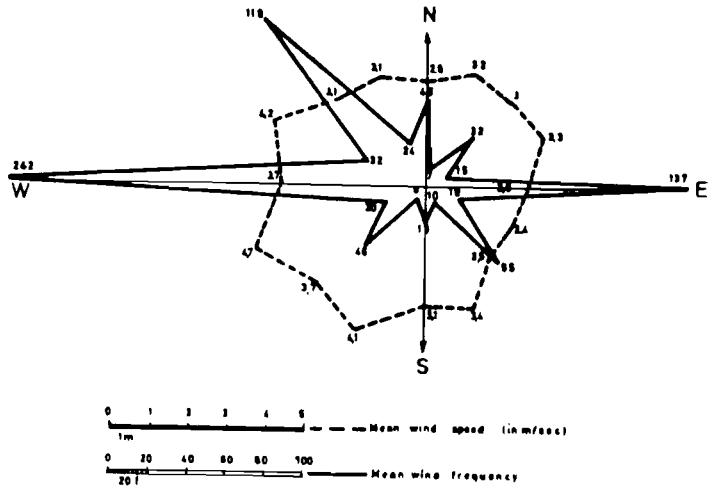

Fig. 2.4 ÇANKIRI

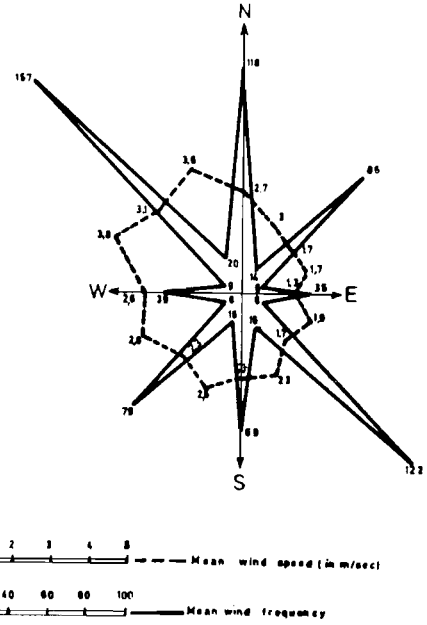

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Fig. 2.5 KONYA

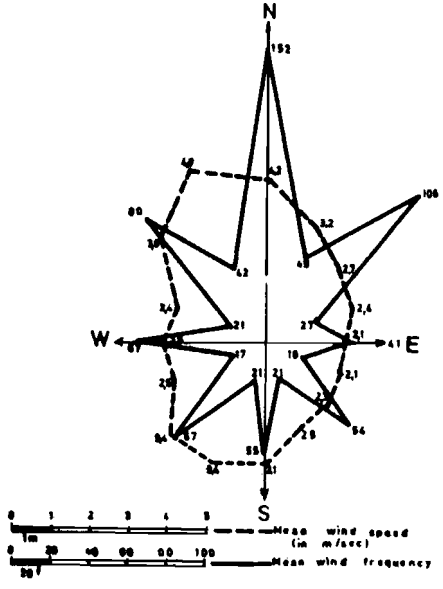
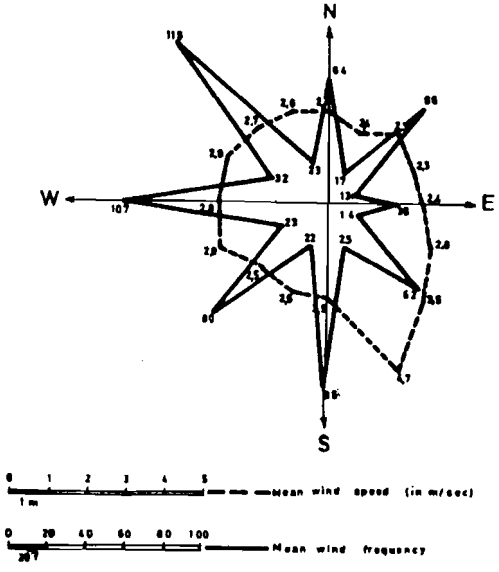


Fig. 2.6 KAYSERİ



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PRECIPITATION

In Anatolia the least yearly precipitation occurs at Iğdır. Next are the meteorological stations of the central plateau (Table 1) where the lowest value is at Konya and the highest one is at Yozgat. The Konya and Niğde areas are the most arid sections of Central Anatolia. The sections of Çankırı, Çorum and Yozgat are more humid if compared with the others, because they are more exposed to moisture-bearing winds which come from the Black Sea.

The distribution of yearly rainfall in various months is very interesting. The winter and spring months usually have more total rain which decreases in the autumn, while during the summer months it decreases even more. The minimum precipitation occurs in the months of July and August.

Clima diagrams (Figs. 3.1-3.6) disclose very well the relations between monthly mean temperature and monthly mean rainfall at all the meteorological stations. There is a rather short arid period, the length and intensity of which change very little. There is a dry period in summer which often begins around the first of June and persists until the end of October. This period is longer and more intense at Konya and Eskişehir as compared with other stations. In general there is a combination of higher evaporation, higher temperature and low air humidity, which strongly affects the vegetation and dessicates the agricultural plants.

In short it is concluded that Central Anatolia has a cold and snowy winter, a rather mild and rainy spring, a less rainy autumn, and a hot and dry summer with a severe arid period. These climatic conditions are mainly responsible for the flora and the xeromorphic vegetation of the central plateau.

VEGETATION

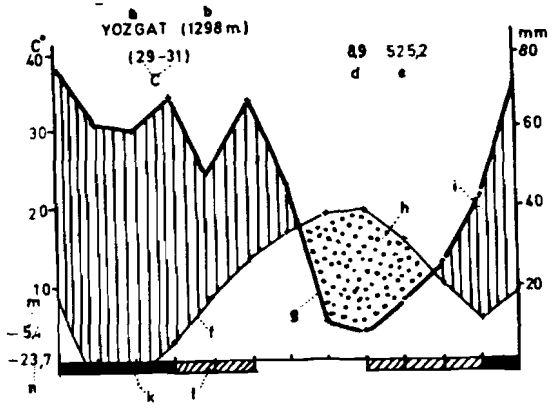
Asia Minor comprises three floristic regions:Euro-Siberian, Irano-Turanian and Mediterranean regions. Central Anatolia covers the far western part of the region which is called Armenia-Anatolian subprovince. Most of Central Anatolia, excluding the mountainous area, did not encounter a glacial period and was scarcely affected by it. This is the reason why in the steppe formations and the lower altitudes of the mountains, there are abundant Turanian species. At the western end of the plateau the representatives of the Irano-Turanian regions are poorer, while the Mediterranean elements are present in abundance. However, some Mediterranean elements such as *Colutea arborescens, Jasminium fruticans*, may be relics of former flora of the central plateau, and they are frequently present in the valleys which have a relatively mild climate compared with other parts of the area. The large plains, stony hills and gravelly bottoms of the mountain areas are often treeless,

TABLE 1

MEAN PRECIPITATION

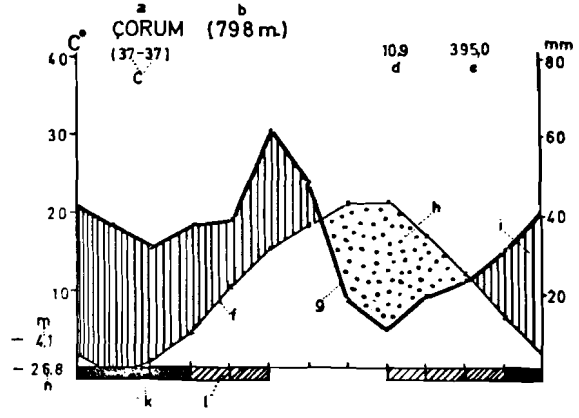
	Years of Observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Ankara (1926-65)	40	34.9	38.2	35.9	33.6	50.0	30.6	12.7	8.4	18.6	22.0	27.9	46.4	359.3
Çankırı (1929-65)	26	42.6	44.0	39.2	35.3	56.8	49.9	13.4	12.7	14.6	13.4	22.7	45.6	390.2
Çorum (1929-65)	37	37.3	31.7	37.3	38.6	61.4	48.0	17.5	9.8	18.5	22.6	30.4	41.9	395.0
Eskişehir (1929-65)	37	40.6	37.7	35.6	33.5	46.1	37.4	12.8	4.9	18.9	23.1	30.0	47.7	368.3
Kayseri (1929-65)	34	36.2	39.3	38.0	50.8	48.9	38.6	7.8	7.2	16.5	22.3	30.6	35.2	371.5
Kırşehir (1929-65)	37	49.6	39.2	41.4	35.3	46.1	33.1	4.7	4.2	11.7	21.8	30.8	50.8	386.6
Konya (1929-65)	37	37.3	33.1	30.6	28.8	43.0	26.4	5.6	3.1	11.6	26.7	29.4	39.6	315.1
Nevşehir (1955-65)	11	43.5	44.8	44.9	47.1	60.4	41.5	4.0	0.4	10.6	15.5	26.3	47.0	386.1
Niğde	31	39.4	37.7	36.9	38.8	52.1	28.1	4.4	6.7	11.3	24.4	29.3	41.7	350.9
Yozgat (1929-65)	31	61.1	59.9	68.3	48.8	67.4	45.4	9.8	6.9	15.4	25.0	42.1	75.2	525.2

Fig. 3.1 CLIMA-DIAGRAM OF YOZGAT



a- Place of meteorological station
b- Elevation above sea level in meters
c- Number of years of observation
d- Mean annual temperature in centigrade
e- Mean annual rainfall in millimeters
f- Temperature curve (Monthly means)
g- Rainfall curve (Monthly means)
h- Drought season
i- Humid season
k- Months with mean minimum temperature below 0°C
l- Months with absolute minimum temperature below 0°C
m- Mean minimum temperature of the coldest month
n- Absolute yearly minimum temperature

Fig. 3.2 CLIMA DIAGRAM OF ÇORUM



a- Place of meteorological station
b- Elevation above sea level in meters
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n- Absolute yearly minimum temperature

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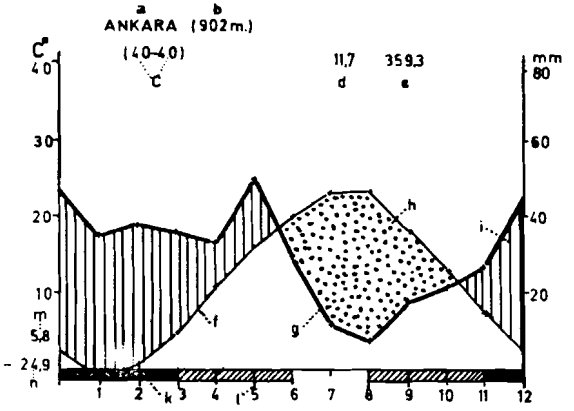
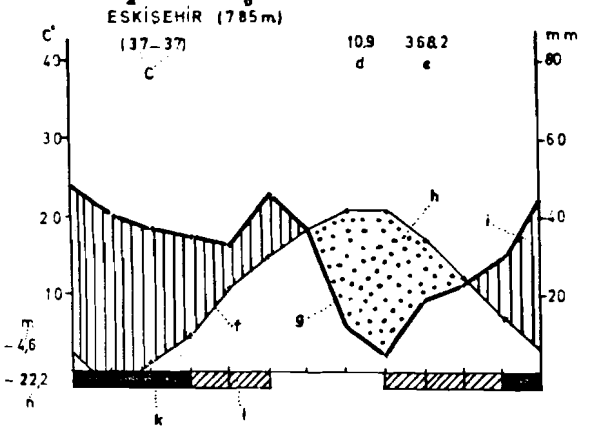
Fig. 3.3 CLIMA-DIAGRAM OF ANKARA



a- Place of meteorological station
b- Elevation above sea level in meters
c- Number of years of observation
d- Mean annual temperature in centigrade
e- Mean annual rainfall in millimeters
f- Temperature curve (Monthly means)
g- Rainfall curve (Monthly means)
h- Drought season
i- Humid season
k- Months with mean minimum temperature below 0°C
l- Months with absolute minimum temperature below 0°C
m- Mean minimum temperature of the coldest month
n- Absolute yearly minimum temperature

Fig. 3.4 CLIMA DIAGRAM OF ESKİŞEHİR



a- Place of meteorological station
b- Elevation above sea level in meters
c- Number of years of observation
d- Mean annual temperature in centigrade
e- Mean annual rainfall in millimeters
f- Temperature curve (Monthly means)
g- Rainfall curve (Monthly means)
h- Drought season
i- Humid season
k- Months with mean minimum temperature below 0°C
l- Months with absolute minimum temperature below 0°C
m- Mean minimum temperature of the coldest month
n- Absolute yearly minimum temperature

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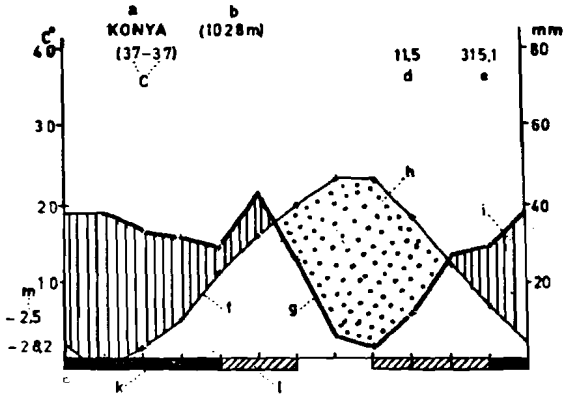
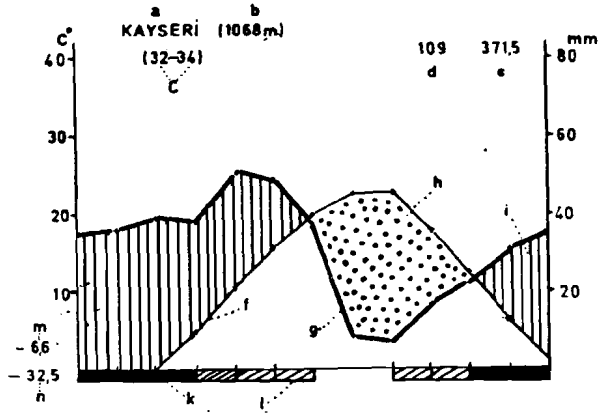
Fig. 3.5 CLIMA-DIAGRAM OF KONYA



a- Place of meteorological station
b- Elevation above sea level in meters
c- Number of years of observation
d- Mean annual temperature in centigrade
e- Mean annual rainfall in millimeters
f- Temperature curve (Monthly means)
g- Rainfall curve (Monthly means)
h- Drought season
i- Humid season
k- Months with mean minimum temperature below 0°C
l- Months with absolute minimum temperature below 0°C
m- Mean minimum temperature of the coldest month
n- Absolute yearly minimum temperature

Fig. 3.6 CLIMA-DIAGRAM OF KAYSERİ



a- Place of meteorological station
b- Elevation above sea level in meters
c- Number of years of observation
d- Mean annual temperature in centigrade
e- Mean annual rainfall in millimeters
f- Temperature curve (Monthly means)
g- Rainfall curve (Monthly means)
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l- Months with absolute minimum temperature below 0°C
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n- Absolute yearly minimum temperature

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except for a few shrubs of *Rhamnus hirtellus* and *Quercus pubescens*. It is quite certain than in previous years these mountainous areas supported a richer flora and were mostly dominated with *Quercus*, *Juniperus* and *Pinus nigra*. Today these areas have a few fragmentary relics here and there of former flora. Elsewhere geophytes and annual plants are plentiful in the spring months and in the summer months shrubby and xeromorphic perennials cover the area sparsely. In this case both the large plains and lowlands of the mountain areas of Central Anatolia are generally covered with steppic or semi-desertic species. Here the average altitude of timberline is about 1,100 meters, but in different areas this altitude may change according to the exposures and facing to moisture-bearing winds from the seas. As an example, it may be mentioned here that the vegetation in the vicinity of Karagöl, not far from Ankara, is richer in tree species as compared with the other vegetation of the central plateau. This is because this area is much more exposed to the moisture-bearing winds which come from the Black Sea.

The Salt Lake occupies the lowest part of the plateau in the center. Its altitude is about 850 meters above sea level. It covers nearly 110 km^2 but usually the area occupied by water varies according to the seasons. In the winter and spring months, more water comes into the lake from the Dondurma and Esme streams and it occupies a large area, but in the summer months, due to intensive evaporation, it becomes smaller and shallower. Salt accumulations usually occur in the areas that have been left by water, and halophytic communities flourish on the surface of salt covered soils. Among these salt bearing communities the stands of *Halochnemum strobilaceum* association densely occupy the first zone (next to the water) and the association of *Salicornia fragilis* is often present in the same zone. It is interesting to note here that the surfaces of the soils which are covered with these communities are often deeply covered with a salt layer, and the salt concentration reaches nearly 2 percent at a depth of 40 cm. This concentration ranges from 0.7 percent to 1.5 percent. Even in the marshes of Konya the associations of *Halochnemum strobilaceum - Suaeda brandii* frequently occur in the same salt concentrations. The next halophytic community which can survive easily in the second zone of salt concentration is the association of *Frankenia hirsuta ssp. hispida - Statice iconia*. Besides these halophytic communities there are some associations such as *Halanthium kulpianum*, *Statice gmelini* and *Bupleurum gracile* which are frequently present on dry and hydromorphic salt marshes with moderate salt concentrations. The association of *Juncus maritimus - Juncus gerardii* is most common and occupies large areas of Konya and Eskişehir. Some herbaceous hygrophyllous communities are found in the swamps and in the fresh water marshes, but they have not been studied yet.

Many flat or moderately inclined areas with deep soils around Konya, Eskişehir, Kayseri and Ankara are often dominantly colonized with a community of *Artemisia fragrans*. The composition of this community greatly changes according to soil structure, cultivation and extent of

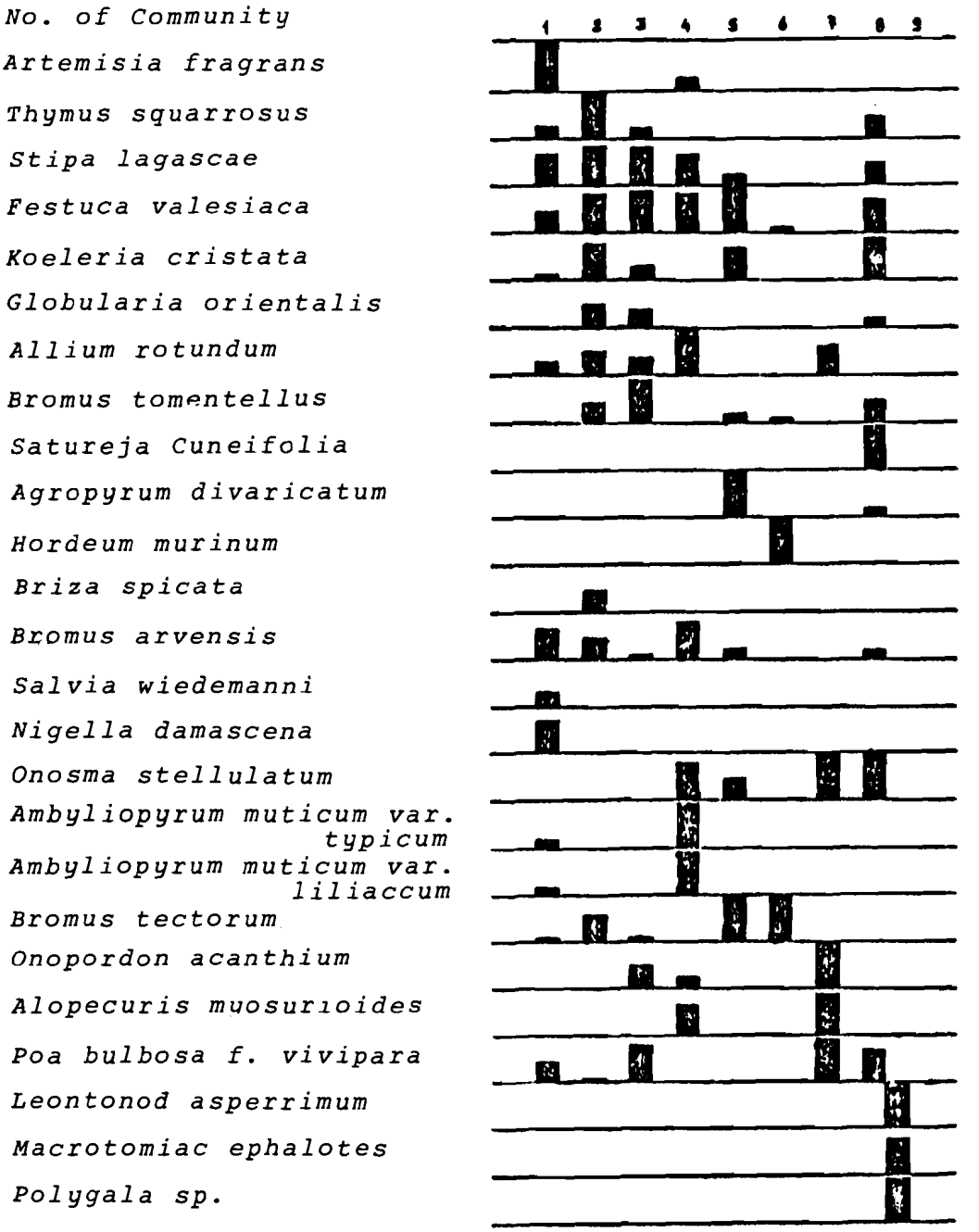
grazing. Both this community and the *Thymus squarrosus* community form the most outstanding climatic vegetation of the Central Anatolian steppe which extends largely from the Taurus to the North Anatolian mountains. The next community is often established in the moderately inclined slopes with superficial soils. Besides these, there are some communities which are named according to dominant and constant species such as *Astragalus microcephalus, Festuca valesiaca, Koeleria cristata* and *Stipa lagascae.* These communities frequently occur in the lower mountain steppes, flattened areas and in the peneplane formations. Figure 4 shows some important species of these communities and their frequencies in the communities. In this figure the *Astragalus* community has been omitted.

Triticum is the main agricultural plant extensively cultivated in the whole central plateau. After that come agricultural plants such as *Hordeum, Secale, Avena* and *Papaver,* which also grow in the area. There is even plentiful sugar beet cultivation and fruit tree plantations in the favorable moist soils and along the rivers.

It should be mentioned here that much steppe vegetation which is dominated by *Artemisia fragrans* has been destroyed by cultivation and overgrazing. This had occurred extensively in the range vegetation of the Karapınar district and a large area extending as far as the town of Karapınar is occupied by sand dunes. Some necessary precautions have been taken against the sand invasion. For many years sheep have been a source of living to the people of Karapınar and the broad ranges of the Karapınar area dominated mostly with *Artemisia fragrans,* which supports the grazing of thousands of sheep. The steppe vegetation in Karapınar is highly damaged and some of the plants (also including *Artemisia fragrans*) have disappeared or have been extremely impoverished by overgrazing. As a result of this continuous overgrazing, which is very common in all Anatolia, the present steppe vegetation reached biotic equilibrium with unpalatable thorny and pubescent steppe plants predominantly established there. At present, the people dealing with livestock and the range managers are faced with a great problem which is very important from the standpoint of range management.

As mentioned before, the steppe vegetation of Central Anatolia, which is in equilibrium with the biotic factors, is very much correlated with its ecology. The growing season here is spring and early summer. Varieties of rhizomatous and bulbaceous geophytes such as *Crocus, Colchicum, Allium, Ornithogalum, Iris* and the following annual herbs and grasses: *Nigella demascena*, *Crupina crupinastrum, Ziziphora taurica, Helianthemum annuum,* some species of *Trigonella, Medicago, Bromus tectorum* and many others become dry in summer, while others make a great deal of morphological and anatomical changes in different organs for surviving in the drought season. The following changes, such as small leaves, leafless stems, thickness of the cuticula and of the mesophyll, reduction of stomata size and increase in the number of stomata densely haired and folded leaves are persistently common

Fig.4 Percentages of occurrences of some important species in the nine communities of the Central Anatolian Steppe (Çetik, 1965)



1. *Artemisia fragrans Com.*
2. *Thymus squarrosus Com.*
3. *Festuca valesiaca Com.*
4. *Ambyliopyrum muticum Com.*
5. *Agropyrum divaricatum Com.*
6. *Hordeum murinum Com.*
7. *Onopordon acanthium Com.*
8. *Satureja Cuneifolia Com.*
9. *Leontodon asperrimum Com.*

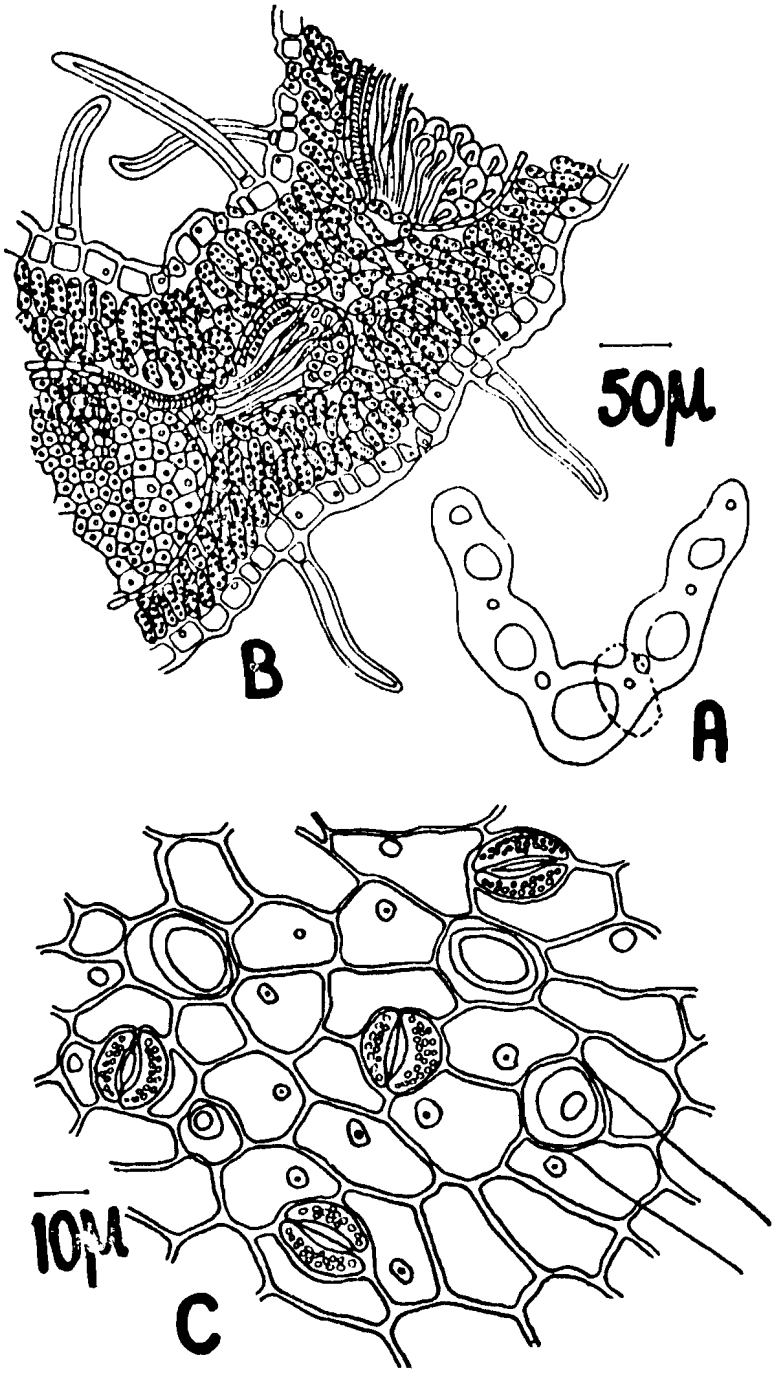
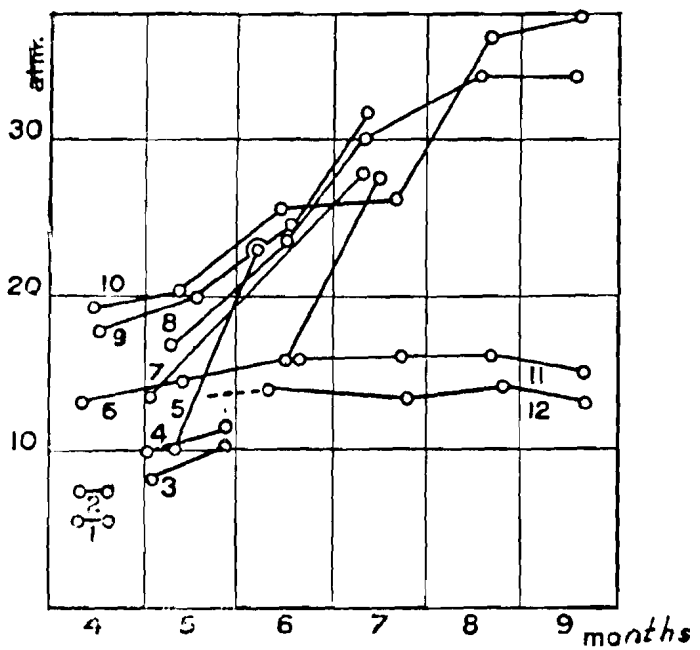


Fig.5 - Astragalus micropterus Fisch.

A,B - Transverse sections of leaf,
C - Paradermal section of leaf

(Çetik and Bozcuk, 1965)

Fig.6 The variations of osmotic pressure of some steppe plants of Central Anatolia (Birand, 1961)



1. *Crocus ancyrensis.*
2. *Colchicum atticum*
3. *Galium articulatum*
4. *Reaumuria hybrida*
5. *Lepidum draba*
6. *Artemisia fragrans*
7. *Coronilla varia*
8. *Teucrium polium*
9. *Pirus elaeagrifolia*
10. *Amygdalus orientalis*
11. *Alhagi camelorum*
12. *Echinophora anatolica*

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TABLE 2

(Çetik, Bozcuk - 1965)

Plants	Average Thickness of leaf μ	Average Thickness of mesophyll μ	The average thickness of cuticula μ		The average number of hairs per mm^2		The average number of stomata per mm^2		The average size of stomata μ	
			In lower Epiderm.	In upper Epiderm.	In lower Epiderm.	In upper Epiderm.	In lower Epiderm.	In upper Epiderm.	In lower Epiderm.	In upper Epiderm.
Astragalus micropterus Fisch.	252.0	157.8	5.04	6.21	500.0	282.2	215.0	192.7	15 x 20.3	16.5 x 23.1
Galium Orientale Boiss.	568.7	345.8	6.30	5.86	76.7	0.8	64.5	59.2	23.0 x 40.6	21.4 x 39.0
Acantholimon Echinus (L) Boiss.	700.0	567.7	5.30	7.40	218.6	154.0	86.7	86.0	24.1 x 31.5	27.7 x 31.6
Leontodon Asperrimum Willd	384.2	336.6	5.70	5.46	40.2	49.5	114.9	99.1	23.1 x 29.3	21.8 x 29.5
Genista Albida Willd	259.0	186.2	9.55	7.16	94.2	50.4	64.2	56.6	18.8 x 24.4	19.5 x 24.7
Scutellaria Sp.	140.0	127.7	6.60	7.90	--	--	--	--	-- --	-- --
Rhamnus Hirtellus Boiss.	189.0	141.2	3.60	4.30	32.5	23.8	72.8	53.8	19.0 x 29.7	17.5 x 23.1
Convolvulus Compactus Boiss.	261.3	226.8	3.30	4.10	--	--	--	--	-- --	-- --
Macrotomia Cephalotes (DC) Boiss	460.6	419.6	4.70	4.00	55.9	50.0	62.8	70.0	23.7 x 31.0	23.4 x 31.3

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(Table 2). Also increasing their osmotic pressures according to the intensities of drought is an interesting property of these xerophytes. Some xerophytes such as *Astragalus micropterus*, (Fig. 5) *A. microcephalus*, *Echinophora anatolica* and *Alhagi pseudalhagi*, which are green in summer months do not show any change of their osmotic pressures (Fig. 6), because, with their long taproots, they can easily obtain the necessary moisture from underground waters.

The flattened area of the central steppe is often interrupted with lower hills and with mountains of medium height. Those hills are often treeless except for some dwarfed sparsely scattered shrubs such as *Amygdalus orientalis*, *A. webbii*, *Rhammus hirtellus* and very rarely *Quercus pubescens* and *Juniperus excelsa*. The last two often occur as a shrub belt at the foot of mountains which surround the central plateau. The open areas among these shrubs are usually colonized with the various cushionlike perennials and other species of *Astragalus*, *Echinophora*, *Verbascum* and with some *gramineae*.

The valleys which have more air moisture are often sparsely covered with the representatives of the shrub communities such as *Prunus spinosa*, *Jasminum fruticans*, *Rosa sulphurea*, *Crataegus orientalis*, *Lonicera etrusca* and *Clematis vitalba*. Bromus tectorum, Bromus squarrosus and others densely cover the area. But this nice appearance of the steppe does not continue. In the summer many annual plants become dry, and geophytes disappear on the soil surface because of summer droughts, and only some drought resistant perennials, with long tap roots and hairy leaves, can survive during the summer.

Characteristically vegetation of the steppe area (xerophytic plant communities) often change their abundance and frequencies according to the total annual precipitation, the localities and grazing. Most of the perennial members of these xerophytic communities are drought enduring and can, economically, manage with the soil water in the summer months.

PROBLEMS IN NATURAL RESOURCES ADMINISTRATION IN IRAN

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INTRODUCTION

For the beginning of this presentation it seems quite appropriate to refer to one of the statements made by Mr. Golesorkhi, the former Minister of Natural Resources on a similar occasion in 1970.

"The flora and fauna of the earth bloomed to life when air, soil and water, the three basic elements of production intermarried. The important point about these elements is that although they are renewable and can transform and translocate under various conditions, yet in volume and quantity they are unfortunately limited to their present content. Air, which essentially renders life possible for both the plant and animal societies is limited in volume and cannot exceed the amount originally contained in the atmosphere.

"Similarly the water element, whether in the form of vapour and clouds or rivers, oceans and lakes, is restricted to the existing amount and man can hardly add a drop more to this quantity.

"The precious soil from which we derive our food is also limited. In whatever form, soil and its parent material cannot be increased beyond the original quantity and since the creation of the world, besides a few meteors which have hit the earth, perhaps the only quantitative or qualitative element added to the earth, is the few kilogrammes of moon soil brought down by the astronauts from that far-off planet.

"As mentioned above, through the interrelation of these three elements, animal and plant life have become possible, and therefore a mere translocation and transfiguration of these elements can impressively influence and condition the existence of the above phenomena. On the other hand, it should not be forgotten that air, soil and water are living elements, for every cubic centimeter of each contains millions of living organisms. Therefore like all living things if they are to survive, they need to be treated with continual care and attention."

EXTENSION AND VALUES OF NATURAL RESOURCES IN IRAN

Forest lands

According to the latest data available, out of 18 million hectares of forest lands (11 percent of the total area of the country) 3,400,000 hectares are located along the Caspian, of which 1,400,000 hectares are considered to be commercially exploitable. Although the remaining portion of the Caspian and also the Zagros belt of oak forests are not being exploited at the present time, there is a good chance that this will become feasible in the near future.

At the present time only 600,000 to 700,000 cubic meters of wood are being utilized, and this could be extended up to 4,200,000 cubic meters. Taking into consideration that if the price of each cubic meter of wood in the common market place is only $25, the total value of this portion of our northern forest will amount to $105 million per year.

Rangelands

Based upon the definition accepted by the Ministry of Natural Resources, the rangelands in Iran are estimated to be 100 million hectares. Much of this is relatively unproductive at present, especially in drier years.

Over 50 million animal units are grazing over these rangelands year round.

Considering the cost of forage consumed by each animal to be only

2 cents, the total value of the rangelands will be $1 million a day or $365 million a year, which is almost equal to 35 percent of our oil income.

PROBLEM ANALYSIS

The present situation of most of the natural lands in the Middle East and other countries in Asia with arid and semi-arid conditions is characterized by overexploitation.

Signs of erosion due to overgrazing, bush cutting and misuse of nature are to be seen everywhere.

Many large dams have been constructed in order to improve agro-industrial situations in the corners of the country, but unfortunately watersheds behind them are threatening the useful life of these dams because of the great amount of sediment and debris being carried into the reservoirs during each storm.

Perhaps the main aspects and causes of such destruction in this part of the world are the following:

1) An old system of animal husbandry which is not integrated with agricultural practices

2) Ever-increasing demands for water, power, recreation and animal products

3) Conversion of range and forest lands into agricultural lands

4) Lack of a sufficient number of well trained technical and executive staff

5) Imbalance in programming.

It has been experienced many times in the past in many different countries that husbandry of the natural resources of wildlands which actually provide the foundation upon which all developmental programmes must rest is ignored until catastrophic or near catastrophic events occur. Individual components of the natural resources system such as a tree that will furnish timber or pulp, a plant species of special value or water per se, have usually received considerable attention as exploitable products, but the characteristics or conditions of the total resource base that must be protected or provided to maintain the enduring health and productivity of the natural resource base have for the most part been ignored.

It appears that the general approach of developmental projects is

for a single component, e.g. water, soil (for cereal production) or trees to become the centre of a "most" important development programme. Impacts of such programmes on the balance of the whole natural resource system have not received sufficient consideration.

This imbalance in development programmes or the failure to safeguard the wildland ecosystems is particularly critical in semi-arid and arid regions where thresholds are more delicate and where restoration following damage is more difficult.

Examples are numerous. The philosophy that land could be most profitably utilized if it were converted to agronomical use promoted the unlimited cultivation of the prairies and plains of the central United States and of the western semi-arid regions. The sand storms and mass emigration of people in the 1930's and the resettlement programmes of the 1940's were the catastrophes resulting from this philosophy.

Adequate regulations for the utilization of land must exist and all lands must be classified according to their capacity to produce and to kinds of uses. All lands cannot be utilized for crop production, and in many instances land that will support crops will serve men best if left under natural vegetation.

Programmes that promote extensive cereal production without providing a means of safeguarding wildland resources invite disaster in the form of air pollution, flood damage, soil destruction and sedimentation. Such is the harvest of imbalanced planning for development.

Wildland resources providing a protective barrier between man and nature are essential to productive agriculture, primarily because water is the most important product of wildlands. The capability to produce useable water depends upon the condition of the ecosystems that receive water. One monster that easily destroys this equilibrium is the tractor.

Mechanization of agriculture seems to be a major objective of development programmes. Yet the tractor, when employed without restriction on land that has not been classified as to proper use potential, has caused tremendous damage to basic wildland resources.

The native wet meadows of the high country are the gems of wildland resources. They should be cherished and protected as crown jewels are. Before tractors appeared, these gems had some built-in protection in the toughness of the sod that covered them and the difficulty with which the meadows were broken. It was easier to plough the adjoining slopes where there was always more land than could be ploughed in one season. The gigantic energy of the tractor can take a plough through the toughest sod. It can churn through all available soil and still find plenty of resting time.

Progress? Perhaps, but without proper restraints provided in programme operation plans, the meadows are converted to brown scars in the ecosystem, scars that may require centuries to heal. Imbalance occurs when one activity is promoted without regard for the needs of the resource base.

Overemphasis on the need for cereal production without consideration of the requirements of other resources leads to pauperization of range livestock when soils most suited for production of native forage or when vegetation required for protection of watershed values is sacrificed to short-term cereal production. Tremendous losses can occur when increasing numbers of livestock are forced to concentrate on decreasing areas of rangeland. Again soil loss, air pollution, and excessive sedimentation are the undesirable results.

There seems to be a strong possibility that balanced and integrated development is possible. There is a need for much more comprehensive planning of a balanced approach than has been presented in the past. Whenever development of a region is proposed, the desirable attributes of the existing situation should be identified. The action necessary to protect and maintain these desirable attributes must be formulated, and the regulations required to implement such necessary action must be available for enforcement before other steps are taken. Such activities should constitute the first stages of a balanced programme.

DEVELOPING PROGRAMMES

Following the declaration of nationalization of all natural resources, and upon establishment of the Ministry of Natural Resources, many developing projects were put into action in order to protect and utilize the wildland in a proper form. The main aspects of these projects are summarized in the following paragraphs.

Forestry

Since 1961 a series of forest management plans has been prepared and executed in order to exploit the commercial forests in the Caspian Zone. Construction of forest roads has been put in the plan and most of the roads are being utilized for timber extraction. To assist these programmes in 1967 the Law of Forest and Range Protection and Exploitation was passed.

Many other projects are being undertaken in the development of the wood and pulp industry.

Afforestation and Recreation

Since 1967 about 14,183 hectares of land have been planted. This figure includes the afforestation around the cities and also in the deteriorated forests.

In order to provide interested individuals with different species of trees, 662 hectares of nurseries have been established in different parts of the country. These nurseries have been able to produce 124 million seedlings and cuttings to be planted on private and national lands.

Recreational parks in which all kinds of facilities have been provided have been established on 720.5 hectares of forest areas. This is going to be extended up to 1,370 hectares in the near future.

Wildlife

The first conservation law, passed in 1956, creating the Game Council of Iran, proved to be inadequate. But the plans and methods pursued on the basis of this law were fundamentally sound and were the mainspring for much of the work undertaken later.

In view of the large size of Iran and the limited funds at the disposal of the Game Council it was recognized that a great deal of the Council's attention would be concentrated on areas of special importance from an ecological or faunistic point of view.

Thus was born the concept of "protected regions" within which grazing, wood cutting and other forms of exploitation were restricted and subjected to the issuance of special licenses. The results were generally good and in some cases outstanding. Proposals for the creation of "wildlife parks" were advanced in later years shortly prior to the submission of a new bill to Parliament which, when enacted in 1967, created the present independent government organization named the Game and Fish Department. The new law, in concert with its regulations, has incorporated and clearly defined the concepts and legal aspects of both wildlife parks and protected regions.

In the establishment of wildlife parks and protected regions, the Game and Fish Department has endeavoured to provide adequate protection in regions of special faunistic value, and in a selection of areas representing the major habitats and ecosystems in Iran.

However, the animal life is worthy of attention in many more parts of the country, and in any event, the game laws and regulations apply throughout Iran. Although it is clearly impossible at the present time to undertake a comprehensive programme of conservation and management in every region of floral and faunal importance within the country, it

is the duty of the Game and Fish Department to pursue the principles of conservation wherever the need arises.

RANGE MANAGEMENT AND IMPROVEMENT

The Range Department of the Ministry of Natural Resources has been able to undertake several measures and activities which have proved to be very effective and beneficial in administration and improvement of the vast rangelands in Iran. The main highlights of such activities are summarized below.

Range Management Planning

Due to existing socio-economic problems and lack of an adequate number of trained technicians, as mentioned previously, it was decided to follow the concept of transitory and long-term planning. This seems most feasible in accordance with the present situation of the rangelands and the system of exploitation being practiced by the nomads.

Transitory planning

This programme supposedly will be undertaken through two main stages:

Primary stage: This stage starts from a point of issuing permits according to current procedures. An exact date of entry to and departure from the range should be given to the permittee, followed by strict control of numbers of livestock as indicated in the permits.

Secondary stage: In this stage the technicians (three to five in a group) will start to build the skeleton of a plan and a base for gathering required data as progress on each stage is made. This basic plan will include all activities by the group to obtain: a physical map of the area, a randomly selected point for permanent transect lines, an estimation of range capacity in a sheep-unit month, and some suggestions for range improvement measures.

Long-term planning

As soon as the information from transects, cages, history of the area, people, feed sources and research data (from the Research Institute at our request) are available, they will be recorded and used for correction of management plans. At this stage a well arranged range management plan based on the latest scientific methods of survey and field analysis will be prepared for execution by livestock cooperatives and livestock companies. The Range Department has been able to achieve and follow the above programme to a great extent since the establishment of the Ministry of Natural Resources.

As an example, the first stage of the plan has been completed over almost 30 million hectares (30 percent of the total area). The rest of the area was prospected to be completed by the year 1974.

Incidentally, in five different climatic zones of the country field analysis, along with vegetational surveys and maps, have been completed in order to fulfill the idea of long-term range management planning. The total extent of the surveyed areas is 588,000 hectares.

RANGE IMPROVEMENT

Range rehabilitation and reseeding in semi-arid and arid conditions had started in Iran at the time that grass and legume seeds were brought to this country for the first time under the American Point Four programme almost 17 years ago. Much of this activity met with bitter failure due to harsh climatic and edaphic factors, and also to some extent, due to lack of know-how. Recently by using new methods of planting in drylands, evolved through years of experience and manipulation of old systems and also selection of the right ecotypes (introduced by the Institute of Research) and finally the time of sowing, modern machinery, etc. we have been able to obtain some appreciable results. Other measures such as stock-water development and water harvesting, pitting, trenching and fencing have been undertaken where necessary.

WATERSHED MANAGEMENT AND SAND DUNE FIXATION

Recently the Department of Soil Conservation in the Ministry of Natural Resources has successfully stabilized several thousand hectares of sand dunes by means of direct seeding and transplanting of drought-resistant species of trees and shrubs during its four years of activity. This activity has shown astounding results and it has become one of the impressive areas for the lovers of nature to visit. As a result of this tremendous work thousands of hectares of bare sands which were threatening the life of people now have been converted to a beautiful stand of desert shrubs where no wind erosion or sand movement is taking place.

The summary of measures taken by this department follows:

Sand Dune Fixation

1) Establishment of 18 desert stations

2) Collection of seed desert shrubs from the desert areas

3) Reseeding of 90,000 hectares of sand dunes in Khorasan, Khuzistan, Kerman, Baluchistan, Sistan, Varamin, Chom, Semnan, Damghan, Esfahan and Garmsar.

This project is progressing and will be continued.

Watershed Management

This activity is mainly concentrated on the drainage systems behind the major large dams. The total yearly fund allocated for such a project is about $5 million.

The activity consists of a series of reconnaissance surveys, field analyses, aerial photo interpretation, mapping (priority is given to the most critical areas) and planning. Following the analyses, areas will be treated according to the existing problems. A considerable area has already been treated. The treatments generally include all kinds of construction work on steep slopes where the soil is loose and susceptible to erosion. Planting of adapted trees and grasses along with the above construction work is essential and it has been practiced where necessary.

LAND AND WATER RESOURCE DEVELOPMENT FOR CROP PRODUCTION IN TURKEY

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INTRODUCTION

In Turkey, agriculture with its social and economic aspects has a dominant role in the nation's life. First of all, it directly affects nearly 26 million (70 percent) of the overall population. At the present time, even though agriculture's share in GNP is only 26 percent, farm products still constitute the biggest proportion in the nation's annual exports.

Even though due importance has been given to agricultural development in the First and Second Five-Year National Development Plans, 1963-72, grave economic, social and cultural problems still exist in the rural sections of the country.

In this paper, after a brief review of the land and water resources, the existing level of development and problems associated with it will be analyzed, and in the light of past experiences more rational approaches will be discussed.

LAND AND WATER RESOURCES

Turkish territory is bounded on three sides by the sea. It is for the most part an elevated plateau enclosed by mountains on all sides but the west. These mountains act as a barrier to the rain-bearing winds from the north and south, leaving the interior plains, which make up more than two-thirds of the total area, with an average annual rainfall of 200 to 500 mm. The summers are hot and dry, with sharp drops in temperature during the nights and the winters may be extremely cold. In contrast to these areas, on the coastal plains a subtropical mediterranean climate prevails. In addition to low precipitation, 75 percent of the annual rainfall occurs off the growing season and dry years follow the relatively suitable ones.

If the drought is defined as an incidence during which the available water is less than that required for normal crop production, the drought area may sometimes include the whole country. According to a study made by DSI in 1932, dry and very dry drought, as defined by probabilistic limitation, prevailed in 80 percent of the country. It is also stated in this study that a very dry condition may prevail in 50 percent of the country with less than one percent probability, while for a dry condition for the same percent of area, the chance is 13 percent.

Evaluation of meteorological data shows that 96 percent of the cultivated land does not have sufficient precipitation during the vegetation period. Under these conditions, irrigation becomes a key factor in the realization of diversified farming and optimum returns from the land resources. As a matter of fact, irrigation is no longer a regional practice in arid countries, but is becoming a basic part of a well developed agriculture throughout the world. Having ample water available for crop production in humid regions as well as in arid regions contributes to profitable and productive agriculture.

Land Resources

The country has a total area of 78.1 million hectares. Of this area approximately 35 percent is cultivated, 26 percent is grass and pasture and the remaining 39 percent is forest and unproductive land.

Important changes have taken place with respect to land use in the last two decades. When the land use figures given in Table 1 are compared with the population in corresponding years (Table 2), it can easily be concluded that the area of cultivated land was expanded as population increased. The biggest change with respect to land use in the said period, was the expansion of cultivated areas to the disadvantage of pasture and forest land, under the pressure of a growing rural population. Especially in the period 1950-60, pastures shrank approximately one million hectares annually, and consequently cultivated lands jumped

Table 1. TRENDS IN LAND USE [1]

Land Use	Years							
	1934	1944	1950	1955	1960	1965	1967	1970[2]
Land under crops	6,882	8,087	9,868	14,205	15,305	15,294	15,513	15,907
Fallow	3,674	4,814	4,674	6,793	7,959	8,547	8,323	8,824
Grass and pasture	44,329	39,021	37,806	31,009	28,658	28,232	26,135	?
Horticulture	1,121	1,385	1,466	1,810	2,060	2,305	2,414	3,012
Forest	9,170	11,893	10,418	10,418	10,584	10,584	12,578	18,730
Unproductive land	12,058	12,499	13,466	13,463	13,132	13,096	13,095	?
Total cropland	10,556	12,901	14,542	20,998	23,264	23,841	23,836	24,731
Total cultivated land	11,677	14,286	16,008	22,808	25,324	26,146	26,250	27,743

1. Figures represent 1,000 hectares.

2. Tentative figures.

from 16 million hectares up to 25.3 million hectares. In the 10-year period after 1960, expansion of cultivated land continued, but at a reduced rate. Since no radical measures have been imposed in this period, it can be concluded that even the villager was aware of the fact that there was no additional surplus land left which could be plowed. Tentative figures show that the cultivated land area reached 27.7 million hectares in 1970.

According to the reconnaissance and semi-detailed land classification surveys completed to date, of the 27.7 million hectares of land presently cultivated, 12.5 million hectares are suitable for irrigation.

In addition, there are some potential areas which can be added to cultivated lands through expensive reclamation works in saline, alkaline and swamp areas. The total area of this land is estimated to be around 2.4 million hectares. There are also 2 million hectares of land to be gained through the reclamation of wild olive groves, pistachio forests and maquis.

Table 2. POPULATION TRENDS IN TURKEY
(Unit: millions)

Years	Population
1934	15.7
1944	18.6
1950	21.0
1955	24.1
1960	27.8
1965	31.4
1967	32.7
1970	35.2

Water Resources

One of the most important aspects of land and water resource development programs is the determination of an inventory of the resources. If the resources and opportunities are not known accurately before the projects are undertaken, in most cases the installations

will not be feasible and failure will result.

The work carried out by DSI up to the present time in 26 main drainage basins of the country shows that the annual potential of surface water is 166 billion cubic meters. Of this amount, 80 billion cubic meters can feasibly be developed. On the other hand, the safe groundwater reserve in the country is estimated to be around 8 billion cubic meters. Thus the combined potential of utilizable water resources in Turkey becomes 88 billion cubic meters a year.

EXISTING LEVEL OF DEVELOPMENT

Water is an indispensable element of life. Man's need for direct personal consumption to insure mere existence, however, constitutes but a small percentage of the total requirements. It is in combination with land that water exerts its main control over human destiny. These primary natural resources, the correct combination of water and land, in space and time will set the upper limits to the population-carrying capacity of a region or a country.

Cropland Expansion

The extension of cultivated land in Turkey surpassed its safe limits as early as 1952. All the later expansion has been mainly achieved at the expense of the poor steppe pastures. One of the main reasons for this expansion was that no significant raise took place in the agricultural productivity level, despite the gigantic explosion of the rural population at this period. Even today there exists a wide gap between the productive level of Turkish agriculture and the developed countries, i.e. it is two to four times lower than central and northern European countries. Consequently the population increase in already crowded villages exercised pressure for opening new croplands in the vicinity of certain village boundaries. Of course, pastures with good soil and slope characteristics are potential cropland in every country. But in Turkey, these expansions were extreme. Everywhere, the landscape of Turkey bears alarming evidence that much land has been plowed that should not have been. Cultivation has climbed from the plains to the hills. Coupled with heavy grazing on shrinking pastures, the resultant accelerated erosion not only destroys the productivity of the hill lands, it also upsets the whole hydrologic regime, contributes to floods, reduces the productivity of the lowlands and chokes streams and reservoirs. Therefore reduction of plowland in the marginal steppe pastures is absolutely essential to the maintenance of the existing level of production, quite apart from any raise of this level.

According to State Planning Organization sources only 18.8 million hectares of the 27.7 million hectares of existing cultivated lands are safe for cropping under soil and water conservation measures. This

means that 8.9 million hectares of absolute pastureland are already under cultivation.

Considering the relationship between water (in its various forms) and the needs of cultivated crops with respect to the extent of deficiency of water, approximately two-thirds of Turkish territory can be considered arid and semi-arid. Boundaries between these zones fluctuate with annual and cyclic variations in rainfall, soil and topographic conditions.

In most parts of the arid and semi-arid zones of Turkey, traditional dry farming, supplemented by a "nomadism" type of animal husbandry, is practiced. In the driest parts of the interior plains (as around the Salt Lake) which receive 200-300 mm. of annual rainfall, farming is marginal and characterized by great fluctuations in production. The uncertainty of rainfall (both in quantity and time) makes farming a gamble in those areas. On the other hand, in those regions which receive 300-500 mm. of annual rainfall, farming is more stable.

Field croplands have taken the biggest share in the land expansion, jumping from 14.5 million hectares in 1950 up to 24.7 million hectares in 1970. Of this area 15.9 million hectares are cropped annually and 8.8 million hectares are left to fallow. At present 85 percent of the cropland is devoted to the extensive grain production under dry conditions. Average harvest yield changes from 590 to 1,270 kg./ha., depending on the favorability of the year.

In the intermediate plains in contact with coastal regions, ecological conditions with respect to precipitation are more favorable. In those areas fruit trees and spring crops are grown without irrigation. On the other hand, excluding a strip of land along the eastern Black Sea coast, all Turkish territory requires irrigation for a diversified agriculture and for growing summer crops.

As already stated, 8.8 million hectares of land are left to fallow in arid and semi-arid regions. This area corresponds to nearly one-third of the country's existing cropland. Fallow lands cause an economic loss and are subject to wind erosion. According to the results of a five-year study made on the water storage efficiency of fallow in Central Anatolia, the efficiency of fallow varied from 18.4 to 22.1 percent of the average annual rainfall. In our opinion, this much moisture increase at soil profile may very well be realized by modern agrotechnical methods of dry farming based on soil and water conservation principles.

Irrigation Development

Development of water resources has several objectives, single or multiple. Among these, provision of irrigation water, flood protection, navigation, production of hydroelectrical energy, supplying of indus-

trial and domestic water may be counted. Here the subject will be treated with the objective of irrigation.

Since agriculture with its social and economic aspects has a dominant role in the nation's life, it must provide employment to the growing population, supply foodstuffs and provide export products for earning foreign currency as well as raw material for developing industry. Under Turkish conditions, it is impossible to fulfill these functions with nonirrigated agriculture.

As has already been pointed out, arid and semi-arid conditions prevail in most parts of the country. In those areas, one of the most important factors limiting agricultural productivity is the need of supplying necessary water in the growing season through irrigation. Under Turkish conditions, with a rational irrigation development, production from the unit area can safely be increased three to four times over present dry farming production.

In view of the fact that there is practically no more surplus land for increasing the area under cultivation, great attention has been paid to the development of existing land and water resources. Thus large sums have been spent for providing major irrigation works during the First and Second Five-Year Development Plans (1963-72).

Considering the limitation imposed by water resources, 8.5 million hectares of the country's 12.5 million hectare-irrigable land potential can feasibly be irrigated. Total area of the state projects completed up to 1970 was about 778,000 hectares. Of this area 660,000 hectares are within a major project, 70,000 hectares within a minor project, and the remaining 48,000 hectares are within a groundwater project. In these project areas, since development programs lagged behind construction programs, at the present time only 376,000 hectares of the land commanded by these projects are actually irrigated.

In addition, there is a considerable area irrigated by individual farmers. These lands are scattered throughout the country and generally consist of small areas that are irrigated by gravity and pumping from springs, creeks and shallow wells. Including those private irrigations, the total area of the actually irrigated lands in the country adds up to 1.5 million hectares. This figure corresponds to the 18 percent of the total irrigable land potential of the country.

PROBLEMS ASSOCIATED WITH IRRIGATION DEVELOPMENT

The ultimate objective of an irrigation development project "is to obtain the greatest permanent benefits to the farmers not only from production or profit by way of increasing the quantity or quality of products, but also to improve the private and public economy, and achieve the material and social benefits for the rural population, such

as the opening up of new lands, the maximum and rational use of labor potential." [1]

In order to fulfill those objectives and cover the increased production costs, the project must be based on a reasonably efficient system, with an adequate water supply, applied to improved crop varieties, supplemented by application of fertilizer and accompanied by disease and pest control as well as by appropriate crop rotation. The cost of intensification is high and can only be recovered by ample yields of high value crops per unit area. In addition, the project area must also be supplemented by the creation of such facilities as roads, electricity and domestic water supply systems, means of transportation, storage depots and socio-cultural institutions like education centers, schools and clinics.

On the other hand, the heavy investments made in major irrigation projects make imperative the guidance of skilled and effective professional personnel living on the spot. In addition there is also a need for establishing cooperatively linked family farm units in order to facilitate the use of improved technology and to permit use of modern mechanization of small holdings. Through cooperation the following benefits can be obtained in project areas: 1) collective purchase and operation of farm machinery, 2) processing of farm products, 3) coordination of plant protection works, 4) the maintenance of irrigation and drainage structures, 5) collective purchase of seeds, fertilizers and other necessities and 6) marketing of farm products.

The history of agricultural irrigation shows us that the success of an irrigation project depends, in addition to engineering structure, on the solution of land, water and human problems in the project area. In Turkey, up to the present time this phase of irrigation development has not drawn sufficient attention in project planning and implementation in comparison to engineering structures, i. e. storage, diversion, conveyance and distribution systems. Until recent years, through the lure of immediate gains, most of the major irrigation projects have been put in service even before their main distribution and drainage networks are completed.

In these projects, even at the end of their assumed development period, the area actually irrigated was not more than a small fraction of the area initially planned. Failure in the creation of a favorable media for rational use of irrigation water resulted in the cost of rehabilitation works being heavier than installation costs.

Land development works in irrigation projects will be discussed briefly under the titles of farm size and land consolidation, farm ir-

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1. Özbek, N. et al, **Annual Report, 1970,**
International Commission on Irrigation and Drainage

rigation systems, field drainage, land preparation for irrigation, salinity control and irrigation water management. In addition to agrotechnical measures, the quality of land development works seems to determine the ultimate success or failure of a project.

Farm Size and Land Consolidation

All available evidence indicates that family operated farms which are large enough to utilize labor saving equipment and other improved techniques, usually can compete effectively with large-scale units, may operate at a considerable disadvantage compared with larger units. Therefore, in most countries the principal objective of irrigation projects realized by public funds, has been directed to the creation of family operated farms and consequently an acreage limitation has been imposed. Another purpose of acreage limitation is to insure wide distribution of the benefits arising from public investments and to prevent speculative actions. Determination of the family farm size has to be viewed in relation to the desired standard of living and to the working hours needed under good technical cultivation conditions to obtain this standard; also the quality of the soil, the capital needed and available to carry on farming operations and actual market conditions are of importance in this context.

Up to the present time, such an objective has not been implemented in Turkey. In major irrigation projects it is not difficult to find cases of individual families who own 30,000 decares of land while only 3.7 percent of the numbers of families cultivate 34 percent of the total project area. According to the results of a survey carried out by DSI, as an average 87 percent of the holdings have farm sizes of 10 to 100 decares and these families cultivate only 46.8 percent of the total irrigable land in eight agricultural regions of Turkey.

On the other hand, scattered holdings in the project areas disturb the integrity and coordination of land development works. In 70 percent of farm family enterprises, holdings have four or more scattered parcels. Even though land consolidation activities started in 1961, they are still on a token level due to the the lack of legal measures. In irrigation projects, the number of plots in family farm holdings must not be greater than the one justified under existing physical and topographical conditions with a view to obtaining a land use pattern which makes possible the most efficient use of the agricultural resources. Plots should at least be so large that the farmer has to work there during half a day, which means that he does not have to walk to another plot during this period. The actual size of the plot will largely depend on the extent to which machinery is applied and on local conditions.

Farm Irrigation Distribution Systems

The main objective of farm distribution systems in irrigation projects is to convey the water from the tertiary outlet to the plots without waste and to provide the controlled application of water to the field. Aside from the land development works recently begun in two major projects (Seyhan and Gediz), engineered farm irrigation distribution systems are lacking. A study made on earth field ditches on three irrigation projects in Central Anatolia has shown that seepage losses were 7.2 to 42.9 percent per hundred meters of field ditch length. Considering the relatively greater length of field ditches in an irrigation project, seepage losses may create lots of damage.

Field Drainage

Until recently, the importance of drainage was not recognized till salinity and alkalinity became a problem. Today in the newer projects the need of drainage is recognized and provision for the principal drainage system is incorporated in the project planning. But again, in most of the irrigation projects, except where the topography and soil condition are such that natural drainage suffices, field drainage is lacking.

Land Preparation for Irrigation

In irrigation projects, the land must be prepared to receive the water before efficient application of irrigation can be accomplished. Therefore land preparation is an important item of irrigation development. Attempting to irrigate land with an uneven surface results in low efficiency of water use, soil erosion, excessive labor requirements, low crop yields, and usually creates drainage problems which can result in salinization of the soil. The application of water by surface irrigation methods requires that the land be smoothed so the farmer can control the water as it flows across his field. The fields that have adequate surface drainage often do not require subsurface drainage.

Excluding the Seyhan and Gediz projects in which extensive land preparation works are undertaken, inadequate leveling and preparation are prevalent in all irrigation projects in Turkey.

Salinity Control

In the past, saline and alkaline (sodic) soils were most often formed as a result of salt accumulation due to natural causes such as floods, impaired drainage and the evaporation of salty groundwater. In recent centuries, however, vast areas of salt-affected soils have developed from manmade causes such as irrigation without provision for adequate drainage, application of an insufficient amount of irrigation

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water or from a combination of these. Equally important, but less well recognized is the fact that saline and alkaline problems arise even when drainage facilities are adequate, unless sufficient irrigation water is applied to provide for both crop needs (consumptive use) and accessory leaching of excess salts out of the root zone soil.

In some older projects (Çumra, Menemen, Seyhan, etc.) detrimental changes have occurred in the soils as a result of inadequate drainage. Resultant salinization has discouraged farmers from changing dryland practices to irrigation farming. For example, in Çumra the oldest irrigation project in the country, 42 percent of the commended land is still left to fallow.

Management of Irrigation Water

The method of water application finally adopted, whether it be surface, sprinkler or subsurface, must satisfy the following criteria: 1) uniform distribution of water, 2)minimum erosion or other damages to the land, 3) maximum efficiency in the use of water, and 4) practical and economical performance from the point of crop, labor requirement, cost of land preparation and maintenance. High application efficiency and uniform distribution of irrigation water on the fields are prerequisites of good irrigation.

A study made on Central Anatolia projects showed that field irrigation application efficiencies measured varied from 16 to 90 percent. Differences in water application efficiencies, even in the same region with the same method of irrigation, were significant. The main reasons for the low water application efficiencies were as follows:

1) Field surfaces were not prepared well enough to permit the uniform distribution of the irrigation water during irrigation.

2) Field irrigation distribution systems were not planned and constructed properly for the control of irrigation water.

3) The use of high head during the irrigation of small plots did not permit uniform and satisfactory application of water.

4) Times to irrigate were not selected according to the soil moisture depletion in the root zone soil. Frequent irrigations with heavy application increased the deep percolation losses.

5) In the investigation areas, one of the most important factors causing low efficiency was the lack of knowledge and skill for proper application of irrigation water among the farmers. Especially in sugar beet farming areas, irrigation was usually practiced by hired irrigators. These hired laborers generally do not pay sufficient attention to the achievement of an efficient field irrigation.

It is the experience of Turkey, as well as other developing countries, that the farmers bound by traditional agricultural methods cannot achieve a high level of production. Since irrigation agriculture is not an easy and simple occupation, the ability of the farmers and their willingness to use available means assume increasing importance in the success of irrigation projects. On the other hand, the introduction of modern agricultural practices into traditional communities are complicated and delicate tasks requiring understanding, knowledge and adaptation. The most careful planning for the utilization of natural resources may not bring the desired result, if no account is taken of the farmer within his social context. Therefore, there is a great need to motivate the traditional peasant to adopt modern agrotechnology in irrigation projects. The only way of achieving such a goal is through realization of a very difficult task, that of a complete socio-cultural transformation in the rural areas.

CONCLUSION

Under Turkish conditions, successful amalgamation of land and water is of primary importance in the development of the country. Considering the limitation imposed with respect to water resources, the country has 8.5 million hectares of irrigable land potential, of which only 18 percent is actually irrigated at the present time. With the full development of this potential, if the production can be increased four times, this increase would be equivalent to plowing an additional 25.5 million hectares of dryland.

In the last two decades, despite the limited financial means of the country, large sums have been invested in the installation of big multipurpose projects. In those projects, though major structures (dams, conveyance and principal distribution systems) have been completed, basic means of production to raise the productivity could not be provided. Therefore, excluding sporadic prosperity areas, expected economic and social returns from irrigation have yet to be achieved.

In existing project areas, there is a chain of problems to be solved, starting from the land tenure system and fragmentation, up to the extension of the farm products to the consumer for optimizing the productivity of irrigation agriculture. Otherwise enormous investments will be wasted and the productivity of the soil will be irreparably damaged.

The success of agricultural development in irrigation projects is dependent on a number of factors, without which the desired development will not be achieved. Usually an institutional approach is needed, especially in developing countries, to permit the proper use of these factors in the development processes. The most important of these

factors are: the human factor, land tenure, administration, agricultural credit, marketing facilities, cooperation, education and extension. These factors are of decisive importance and the whole development process is dependent on them.

Solution of these problems in project areas requires a comprehensive social, economic and technical development plan that takes primary account of inhabitants' traditions and mental capacity to go along as a part of a national plan for agriculture. The drawing up of attractive plans does not as yet assure their [illegible] planning should be regarded as a dynamic [illegible] dinated with its implementation.

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THE DISTRIBUTION, VALUE AND MANAGEMENT OF THE NATURAL VEGETATION OF IRAN

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INTRODUCTION

The national vegetation of Iran, composed of deciduous forest, savanna, steppe and desert vegetation is the direct source of wood used in construction and industry and grazing of livestock and wildlife. It also indirectly protects watersheds, conserves soils, and provides recreation areas for all concerned.

It is the most important element of the national wealth upon which the majority of the population depends. The extended rhythm of exploitation and misuse of the vegetation during the past 30 years has depleted much of the land and necessitated sound management practices which I intend to refer to briefly in this presentation.

DISTRIBUTION

Historical and ecological factors including climatic, edaphic, topographic and biotic factors have acted upon the natural vegetation

and etched the following land distribution and use pattern.

Some half of the natural vegetation of Iran is either desert (25 percent) or semi-desert (25 percent); another 20 percent is depleted pasture and 5 percent is pasture in good or fair condition. The remaining one-fourth is composed of the following:

Forests	1.2 %
Depleted forests	8.8 %
Dry farming	12.5 %
Irrigated land	2.5 %
Total	25.0 %

The present pattern is a result of the distribution of three main climatic zones, which are as follows:

1) The Caspian Zone: 600 - 2,000 mm. minimum in June, no real drought, maximum in the autumn, relative humidity generally above 80 percent, mild or cold winters, January mean temperature below 8°C, July mean temperature below 26°C, annual temperature range (continentality) between 16°and 19°C. Gorgan on the east of the zone is drier and is transitional towards the Irano-Turanian Zone. It has Caucasian and medio-European affinities. This zone is also known as the Hyrcanian.

2) The Baluchi Zone: Generally less than 200 mm., entirely in the winter, 6 to 9 months without precipitation, relative humidity 60 to 80 percent, warm winters, January mean temperature above 15°C, July less than 34°C, continentality 10°to 18°C, includes most of Baluchestan but excludes Khuzistan. It has Saharo-Sindian and subtropical affinities.

3) Irano-Turanian Zone: Slight Mediterranean affinities, most variable precipitation, generally 100-500 mm. maximum in the winter or spring, 3 to 9 months of total drought, relative humidity in the winter 80 to 55 percent even falling to 20 percent in the summer, winters generally cold or very cold except Khuzistan and north of the Baluchi Zone. Continentality 21°to 26°C.

This zone comprises 90 percent of the area of the country and has been divided according to average precipitation to:

a) subdesertic zone, less than 100 mm.

b) steppic zone, 100-200 mm. (south) and 100-230 mm. (north), covers two-fifths of the country, and might be subdivided according to winter temperature to warm, mild and cold subzones.

c) substeppic zone, 200-230 to 400-450 mm.

d) xerophilous zone, 400 mm., 800 to 2,600 meters

e) high mountain zone above 2,000 meters

The pattern also corresponds reasonably well to the phytogeographic zones of Iran which are as follows:

1) Caspian flora comprising lower, medium and upper forest belts respectively up to 1,000, 2,000 meters and above.

2) Baluchi flora especially rich in species composition and exceptionally dense in vegetation, due to a lesser degree of grazing pressure as compared to the Irano-Turanian region.

3) Irano-Turanian flora which might be divided into subdesertic, steppic, substeppic, xerophilous forest and high mountain flora.

For a comparison of the percent of bioclimatic zones to the land distribution pattern the following approximations are quoted (FAO, 1970).

Bioclimatic Zones	Area in millions of hectares	Percent
Lower Caspian	1.4	0.9
Upper Caspian	1.6	1.0
Baluchi	7.9	4.8
Subdesertic	23.9	14.6
Steppic	51.0	30.6
Substeppic	42.8	26.1
Xerophilous forest	18.6	11.3
High mountains	7.0	4.3
Salt flats	7.0	4.3
Sand dunes	3.4	2.1
Total	164.6	100

VALUE

It is difficult if not impossible to arrive at an objective figure for the value of the natural vegetation of Iran. It might, however, suffice if we are reminded that along with soil and water resources, the natural vegetation is, next to manpower, the most valuable part of our national wealth, including the oil or livestock industry.

The classic calculation of accounting for every kilogram of N, P, K, and other nutrients in the soil and considering the value of grazing for the total number of animal units for every day of the year they graze the ranges of the country are not unknown to most students of ecology and I do not intend to go through these methods exhaustively.

A number of points, however, will serve as eye openers in the process of considering the value of the natural vegetation of Iran.

Morale value: The morale value must not be underestimated. Local newspaper accounts of floods which often occur in the fall and winter months of the year speak eloquently of the loss of life and property that affects residents of hundreds of Iranian villages.

Mention also must be made of the amount of silt accumulating due to erosion behind dams. The Karadj reservoir receives some 600 tons per square kilometer. Of the Sefid Rud watershed some 33,000,000 tons of sediment are carried to the reservoir, which has in 10 years lost a quarter of the original investment while with a good cover of natural vegetation it could have lost only a few percent. The Diz Dum reservoir received double the amount of sediment predicted, shortening its life span to as little as 70 years.

If these processes are not slowed down by conserving and building up of the natural vegetation, then the morale of the people will sink to its lowest ebb, and this will present a most serious threat to the country.

Nutrient value: The 1969 winter Karoon flood eroded some 216,000,000 cubic meters of soil into the Gulf. Similar losses occur each year in other rivers of Iran, bringing about heavy losses of soil nutrients impossible to redeem.

Grazing and wood value: Some ranges have accounted for the annual grazing value of the ranges, using 60,000,000 animal units, 5 rials per head per day and 365 days per year, and concluded the annual revenue of all ranges of Iran to be more than the annual oil revenue, thus:

$$365 \times 5 \times 60{,}000{,}000 = 110{,}000{,}000{,}000 \text{ rials.}$$

Others have used 2.5 rials instead, bringing the total income to

55,000,000,000 rials.

Different authors have similarly used different figures for the estimation of annual forest production of Iran.

Recreation value: Iranian cities, especially Ostan centers, face a mass exodus on summer holidays by the people who enjoy a gravel pile under the sun or the quaking shadow of a tree. No estimate of the value of the natural vegetation might be made in this regard.

MANAGEMENT

It is most essential that consideration be given to research, teaching and training in developing management techniques and personnel.

Research

In the area of research, before drastic measures are taken in introducing new land utilization methods, an ecosystem study and a reasonably detailed map of the natural communities, together with preferred land use recommendations, will base the work of all organizations concerned on a rational and scientific basis.

It is a source of consolation that the Iranian ministries concerned are developing through research:

1) Irrigation and fertilizer techniques for food and fodder crops

2) Nonirrigated fodder crops in fallow wastelands and depleted rangelands

3) Reseeding and management techniques applicable to depleted rangelands and forests

4) Soil conservation techniques

5) Utilization techniques of straw and all types of manure

6) Utilization of solar energy, kerosene and firewood to replace eradication of plants for fuel

7) Optimum production by selected strains of crops, livestock and fish to replace production on protected depleted lands.

Teaching

In the area of teaching, the importance of proper orientation is

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essential. Some misunderstandings that have crept into the minds of many students of natural resources are to be guarded against, and a few examples are as follows:

Misunderstanding No. 1: Conversion of forests to pasture

Forests are of great multiple value to man. Where they do grow, they must be cared for, improved and kept, especially in the vicinity of arid regions.

The pseudo-zeal to convert forests to pasture has demonstrated itself on many occasions in a number of publications which contain what I believe to be dangerous recommendations. These may leave the reader with the impression that: 1) the Caspian forest region is totally degraded, 2) it is bush land, 3) it is of low productivity and 4) it is to be converted to pasture and 5) that the sacred cow, science, has undebatably proved the value of such conversion in past years.

Misunderstanding No. 2: Premature judgments based on insufficient statistical data

A graphic representation was made of 19 years of annual precipitation data collected between 1940 and 1968 of one of the cities of Iran showing variations between a minimum of 120 mm. and a maximum of 400 mm. The researcher applied to the data the "rounding up effect" of the "gliding average" principle and observed and expounded his premature findings to amazed audiences that the steadily down-sloping 10-year gliding average curve meant that the said area is climatically drying up.

This was taken to generalize the secular post-glacial drought which the researcher believes is generally encroaching upon the climate of Iran.

It is not, however, correct, since the gliding average method cannot be relied upon, especially when other analytical techniques could well be utilized.

Similar fallacious results derived from a 10-year gliding average curve of the Tehran precipitation data should also be avoided. If Tehran climatic data were only taken during the following periods, the "sloping-down" gliding average curve would show Tehran going through a drying up stage.

a) 1890-1909

b) 1910-1918

c) 1926-1934

d) 1945-1952

e) 1954-1965

It might be supposed that these notions are partly adhered to in order that failures and ignorance might be covered up.

Misunderstanding No. 3: Weather cycles

More sophisticated analysts have applied certain methods to weather records and have derived results which demonstrate weather cycles of differing amplitudes. However, statistical analysis of random figures in accordance with these methods according to Bernier have also produced the same cycles, a phenomenon referred to as the "Slutsky effect."

Misunderstanding No. 4: Change of climate

Some erroneous notions about the "change of climate" of a region have also dramatically appeared among students. Numbers of trees to be planted in an area to double or triple the average annual precipitation have also been quoted.

In conclusion, emphasis should be given to the obliteration of all these dangerous notions by all concerned with teaching and training technicians.

SUMMARY

Capital consumption and the resulting deterioration of natural resources and especially of the natural vegetation have victoriously marched ahead of production and conservation of these resources.

The harsh race is continuing in the year 1971 not only because of still uncontrolled accelerated soil erosion, but also due to continued eradication of range vegetation and resulting soil denudation in some parts of this country and other misuses of the natural resources.

Iran should march ahead of or at least along with other parts of the advanced world in:

1) Increasing the yield of every hectare of its marine resources

2) Saving as much as 50 percent of the agricultural produce from pest invasions and disease outbreaks

3) Conserving moisture and organic matter in the soil

4) Conserving and rationally boosting production of natural resources and stopping their pollution

5) Preparing detailed land use surveys prior to application of drastic land use measures

6) Establishing an arid zone research institute to operate regionally under the highest patronage possible.

EROSION CONTROL AND VEGETATIVE COVER UNDER DRYLAND CONDITIONS IN TURKEY

by Dr. Selman Uslu, Professor,

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Turkey is a country which is surrounded by the Black Sea, the Mediterranean Sea, the Aegean Sea and the Marmara Sea. There are steep mountain ranges on the coasts of this peninsula. Therefore this morphological structure prevents rain clouds penetrating into Central Anatolia, which has the characteristic of semi-arid steppe areas. Due to its geographical and climatic conditions, it is very poor in vegetative cover. However, the coasts and mountain areas are rather rich in forests.

In addition to the above-mentioned factors, the soil conditions in Turkey offer favorable conditions for the attack of soil erosion by water and wind. Soil erosion has reached a high degree through destruction of forests and incorrect farming methods.

During the past years in Turkey, large-scale soil erosion studies were conducted by the Institute for Forest Geography and Forestry Problems of the Near East of the Faculty of Forestry of Istanbul University in cooperation with the Electricity Works Study Administration and the State Hydraulics Works General Directorate. The studies were aimed at

prevention and control of soil erosion on watersheds above several dams, constructed for different purposes in Anatolia.

Turkey is an old country, however, and one which has been under cultivation for thousands of years. Forests in many areas were cleared long ago and the steppes have been tilled.

In addition, during the long history, on many slopes soils were almost completely lost and the land abandoned. In these areas several hundreds of years ago development might have begun anew, but once again the land was cleared of vegetation and cultivated.

As the soils were very shallow, they were re-eroded in a few years and the land was again abandoned. The number of such cycles can rarely be determined. As a result of this history it is almost impossible to find an undisturbed soil profile. This situation is encountered almost all over Turkey and in many other Near Eastern countries.

The main watersheds, which were studied by the Institute for Forest Geography and the Forestry Problems of the Near East of the Faculty of Forestry of Istanbul University, included the chief river basins of Turkey: Kızılırmak, Sakarya, Gediz, upper Fırat (Euphrates), Seyhan, Ceyhan and others. The total surveyed area is 20,481,000 hectares or about 27 percent of the land area of Turkey.

As a result of soil erosion in the area surveyed, Turkey has lost about 36 percent of its soil almost completely, and these areas help the nation's economy very little or not at all. On another 32 percent of the region surveyed (9 percent of the country) soil erosion is very active and unless it is controlled this area will also be lost. On only 28 percent of the area is water erosion not serious.

A brief description of the arid areas of Turkey and of their vegetative cover and erosion problems is given below.

Steppes that occur in the arid zones of the country spread over Trachia, inner Anatolia, east and southwest Anatolia. The arid zones of inner Anatolia, especially where the great erosion damages occur, have been chosen as the subject of this paper.

The interior of Anatolia is a plateau divided by valleys. The average elevation is 900 meters, and reaches 1,500 meters in some places. The steppe-climate dominates this area. Meteorological figures according to the measurements carried on for 30 years at the Meteorological Station of Ankara indicate that the mean annual precipitation is 340.7 mm., mean annual temperature is 11.7°C, minimum temperature is -24.9°C, and maximum temperature is 38°C. Late frosts continue until the end of April and early frosts start in October. The greater part of precipitation falls in winter and spring.

From the standpoint of the amount and distribution of precipitation and evaporation, the climate can be classified as semi-arid.

The soil layer is rather thick on level and gently sloping lands, but it is very thin on slopes. The soil surface frozen 50 cm. deep becomes very soft and swollen in the spring because of frequent freezing and thawing. Besides these, the causes of soil erosion in inner Anatolia are the following: destruction of forests, deterioration of rangelands because of too early grazing, exposure of very well prepared fallow lands to wind erosion during the summer, and plowing under of some of the rangelands to produce field crops.

Two kinds of erosion can be seen in this region: water and wind erosion.

The following examples can give enough ideas on the magnitude of soil loss due to erosion. The amount of annual soil loss to dam or sea by river is 43 million tons. It shows only a part of the water erosion damage in inner Anatolia.

On the other hand, wind erosion damaged the products of three state farms in inner Anatolia in 1956. According to Prof.Dr. Ö. Tarman, the soil loss by wind erosion was equal to 396.6 tons of wheat. This amount of wheat is 12.6 percent of the total wheat production of this region.

In order to prevent the local influences of wind erosion in inner Anatolia, shelterbelts were established at Bala State Farm in 1954.

The experiment aims at first selecting tree and shrub species suitable for the purpose, and then determining methods of soil preparation, planting and tending, determining proper spacing, number of rows, composition of rows, width of belts, and investigating the effects of the shelterbelts upon the environment. The experimental area is 90 km. from Ankara in a southeasterly direction; the elevation is between 930 and 960 meters above sea level. It covers 220.6 hectares of land and has an inclination of 5 to 17 percent toward the northeast.

This study was suggested in 1952 by the Institute for Forest Geography and the Forest Problems of the Near East of the Forestry Faculty in Istanbul and started in cooperation with the Turkish Forest Research Institute in 1954.

In the first planning, it was assumed that the trees would reach a maximum height of 15 meters and ten times this height (150 meters) was taken as the average distance between the belts.

The length of the shelterbelts changes according to the shape of

the land. The total length of the eight shelterbelts, which have been established up to now, is 8,800 meters.

The width of the belts established in 1954 and 1955 was quite large, every belt consisting of 10 rows of trees and shrubs with a distance of two meters between rows, so that the area covered by trees had 20 meters of width. By the addition of five-meter strips at two sides, the belts were kept free of vegetation; the total width of the belts was 30 meters.

The first row on the windward side was assigned to shrubby species, the following two to short trees, the middle rows to high trees and the last two again to shrubby species, so that the shape of the cross section would be deltoid.

The soil of the belts was plowed to a 20-25 cm. depth and disked out in the autumn. Planting was done in the holes, 30 x 30 cm. in size.

The species with large seeds, such as *Amygdalus* and oaks were spot sown in general. Oak sowings maintained a high survival rate in the early years, but later most of the seedlings died.

No watering was practiced except in special trials, and continuous hand weeding was done.

Among the broad leaved tree species *Robinia pseudoacacia L.*, *Ulmus pumilla L.*, and *Quercus haas Kotschy* were the best in growth, survival and adaptability to the site conditions.

Conifers: *Cupressus arizonica, Pinus nigra Arnold, Pinus silvestris L.*, have shown satisfactory survival and growth. Especially *Ulmus pumila* and *Cupressus arizonica* were the best of all in height growth, reaching a mean height of 3.46 meters and 3.81 meters respectively, in seven growing seasons. Also, *Ailanthus glandulosa* showed a good survival and growth rate, but the tree was not suitable for the shelterbelt plantings.

Among short trees (wild fruit trees) *Eleagnus angustifolia L.*, *Prunus mahalep L.*, *Pirus amigrifolia L.*, *Amygdalus communis L.*, and *Prunus armąniaca L.*, are all growing satisfactorily in the belts.

Among the shrubby species *Amygdalus Webii Spach* is the best. *Rosa foetida L.*, and *Crateagus orientalis Pallas* are surviving and growing very well.

The experiments, which were conducted to make comparisons between spot sowing and planting, have proved to be good for all species in general. More successful results were observed by spot sowing in *Quercus haas*, but survival, which was reasonable in the first 2 to 3 years, dropped later, because of a lack of mychorriseae in the soil;

Amygdalus species were brought to the area satisfactorily by spot sowing.

In the experiments related to the planting season, better results were obtained by planting pines in the spring, *Quercus* and *Amygdalus spp.* and broad leaved species in the fall.

The 1954 and 1955 experiments in watering showed no differences between the first-year survival of the plants watered at different rates during the summer period and of the plants not watered at all.

In the light of the results of early establishments and tests and of the recent developments in other countries, some new experiments were started by extending the shelterbelt plantings in 1964.

In addition to the Bala experiments in Ankara, very important measurements have been taken by the Ministry of Agriculture in Karapınar, where catastrophic effects of wind erosion can be clearly seen.

A brief description of the vegetative cover of the interior of Anatolia follows.

Many Turkish and foreign scientists have made studies on the vegetation species of Central Anatolia, of which the characteristic plants are as follows: *Artemisia fragrans, Artemisia spicata, Achillea santolina, Euphorbia tinctoria, Globularia orientalis, Isitis glauca, Linum hirsutum subsp. Anatolicum, Peganum harmala. Poa bolbosa, Bromus erectus, Bromus tomentallus. Festuca ovina, Festuca sulcata.*

Around Tuz Gölü the halophytic vegetation includes many *Chenopodiaceae* of Iranian or Trans-Caspian affinities and several distinctive endemics in genera which are not usually associated with halophytic habitats.

Furthermore, the existence of the following species of hardwoods and conifers has been observed by the Institute of Forest Geography and the Forest Problems of the Near East: *Pinus nigra var. Pallasiana, Quercus pubescens, Quercus infectoria, Quercus pedunculata Haas, Juniperus oxycedrus, J. foetidissima, J. exelsa, Prunus mahalep, celtis tournefotii, Jasminum fruticans, Pirus eleagrifolia, Rhus coriaria, Crataegus monogyna, Sorbus aria, Pirus malus.*

SOIL AND WATER CONSERVATION ON ARABLE LANDS

by Mr. A. Ganjini,
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and Mr. B. Azimi

Recognizing the specifications of arid and semi-arid areas in Iran and the majority of the countries in the Middle East for the purpose of an agricultural development program, soil exploitation and an increase in production rate is a necessary matter. The factors which have created these specifications are numerous and for determining whether an area is arid or semi-arid different formulas and coefficients are used.

In general, an arid area cannot be defined and interpreted simply by taking into consideration only one factor such as the precipitation rate or rain distribution or changes in the temperature.

CLIMATIC FACTORS

Annual precipitation : Insufficient precipitation is one of the main causes of aridity. In arid areas, precipitation is less than 100 mm.

per year. Moreover, in some cases, the seasonal distribution pattern of the area plays an important role in determining the climatological characteristics of a region. For example, the central part of Australia, with 500 mm. rainfall during the year, is considered an arid area. Generally, the seasonal distribution of precipitation in arid areas is very irregular.

Changes in temperature : Daily variations in the temperature of air and soil are wide, sometimes reaching 20-30°C. Also the maximum temperature is high, and in most cases it goes above 40°C, and at this temperature synthesis of chlorophyl by plants is not possible.

Air currents (winds) : In arid areas, due to high variations of temperature, many air currents are developed, which, in many cases, cause a lot of erosion and result in transportation of soil particles from one area to another.

Evaporation : Due to the low humidity of arid areas, most of the precipitation is lost through evaporation, while only a small amount percolates into the soil. Even this amount evaporates into the air soon after the end of precipitation.

Light intensity: Although light is necessary for plant growth, its high intensity in arid areas increases water use of crops.

CHARACTERIZATION OF THE DEGREE OF ARIDITY OF AN AREA ON THE BASIS OF ARIDITY COEFFICIENTS

As mentioned before, aridity is caused by the interaction of several factors. To determine the degree of aridity of an area the following two approaches are commonly employed:

1) Determination of aridity on the basis of temperature and rainfall

2) Determination of aridity on the basis of evaporation and rainfall

Among formulas concerning the first approach, the most simple one is Goussen's, which uses a coefficient in the form of $P = 2T$, where P stands for precipitation and T for the mean monthly temperature. According to Goussen, wherever rainfall is equal to or less than the doubled value of temperature, aridity conditions exist and the area is considered to be arid.

Another formula is that of Koeppen, which is shown below:

$I = \frac{P}{T + Y}$, where Y is related to rainfall distribution and intensity. According to this formula, the smaller the value obtained for I, the more is the aridity of the area.

The Ambergert formula, shown in the form of $I = \frac{P}{M^2 - m^2}$, is also employed for this purpose.

In this formula,

I = Evaporation

P = Average yearly precipitation

M = Average temperature of the hottest month of the year

m = Average temperature of the coldest month of the year.

Different values obtained for various parts of the country are shown below:

Bandar Pahlavi	159	Tabriz	28
Ramsar	143	Shiraz	27
Babolsar	103	Chah-Bahar	9.2
Gorgan	51	Boshehr	17.5
Meshed	21	Tehran	16
Hamadan	31	Kerman	10.6

According to the above figures, more than nine-tenths of the total area of the country is arid/semi-arid.

Through the joint cooperation of FAO and UNESCO, a map has been prepared for most parts of the world showing the arid, semi-arid areas and generally climatic zones.

The aridity index and monthly temperature = $31 - (4 + \frac{8}{2}) \times .8$,

where 31 is the days of the month, 4 is the number of rainy days of the month, 8 indicates the foggy days and .8 has been obtained from the

table of relative humidity, as shown below:

For relative humidities between 40 - 60 % use 0.9

For relative humidities between 60 - 80 % use 0.8

For relative humidities between 80 - 90 % use 0.7

For relative humidities between 90- 100 % use 0.6

In each area, the closer the value of the index to the figure 365, the more is the aridity of the area.

CAUSES OF WATER LOSS AND SOIL EROSION IN ARID AND SEMI-ARID AREAS

From the geographical point of view, North Africa, the Middle East, India, Southern Europe, China and the southern part of America are most susceptible to erosion. These areas are generally considered to be the arid and semi-arid areas of the world. The causes of erosion in these areas are as follows:

1) Precipitation in these areas has high intensity and short duration. Consequently, the water does not have enough chance to infiltrate the soil; rather, the excess rainfall runs along the surface of the soil and causes erosion.

2) Crop cover is very poor and offers very little protection to the soil.

3) Due to high temperatures and the intensity of sunlight in these areas, the humus content of the soil decreases and, consequently, soil aggregation is poor and the soil cannot resist the erosive forces.

4) With the increase in the rural population of these areas, there has been some improper use of land, which has increased erosion.

Land Situation and the Increasing Soil Erosion and Water Loss in Iran

Generally, soil erosion is accompanied by water loss. In Iran, soil erosion takes place under a wide range of conditions. The following figures indicate the seriousness of the problem of erosion in this country:

WATER EROSION

Data on Silt Accumulation Behind Dams

Name of Dam	Catchment Area	Annual Accumulation of Silt	Command Area(ha)	Total Capacity (MCM)
Mohammed Reza Shah (Dez)	17,245	200.5 million tons	125,000	3,300
Shah Bano Farah (Sefeed Road)	57,800	75 million tons	240,000	1,800

In Khuzistan, the flood of March 1969 caused a loss of 216 million tons of soil and 2,160 MCM of water.

A study on the fertility level of eroded soils has shown that the nitrogen, phosphate and potassium content of eroded soils is 2.5, 3.4, and 29 times less than that of the noneroded soils.

In Iran, the average yield of wheat grown under dry farming conditions is about 700 kg./ha. a figure which reflects the low fertility levels of soils.

The following table shows the number of days in the years 1951-60 during which storms occurred in different parts of the country and caused wind erosion:

Region	Number of days
Khuzistan	60-150
Ghazvin	60- 90

Of the total area of the country, 53.2 percent has an elevation between 1,000 and 2,000 meters above sea level. A considerable area of this region, which covers the lands below the Alborz and Zagros chains of mountains, is under cultivation. Accordingly, most of the cultivated land is located on slopes of different degrees. The most impor-

tant cultivated areas of the country are located in West and East Azerbaijan, Kurdestan, Hamadan, Kermanshah and Khuzistan (along the Zagros mountains), Tehran, Gorgan and Khorasan, (along the Alborz chain of mountains).

It should be mentioned that 12 reservoir dams have already been built in the above mentioned areas to supply the water required for agricultural use and public consumption.

The types of soil in these regions are shown below in the order of the area they cover:

1) Calcareous lithosol in areas of Brown or Chestnut soils

2) Lithosol developed from igneous rocks in areas of Brown or Sierozem soils or Brown soil mixed with Rendzina

3) Calcareous lithosol in areas of desert and Sierozem soils

4) Calcareous lithosal developed from saltiferous and gypsiferous marls

5) Brown and Chestnut soils.

Climatologically speaking, these areas have the characteristics of arid and semi-arid areas. The main limiting factors of the soil for agricultural use are shallow depth of the soil (caused by erosion) and its surface undulations. Lack of sufficient water is the main factor determining the crop yield in these areas.

The existing problems which decrease the yield of crops in these areas are as follows:

1) Improper use of lands

2) Intensive erosion accompanied by water loss

3) Unsuitable rotation, normally wheat-fallow, which leaves the soil with no cover for one growing season, consequently causing erosion during the fallow season

4) Overgrazing of pastures

5) Improper cultural practices which intensify erosion

6) Improper irrigation practices and water management, mainly due to farmers' ignorance about the amount of water required for crops

7) Rapid mechanization and increase of cultivated areas on sloping

lands, usually accompanied by improper cultivation practices.

Area Studies

Studies carried out for the determination of water storage and control of erosion in dry farming areas are indicated below.

In West Azerbaijan, an experiment was started in 1968 to study the possibility of increasing water storage in the soil. The experiment was conducted in a one-hectare field which was divided into four blocks as follows:

Block A: Cultivation practices were done according to the local practices, and included disk plowing of the field in the spring and seeding (with a drill) in the fall.

Block B: The field was grazed after harvesting and was plowed with a disk in the fall of 1968. No cultivation was done on this block in the spring and, therefore, the weeds could use the moisture and nutrient content of the soil. In the fall of 1969, this block was first disk plowed and then seeded with a drill.

Block C: After harvesting and grazing in 1968 the land was plowed with a disk, and in the following spring a cultivator was used for destroying the weeds. In the fall of the same year the land was sown with a drill.

Block D: All agricultural operations were the same as Block C, except that an additional cultivator was used in order to destroy the weeds and break the soil surface.

For determining the soil moisture samples were taken at three different times from depths of 0-30 cm., 30-50 cm., 50-80 cm., and 80-100 cm.

The results obtained show that those blocks (C and D) which had cultivation practices in the spring and summer have a higher moisture rate in comparison with other blocks.

The annual precipitation rate for the years 1968-69 and 1969-70 was 526.2 and 215 mm., and since the percentage of moisture has some influence on cultivation practices, a complementary study was carried out as described below.

1) Fall plowing in blocks B, C and D, in November 1968

2) Time spent for plowing these three blocks, about 2.5 hours

3) Use of cultivator in blocks C and D in April 1969, about 1 hour

4) Use of cultivator in block D in July 1969, about half an hour

5) Sowing of wheat in the fall of 1969 in blocks B, C and D, about one and one-half hours

Block A	-	1,660 kg./ha.
Block B	-	1,375 kg./ha.
Block C	-	2,460 kg./ha.
Block D	-	1,620 kg./ha.

It will be noticed that the rate of extra yield in block C in comparison with block B is 1,085 kg./ha. while the agricultural practices in all 1,800 m^2 have been the same with the exception of one spring cultivation for about half an hour, and this is a very meaningful difference. The rate of yield on block D with a summer cultivator was less than block C. It seems that the evaporation rate is high, and as a result the moisture accumulation has been low.

It is necessary to mention that these studies have been carried out only in one area so the results cannot be generally recommended for other areas.

Rainfed Cereal Increase Production on the Basis of Soil and Water Conservation

At present about 2.5 million hectares of irrigation land in Iran are under wheat cultivation which is comparatively high. In some areas like Mahabad more than 70 percent of the land is under wheat cultivation and this is for the purpose of getting maximum advantage of the available rainfall and water from the rivers in a cropping season which in most places ends in late spring. While there is not enough water from other sources replacing cereal with other crops is not advisable. Even if there was more water available increasing the hectarage of cereal is not recommended. On the other hand, the shortage of cereal in the country and importing from abroad has to be solved by the right use of land and soil and water conservation. The studies mentioned above provide a successful way of solving this problem.

WHEAT PRODUCTION PROBLEMS AND POTENTIALS ON DRYLANDS

by Dr. Ahmet Demirliçakmak,

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Wheat is the most important food commodity in Turkey when measured in terms of cropland used in its production, number of villagers involved, production and its importance in the population diet.

During the past 20 years, total wheat production has increased at an average annual rate of 33 percent, or 276,000 tons. This level of production and the rate of increase have been enough to satisfy about 96 percent of Turkey's needs. The balance has been improved. The amount varies from year to year, because production varies dramatically. In fact, overall production has varied from year to year.

Over the past 20 years, increases in area sown accounted for about 60 percent of the increase in production. The other 40 percent was accounted for by an increase in yield. The area sown increased by about 172,000 hectares per year, while the yield increase per hectare was slightly under 10 kilograms per year.

If yield continues to increase at the same rate for the next 10

years, Turkey will need to have 11.4 million hectares planted with wheat in 1980, but if in fact the area sown has already reached its maximum level, average yields will have to be increased at an even faster rate to maintain the same wheat supply per person.

It is recognized that the cultivated land cannot be increased further. The area available for reclamation is less than that of the land now cultivated. The object of the plan is to increase productivity by means of imported techniques and some irrigation rather than expansion of the total cultivated area.

Wheat has always been the most important crop in Turkey in terms of both acreage and production. Because of its adaptation to dryland conditions, it will continue to be the most important crop in terms of area and in terms of domestic needs. The annual consumption is more than 200 kg. per person. Its high consumption, coupled with an average population increase in excess of 2.5 to 3 percent only magnifies the domestic supply problem.

There are two basic sets of conditions in Turkey under which wheat is grown.

The first set of conditions includes generous rainfall, a mild or very mild climate, and in many cases, the availability of irrigation water. These conditions are found along the coastlands and to a limited extent, in certain parts of the plateau.

The second set of conditions, which is the main, includes limited rainfall (between 200 to 400 mm. of rain per year), cold winters, and little, if any, developed irrigation water. Under these conditions, which characterize much of the central plateau, the southeastern and eastern parts of Turkey, winter wheat is grown. In this paper, the second set of conditions will be discussed.

Wheat production practices for water conservation on the Anatolian Plateau are different in many respects from those in the coastal regions of Turkey. The chief contributing factor making these changes necessary is the fact that the Anatolian Plateau is a relatively low rainfall area, whereas the coastal regions normally receive 500 to 600 mm. or more rainfall annually. The Anatolian Plateau receives, on an average, 200 to 400 mm., most of which falls during the winter.

The topography and climate of much of the Anatolian Plateau is similar in many respects to the semi-arid regions.

Most of the wheat in Turkey is grown under dryland conditions where yields are low and fluctuate in direct relation to rainfall. Cultural practices are adapted to a livestock economy that depends on stubble and weeds coming up in summer fallow as one of the main sources of feed. Moisture holding capacity is low since most of the organic

matter has been removed. These practices are not conducive to moisture conservation since weeds remove most of the moisture. In dryland conditions, wheat is normally planted in October and harvested in July and August. The land must then lie fallow until October of the following year. During this period the soil recovers some fertility and accumulates a limited amount of moisture during the late fall and winter months.

At the present time, production management is the major limiting factor in the wheat production in dryland areas. The varieties now grown are capable of much higher yields than are currently being produced. The problems are:

* To accumulate all possible moisture in the soil and hold it close enough to the surface of the soil

* To prepare a good clean seed bed into which the seed can be planted with sufficient moisture present to insure not only germination but also continued growth of the plants.

In general the fall sown wheat depends upon rain after seeding in order to germinate. Very often there is not enough precipitation and seed does not germinate until next spring, thereby missing the favorable fall growing period for root development and tillering with a resulting sharp yield reduction. In this case, the development of the technique and scientific basis for a program of soil and moisture conservation and management and cultural practices are very important. The large Central Anatolian plain and the regions in southeastern Turkey are very promising areas for production management improvement.

The fact that the land is in a relatively hard condition, a condition that is often aggravated from compaction by the sheep's feet, causes excessive runoff of winter rains and melting snow. This causes undue loss of moisture and frequently leads to a serious erosion problem.

Preparation of the land is usually done during the summer, just before planting, with a plow of some kind. This may be the old traditional wooden plow, or a small drawn turning plow, or it may be a tractor drawn plow or disk. The land is usually left rough with a consequent loss of any moisture that might have been present.

Sowing is largely accomplished by hand broadcasting the seed, although an increasing number of grain drills is becoming available by local manufacture. When hand broadcast, the seed may be covered by plowing, disking or dragging. Both of these methods of sowing place the seed in dry soil and germination cannot occur until there is adequate rain for the purpose. This often comes so late that the emerging plants are unable to make any substantial growth or enough root development to enable them to withstand the winter cold. This leaves them in poor

condition to begin growth in the spring, and when spring rains are inadequate the poorly developed root system leads to very low yields.

The fall sown wheat needs a good distribution of rainfall in the spring, particularly April, May and early June. For this reason, regardless of the total amount of annual rainfall, the amount of precipitation in April and May plays a very important role in the yield performance.

As mentioned before, the average rainfall of Central Anatolia ranges from 200 to 400 mm., depending upon the locality. Also the diversity of this rainfall varies greatly from year to year even in the same locality. The precipitation from 1960 to 1968 for the two main provinces in the central plateau is given in Tables 1 and 2.

The high precipitation in June 1961 did not affect the yield. In general June rains are too late to be effective. In 1963 rainfall in May was very high and yield was high. Also, total rainfall was high in that year. In 1966-67 total rainfall was one of the lowest, but the yield was the highest because the precipitation in early April and May were rather high. In 1960-61 and 1961-62 the yields were low, but the total rainfall was better than the average, the only reason for this being the unfortunate distribution of rain, especially in April and May.

In Konya, 1960-61 was one of the worst crop years. The annual rainfall was lowest, accompanied by the lowest precipitation in May. In 1962-63 total rainfall was one of the highest and the precipitation in May was the highest also. As a result of this, the yield was the highest. In 1966-67 the total rainfall was normal, but the rainfall in May was high and the yield was one of the highest. The late rains of June in 1964 did not affect the yield.

The soils of Anatolia have a very high clay content, often 50 percent or more. The clay soil is more difficult to cultivate, as it limits root development to 1 to 1.5 meters in depth, and presents many more problems with the use of agricultural equipment than a loam soil. For example, in clay soils power requirements are higher and timeliness of cultural operations is extremely important. The equipment in general use in Anatolia is not satisfactory for the clay soil. Also soils in Anatolia are low in available phosphorus and nitrogen.

These are major factors that will make it necessary to conduct extensive research in tillage methods, timing of tillage operations, different types of tillage, use of fertilizers and seeding rates, dates, row spacing and fertilizing practices.

Table 1. PRECIPITATION IN ANKARA
(in mm.)

Years	Annual Precipitation September to August	October	November	April	May	June	Wheat Yield Kg./ha.
1959-60	327.9	17.8	35.4	48.8	27.5	42.5	1,064
1960-61	365.3	31.7	22.2	11.0	33.0	121.9	720
1961-62	400.0	26.7	5.6	20.4	25.7	9.5	841
1962-63	656.1	30.3	9.6	82.5	121.5	22.9	1,375
1963-64	392.6	28.4	10.6	14.2	40.1	58.2	1,059
1964-65	410.4	-	41.0	47.2	62.4	14.6	1,097
1965-66	380.7	10.4	41.3	49.2	64.1	16.8	1,278
1966-67	358.6	7.7	19.2	82.7	53.8	11.1	1,502
1967-68	438.8	10.9	30.6	49.6	40.7	64.8	1,216

Table 2. PRECIPITATION IN KONYA
(in mm.)

Years	Annual Precipitation September to August	October	November	April	May	June	Wheat Yield Kg./ha.
1959-60	284.0	27.2	26.5	25.4	37.1	44.1	1,222
1960-61	205.3	11.7	6.1	5.6	7.3	5.8	7,703
1961-62	252.5	21.3	26.6	20.2	49.3	-	822
1962-63	402.6	44.0	2.6	40.5	122.2	34.2	1,566
1963-64	297.2	39.4	32.2	2.8	32.6	60.5	889
1964-65	282.6	4.6	38.2	23.1	32.0	13.6	1,136
1965-66	287.0	13.6	16.5	20.5	21.3	6.8	1,239
1966-67	340.1	-	12.8	24.9	104.1	6.6	1,485
1967-68	438.0	5.8	55.6	12.7	56.7	21.4	1,393

The problems of tillage, production management and equipment can be solved. To do this a concentrated effort must be made on tillage and management research. The general principles of tillage practices for moisture conservation will apply in Anatolia. It is necessary to find through research the best methods of using available equipment and modification of equipment and methods to improve wheat production.

The lack of well trained technicians in the area of dryland conditions is still a serious and continuing problem. The difficulty is that this type of training is not available as an academic program in any university. It usually means that the research people and extension technicians need further training and experience in order to handle the work. A good program of post academic research and practical work training are needed by these technicians for production of wheat.

It is understood that the primary emphasis for increased wheat production will be directed to the continuation of present research and adaptive research, utilizing new and special techniques and developing an effective extension and farmer education program covering:

1) Soil moisture conservation (improved summer fallow tillage)

2) Use of new or improved tillage and seeding equipment

3) Use of fertilizers

4) Use of pesticides and weedicides

5) New varieties.

Research to be conducted will determine the systems of soil management which will conserve the maximum amount of soil moisture. The use of more advanced equipment, and improved and refined soil moisture management practices should stabilize higher yields and make it more profitable for the Anatolian farmer. Therefore, the soil tillage research now being conducted is of primary importance in order to formulate a combination of tillage operations needed to conserve the maximum amount of moisture. This research now in progress is designed to determine the effectiveness of good soil moisture conservation and the most effective equipment combinations to use in the various soil types. With the establishment of the Wheat Research and Training Center in coordination with the Rockfeller Foundation, research is being carried out to determine the optimum fertilizer rates, seeding rates, seeding dates, row spacing, weed control practices and varieties of wheat that are capable of maximizing the benefits of increased moisture. It should be understood that it will require the application of a combination of these practices, rather than any one individual practice, to achieve the most significant influence on dryland wheat production on the Anatolian Plateau.

SYSTEMATIC LAND RESOURCES INVENTORIES AS A TOOL FOR AGRICULTURAL DEVELOPMENT AND PROPER LAND USES

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INTRODUCTION

For many years, in many countries, the soil survey was the only study to determine land feasibilities for agriculture and other land use. The environmental factors such as climate, geology, geomorphology and vegetation were not often given adequate emphasis. At the same time, soil surveys were limited to certain areas where irrigation projects were carried out.

In the same way, during soil surveys in Iran, only the suitability of lands for irrigation is determined. But as the soil is only one of the factors in agriculture, and by soil survey other environmental factors were not defined completely, soil surveys would not answer all

questions dealing with the development of agriculture or use of the land in a vast country like Iran, with 165 million hectares, with wide ranges of climate, geology, soil, etc. Because of this it was felt that some comprehensive studies had to be carried out on lands, giving emphasis to studying all factors affecting agriculture, and in a broad sense, on land potentialities for different uses. These kinds of studies were started in Iran in 1967 by the Soil Institute, under the heading of "Systematic Land Resources Inventories," separating different land types and land units, according to physiography, climate, geology, vegetation and other factors with delineation of land type/land units on the map and determination of land potentialities for:

* Irrigated annual crops

* Dry farming or rainfed crops

* Orchards

* Range

* Forest

* Recreation

* Industry, urban.

This paper deals with different approaches on the land resources inventories and describes methods considered applicable to Iran with assessment of land potentialities or capabilities for different land uses and initial input requirements for land conservation and improvement works.

BRIEF REVIEW OF THE METHODS OF LAND EVALUATION

As long as the pattern and the techniques of land use do not change, the lands are evaluated according to their actual production. In many countries, this is expressed by the average yield of the major crop, wheat for example, per unit area. But wherever men want to use new land or to change the present land use pattern, or to introduce new management practices, there is a need to assess the productivity of the lands under the future conditions of use. In this case, land evaluation becomes a prediction which is of paramount importance in decision making, and in allocation of natural, human, technological and financial resources for agriculture or other land uses, yet requires specialized studies with appropriate methods and norms.

Different countries have developed various systems of land evaluation according to their local conditions, their objectives, their land use problems and policy. However, some similarities can be found in the

approaches and principles of different systems.

In all methods of land evaluation, there is the first step, which is the collection of facts about the different aspects of the lands: soil, climate, topography, vegetation, drainage, present land use, etc. Since these land characteristics vary in a more or less continuous way in space (and some of them in time), the delineation of areas where land characteristics can be considered as homogenous, is the first problem faced in land evaluation. It is solved in different ways in different countries and is summarized below.

Land classification mapping such as for irrigation. In this system, land evaluation is made practically at the same time as survey of the land.

Survey of "natural" land units: To discover natural homogenous areas and to delineate them. Norms of interpretation are applied to these natural land units.

Different approaches are followed in this group of methods.

Soil survey: Soil reflects the interaction of parent rocks, climate, vegetation, etc., and it is assumed that homogeneity in soil implies some homogeneity in the other environmental conditions.

Vegetation survey: It is assumed that the nature and composition of natural vegetation are closely related to other land features, so that homogeneity in natural vegetation reflects some homogeneity of the other features.

Geomorphologic survey: Detailed survey of land forms has recently proved extremely useful in the understanding of land features.

Integrated land surveys: All the methods explained above usually give a very valuable picture of the land, but a somewhat incomplete and unbalanced one, since special emphasis is given to one of the land characteristics (soil or vegetation or land form). Moreover, some variations in soils are not always related to changes in climate, or in vegetation or geomorphology. It is therefore necessary to supplement these surveys of one main aspect of land, by collecting directly the other data on the land characteristics and integrate them with those already collected by one of these specialized surveys.

A METHOD OF LAND EVALUATION APPLICABLE TO IRAN *

Basic and general principles: For the choice of a method of land evaluation applicable to Iran, it was necessary to take into account:

*See Appendix

* The background information available and experience gained in land evaluation in Iran

* The condition of the land resources and of land use

* The specific needs of land evaluation according to the present trend of development

* The recent advances in the subject.

By collecting considerable information existing on the different aspects of the land resources of Iran: climate, soil, topography, geologic substratum, present land use, etc., a method of integration "by stages" was adapted for the land resources inventories of Iran. This method leaves to each study its individuality and permits a progressive integration of the data, essentially on the basis of a framework of physiography and soils.

Preparation of maps of soils and physiography are therefore a prerequisite for elaborating land resource maps. This integration leads one to define "land units," which are described as a combination of conditions of climate, soils, physiography, vegetation or present land use, drainage of the area, etc.

The presence of mountains in most of the regions of Iran makes the pattern of land units rather intricate. It is therefore necessary in Iran to show on the map the actual distribution of these individual land units separately.

Use of complex mapping units would lead to grouping lands of quite different potentialities in the same mapping unit. This would not provide an adequate inventory for land evaluation. However, in order to avoid the difficulty of defining and mapping all existing different land units, major types of land units have been defined as follows:

1) *Mountains:* Entirely destructional landscapes with high relief intensity.

2) *Hills:* Usually corresponding to old geomorphic surfaces of erosion or accumulation which have become completely destroyed; however, relief intensity and slope gradient remain moderate.

3) *Plateaux and upper terraces:* Corresponding to geomorphic surfaces of erosion and accumulation which are undergoing erosional processes of degradation. Many flat or gently sloping remnants of the former surface are still found, and relief intensity and slope gradient are low.

4) *Piedmont plains and nongravelly fans:* Gently sloping plains

at the foot of mountains and hills, with slope direction perpendicular to mountain ranges, and nongravelly colluvial or alluvial fans (fine textured).

5) *River alluvial plains:* Made by recent fine deposition of a major water course. The general slope of these plains follows the direction of the river.

6) *Lowlands:* Corresponding to areas of varying shapes and sizes with nearly level and often concave topography, where groundwater and surface water tend to accumulate with subsequent accumulation of fine sediments and eventually of subsoil salt.

7) *Flood plains:* Corresponding to nearly level areas where running surface water tends to spread frequently through active flood channels.

8) *Gravelly colluvial fans:* Built by many parallel small water courses debouching at the foot of the mountain fronts.

9) *Gravelly river fans:* Built by a major water course, consequently fan-shaped with a convex transversal section.

C: when a land unit is made of an intricate combination of several land types, the land unit is classified under the heading "complex land types."

X: when a land unit cannot be related to any of the standard definitions of land types, it is classified as "miscellaneous land type." For example: dune fields, coastal sand bars, etc.

Each of the above mentioned land types has its own characteristics of:

* overall slope classes

* local relief intensity

* soil conditions, etc.

They can be subdivided into land units according to various characteristics such as:

* thickness and continuity of soil cover

* type of underlying rock or soil material

* relief intensity

* density of hydrographic network

* shape of the valleys

* relief elements

* gradient or transversal slope

* degree of erosion/dissection

* position and location

* other factors, which have great influence on subdivision of land types.

By recognizing and mapping the major land resources types, the main land resources of any region can be shown on the map and individually evaluated.

Land Evaluation

The land evaluation should be a multipurpose one. Potentialities have to be studied separately for each major land use:

* irrigated crops

* dry farming-rainfed farming

* orchards

* range or pasture

* forest

* other land uses.

This land evaluation should permit comparison of the various potentialities for different uses of the same land unit and also the potentialities of different land units for the same use.

This comparison requires the definition of "classes" of different potentials. A system of land classification has been devised with six classes having the same general definitions as the one used for irrigation, but based on a wider range of parameters and also different criteria according to the land use contemplated (Class 1, high potential up to Class 6, no potential).

As a result, the land evaluation has to be presented here in the form of a table, giving the land classes of each land unit for each major land use.

The assessment of land potentialities is made by three approaches:

1) Overall judgement

2) Comparison and correlation with other lands

3) Analysis and rating of the parameters influencing the potentialities of land.

Whereas no guidelines can be given for the first approach, besides the basic definitions, some rules are presented for the correlation and parametric methods of land evaluation.

Since two land units are rarely identical in all their aspects, comparisons and correlations can only apply to a limited number of land characteristics; for example: correlation of lands with a similar climate, or with similar soils or with similar physiography. Transfer of experience on the basis of these similarities will necessarily require some adjustments taking into account the other land characteristics.

Similarly, the land limitations can be rated as separate parameters, but the assessment of their combined effect on land potentialities will require some judgement and interpretation. On this aspect some guidelines can be given by indicating the "maximum land classes" in relation to each limitation and each degree of limitation.

The influence of a given limitation varies with the type of land use considered. Standard ratings of limitations are indicated in "The Manual of Land Classification for Irrigation." For other uses they are defined by comparison to those of irrigation. The cumulative effect of limitations should be estimated and the land class indicated accordingly.

The potentiality classes, indicated for the existing limitations and factors, are *present potentiality classes* but when these limitations are eliminated, by land improvement and/or land conservation works, the potentialities of land units will change and other potentiality classes can be expected. These classes, after land improvements, are called *future potentiality classes*.

The present trend of development in Iran requires an evaluation of the investment needed for improving each potential land use. It is therefore necessary to make the land evaluation under two sets of assessments:

a) to evaluate the present potential with improved management practices, but without investments for land improvement or land conservation works.

b) to evaluate the potential *after initial input*, i. e. with improved management practices and the removal, by capital investment, of some land limitations and degradation hazards by drainage, leveling, salt leaching, etc.

For this purpose, four levels of initial capital investment are defined: low, moderate, high and very high.

The other principle of the method of land resource inventory in Iran is that the data should be presented in a simple way, easily understood by the nonspecialists. It is also important that the maps should be easy to read with a limited number of mapping units. Land resource maps should therefore summarize, synthesize and simplify all information obtained by different studies, on soil, geology/geomorphology, climate, vegetation and land use, etc.

APPLICATION OF THE METHOD

Different types of land evaluation studies are carried out in Iran:

Land Evaluation for Regional Planning

* Regional land resources and potentialities of large regions of high agricultural potential, (humid areas, Caspian Zone, scale 1:250,000) until now covered 3.27 million hectares.

* Regional land resources and capabilities of large regions of low to moderate potential, arid and semi-arid areas (Central Province, Northwest Iran, etc., scale 1:100,000 to 1:1,100,000), until now covered 26 million hectares.

Land Evaluation for Specific Development Projects

* Land resources and potentialities of limited areas, on a scale of 1:20,000 to 1:50,000, for instance, for soil conservation purposes.

* For irrigation projects, on a scale of 1:20,000

* For forestry development on a scale of 1:20,000 to 1:50,000

Local and Detailed Land Evaluation (Site Evaluation)

To make rapid land assessment on requests for land use recommendations on the basis of field observations and laboratory data on soil and water samples, for instance in private farms, experimental stations.

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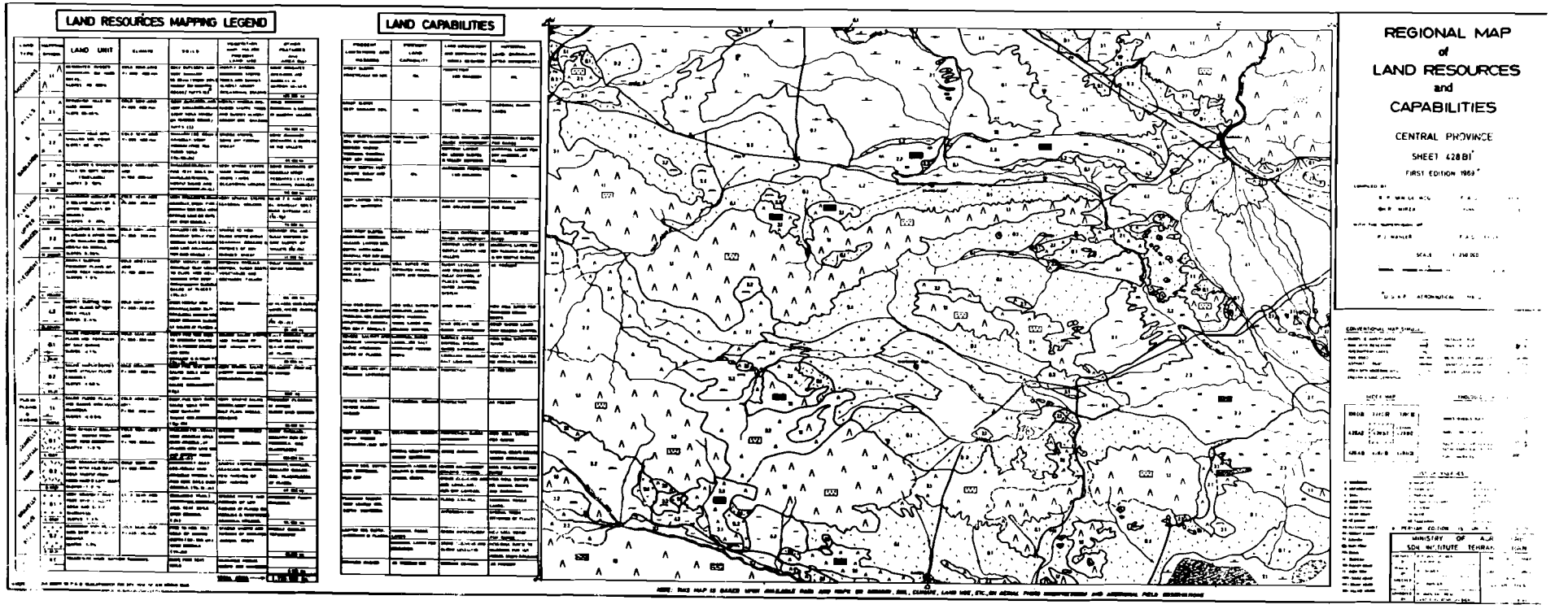

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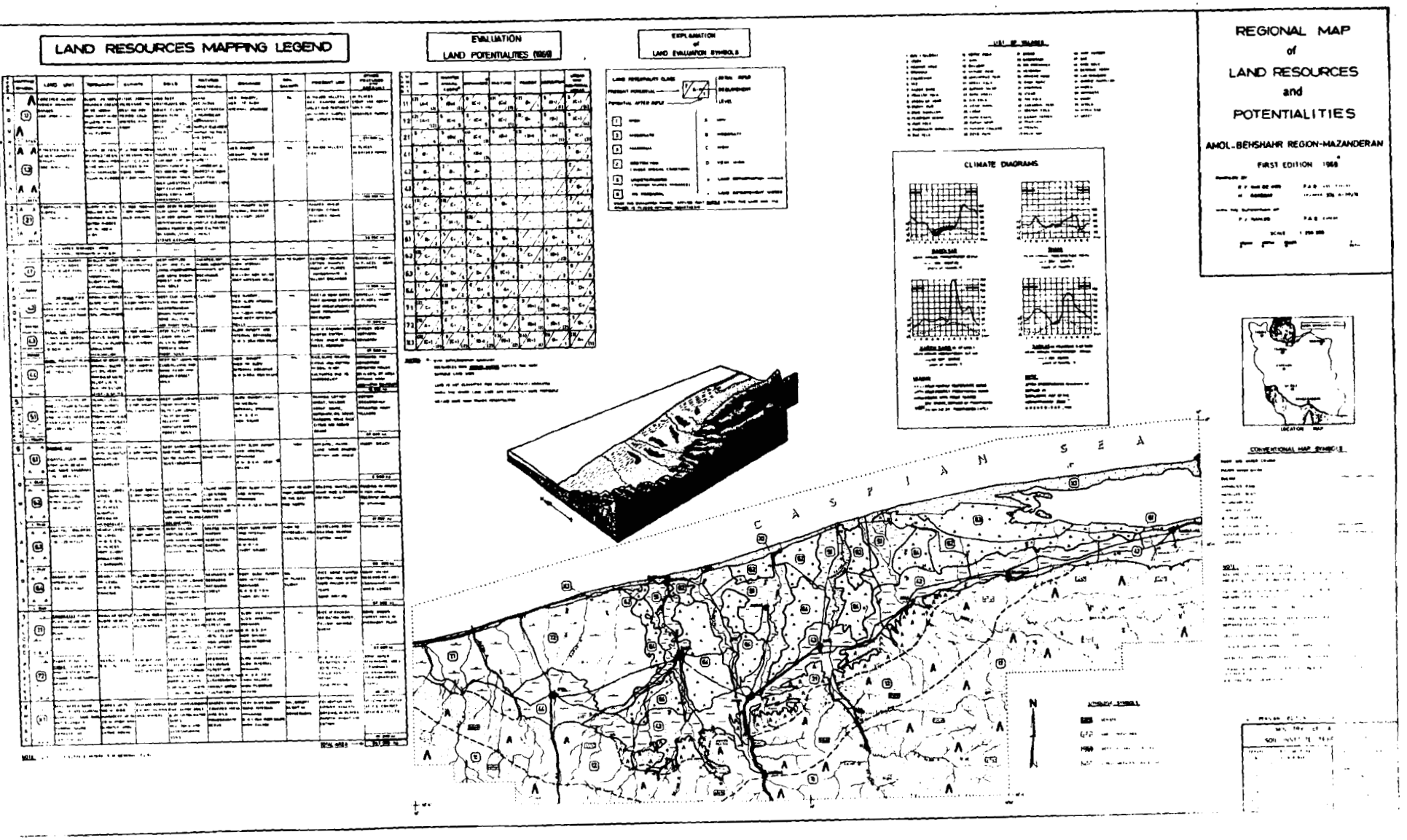

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CONCLUSIONS AND RECOMMENDATIONS

1) Further studies will be needed for evaluation of economic aspects or to extrapolate the results obtained in some areas to other areas:

   Quantitative land evaluation: taking into account input and output of different crops in croplands, with consideration of economic studies and marketing, level of investments for irrigation projects, change in cropping pattern of an area. This kind of study has started recently in Iran.

   Standards for specification of land classes: to provide a more precise and objective basis for the evaluation of land potentialities.

2) Further work has to be implemented in order to extrapolate results of trials and experiments to wider areas on the basis of soil survey and land resource surveys.

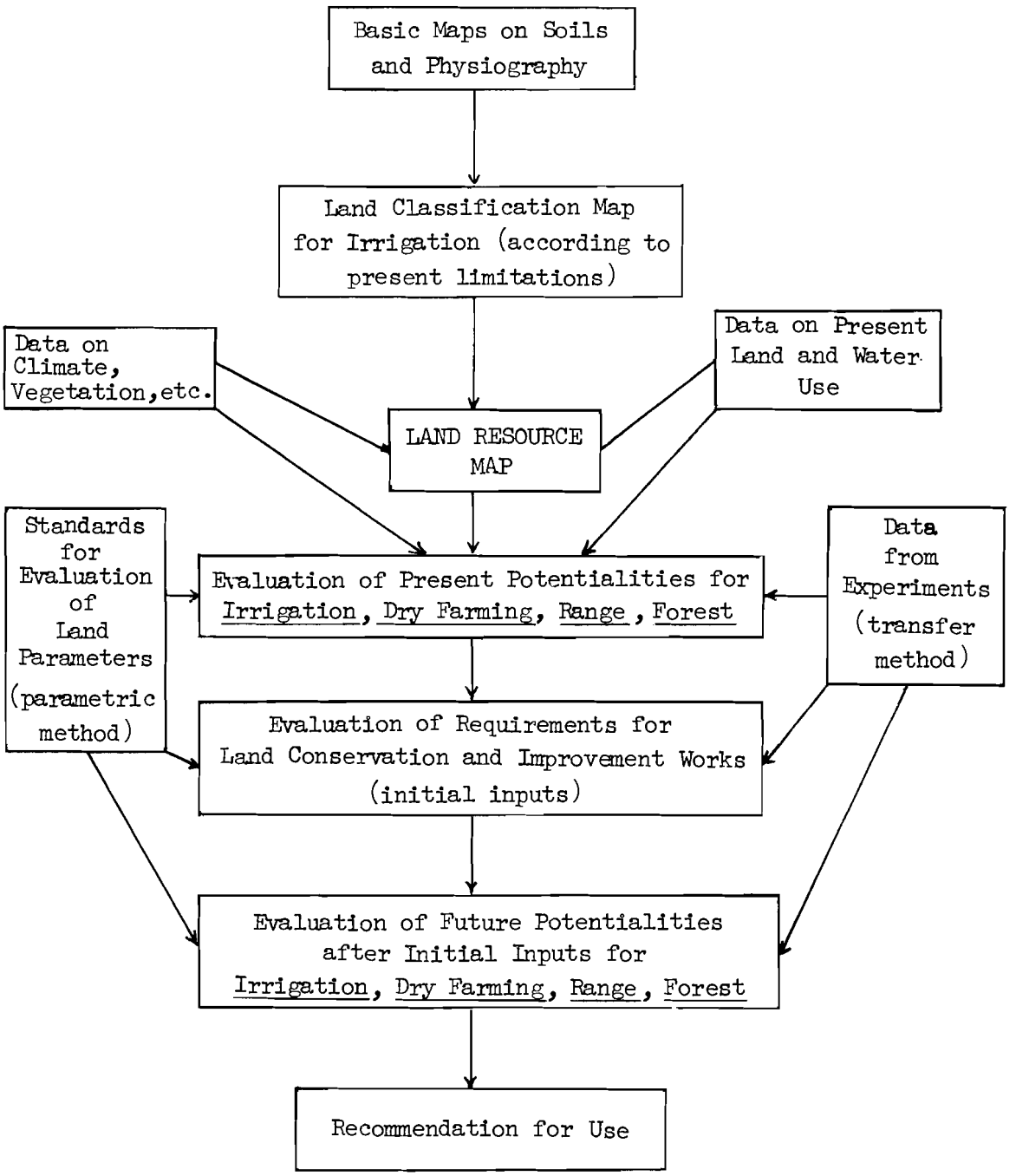
3) As the potentialities or capabilities of lands for different uses are indicated by land resource mapping, it is recommended that the planners use these kinds of maps to select more potential areas for any possible use in project areas, to avoid misuse of the land.

4) As a regional land resources map shows all possibilities of proper land use in different land units of the surveyed area, with indication of present limitations and improvement works to achieve the future land potentialities for different uses, it is recommended that the Plan Organization should refer to the regional land resources maps, before starting any new activity in any area. This saves time and money, in any development project, by indicating the suitable areas for uses, land improvement requirements, other studies needed for projects in useful land units and proper land use of any area.

5) Many times different agricultural organizations ask to survey the soils of some areas and, after spending time and money, learn that the area is not suitable for the considered use. As the land resource studies are carried out on a larger scale and in a short time, in comparison with the soil survey, and indicate any possible use of different land units, it is recommended that any agricultural, forestry, range, seed and plant improvement or other organization make a request for land evaluation of their terrain.

APPENDIX

"By Stages" Integration and Evaluation Method Applicable to Iran



WATER REQUIREMENTS OF VARIOUS CROPS IN ARID AND SEMI-ARID ZONES OF TURKEY

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ARID AND SEMI-ARID REGIONS AND IMPORTANCE OF IRRIGATION

Vast areas of the world bordering on the subtropical belt receive practically all of their precipitation in one season of the year. These areas lie somewhere between 30° and 40° N and S latitude and the extensive drylands of the world generally lie between the latitudes of 10° and 35° S.

The typical climatic pattern of these areas is a dry summer and rainy winter, which is the reverse of the usual agricultural need. This causes what we call "agricultural drought," a condition of rainfall deficiency with respect to crop production. Drought so defined is somewhat different from the hydrologists' definition, which is the exceeding of outlow to inflow in the water balance of an area. The incidence of drought, with more agronomic character, for a particular crop is the number of days during its growing season on which soil moisture exceeds a value which is known to impede the crop growth appreciably.

Irrigation is man's method of partially overcoming deficiencies in the natural pattern of precipitation. These deficiencies, as stated above, may stem from lack of precipitation, unfavourable seasonal dis-

tribution for natural plant growth, or introduction of plant species which can take advantage of favourable soil or temperature conditions, but require more water than naturally provided.

EVAPOTRANSPIRATION AND IRRIGATION PROJECT PLANNING AND MANAGEMENT

The success of an irrigation project depends in large measure on how well the water supply meets crop requirements, both as to the total and the peak requirements. The basis of an irrigation project is at the plant-soil-atmosphere environment. Water is delivered to this community from the water supply source, but the project planning starts from the reverse, from plant to source. Therefore the studies of water requirements begin with an estimate of the evapotranspiration of the crops grown or those that will be grown in the project area.

The project planners are more familiar with the term "irrigation, water requirement," where evapotranspiration is only one of the components.

The irrigation water requirement equation might be written as follows:

$$IR = \frac{100\ (ET + LR - R_e - \Delta S - R_{ss})}{E_a} + L_c$$

where

IR = Irrigation water requirement

ET = Evapotranspiration

LR = Leaching requirement

R_e = Effective precipitation

ΔS = Stored soil moisture

R_{ss} = Groundwater contribution

E_a = Field application efficiency

L_c = Conveyance and operation losses

In arid and semi-arid climates the main component of the IR equation is evapotranspiration (ET). How large an area of a crop or

crops a water source of known volume can supply can be determined only by knowing at least the monthly or peak evapotranspiration values.

The planning of irrigation projects, the appointment of water supplies, and the conservation and efficient utilization of the whole water resources all rely in some degree on estimates of evapotranspiration.

Crop yields are known to be highly dependent upon the ready availability of water at certain stages of growth. The knowledge of the time distribution of evapotranspiration is very important in irrigation practice and project management.

Evapotranspiration is the best index of when and how much water will need to be supplied by irrigation for good crop production.

The term "evapotranspiration" as used here is synonymous with "consumptive use of water." It is generally defined as the sum of the volume of water used by vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from the adjacent soil, or intercepted precipitation in the area in any specific time, divided by the given area.

Many factors operate singly or in combination to influence the amounts of water consumed by plants. The effects of these factors are not necessarily constant, but they fluctuate from year to year as well as from place to place.

Evapotranspiration is influenced by temperature, irrigation practices, length of growing season, precipitation and other factors. The volume of water transpired by plants depends in part on the water at their disposal, and also on temperature and humidity of the air, wind movement, intensity of sunlight, the stage of development of the plant, its foliage and the nature of its leaf.

It is evident that evapotranspiration is highly dependent on climate. Scientists and irrigation engineers have developed or proposed many models for estimating or predicting potential evapotranspiration from climatological data.

IRRIGATION RESEARCH IN TURKEY

Location: Roughly, Turkey resembles a rectangle, its long sides extending in the east-west direction. It is located between 36° and 42° N latitudes, 26° and 45° E longitudes.

Climate: In general terms Turkey is within the subtropical climate zone. But due to geographical formations, especially the mountains that follow the coastline, the milder subtropical climate is replaced

by a more severe continental character. Without these formations Turkey would have an average of 4° to 8° C for the coldest months, and 22° to 25° C for the warmest months. This would leave us with about 20° C difference in extreme temperatures. But the existing variations are around 15° to 20° C on the coast and 25° to 35° C inland.

Annual rainfall varies between a minimum of 200 mm. in Central Anatolia and a maximum of 2,500 mm. on the eastern Black Sea coast. The Aegean and Mediterranean coasts get about 600-800 mm., and the Black Sea coast 1,000-1,200 mm.

The distribution of rainfall varies a lot between these regions. The Black Sea coast receives a more uniform annual distribution with winter having the peak months. The Mediterranean rainfall takes place in the winter months, leaving a dry summer. Central Anatolian distribution varies between winter and spring, again with a dry summer.

Land and Water Resources: Present land use in Turkey is summarized in Table 1.

Table 1. PRESENT LAND USE IN TURKEY

Type of Use	Area		(1,000 hectares)
Agricultural land			23,539
Cultivated land		21,200	
Cropped	14,170		
Fallow	7,030		
Orchard, vineyard		2,339	
Pasture, range			30,839
Forest			10,584
Unproductive land			13,096
TOTAL:			78,058

The effect of irrigation on crop yields in various parts of Turkey is outlined in Table 2.

Table 2. YIELDS OF DIFFERENT CROPS

UNDER DRY AND IRRIGATED CONDITIONS

Crop	Fertilizer Application	Yield (kgs./dec.)		Location
		Nonirrigated	Irrigated	
Sugar beets	No	830	1,870	Eskişehir
Sugar beets	Yes	1,960	4,100	Eskişehir
Wheat	No	130	215	Eskişehir
Flax	No	21	144	Eskişehir
Chickpea	No	73	190	Eskişehir
Sunflower	No	60	270	Eskişehir
Cotton	No	100	155	Tarsus (Mersin)
Cotton	Yes	110	205	Tarsus (Mersin)
Peanuts	No	190	300	Tarsus (Mersin)
Cotton	No	70	225	Menemen (İzmir)
Sesame	No	75	125	Menemen (İzmir)
Corn	No	135	250	Menemen (İzmir)
Wheat	No	135	210	Çumra (Konya)
Sugar beets	Yes	960	2,660	Çumra (Konya)
Corn	Yes	540	785	Samsun
Soybeans	Yes	160	350	Samsun

The total area of plains in the major watersheds of Turkey is 16.7 million hectares, out of which 12.5 million hectares are believed to be irrigable from the standpoint of soil character.

The annual surface runoff potential is estimated to be 167 x 10^9 $m.^3$. About 155 x 10^9 $m.^3$ of this can be controlled.

The total amount of water that can be withdrawn annually from underground reservoirs is estimated to be 4 x 10^9 $m.^3$.

With these sources the annual total water potential of Turkey is approximately 170 x 10^9 $m.^3$.

Due to the geographical and seasonal distribution of precipitation approximately 90 percent of the agricultural lands do not receive adequate rainfall during the vegetation period of crops.

The potential volume of water given above in the first approximation seems to be adequate to supply 12.5 million hectares. But in many cases the individual water supplies do not have irrigable land around them or some irrigable lands are not close to potential water supplies.

Considering these water supply-land relations it is believed that about 8.5 million hectares of the agricultural lands can be irrigated.

Reconnaissance soil surveys conducted in the watersheds indicate approximately 6 million hectares could economically be provided with irrigation and so far 1.6 million hectares of the land are supplied with irrigation water.

By the end of 1970 the total area under irrigation was estimated at 1,664,000 hectares, of which 1 million hectares obtained water from systems constructed by individual farmers, local organizations and private enterprise. The remaining 664,000 hectares are provided with water by means of irrigation systems constructed by the state.

Research on Irrigation

The first modern irrigation system was constructed in 1908 on the Konya-Çumra plain to irrigate 53,360 hectares. Another major irrigation system was opened for operation in 1944 on the Adana-Tarsus plain to irrigate 17,000 hectares.

A few years after each system started to operate a number of irrigation and drainage problems came into existence.

The State Hydraulic Works (DSI) and the Ministry of Agriculture, later the Soil Conservation and Farm Irrigation General Directorate (TOPRAKSU), cooperated in establishing organizations for irrigation research.

Now TOPRAKSU has eight stations around the country with six of them having data on irrigation methods, water requirements and consumptive use (CU) for various crops.

Evaluation of the Data

The research stations dealing with irrigation were established on the dates and in the locations listed in Table 3.

Table 3. LOCATIONS OF THE RESEARCH STATIONS DOING IRRIGATION RESEARCH IN TURKEY

No.	Year	Region	LOCATION				
			Province	County	Latitude	Longitude	Elevation (in m.)
1	1948	South Mediterranean	Mersin	Tarsus	36°55'N	34°55'E	11.6
2	1949	Central Anatolia	Konya	Çumra	37°45'N	32°41'E	1,012
3	1949	West Aegean	İzmir	Menemen	38°35'N	27°05'E	10.3
4	1952	Central West Anatolia	Eskişehir		30°31'N	39°46'E	781
5	1952	Central Anatolia	Ankara		39°53'N	32°45'E	924.3
6	1963	Central East Anatolia	Tokat		40°18'N	36°34'E	585
7	1969	North Black Sea	Samsun		41°17'N	26°20'E	44

This final equation is used to estimate cumulative evapotranspiration curves from which periodical evapotranspiration values are obtained.

The first six have so far carried out experiments on irrigation water requirements and consumptive use for major crops of their area. Most of these data were evaluated on the basis of irrigation water requirements, time of irrigation, and seasonal CU.

Other people have evaluated the original data for monthly CU values for specific crops.

In 1969 my colleagues and I at Ankara Central TOPRAKSU Research Institute started an investigation of these stations by compiling raw data from their reports and files and by evaluating monthly CU values for the crops of their area.

Some of these data are now evaluated and presented here. Now we are in the process of creating models to correlate these data with climatic factors.

In the evaluation of the basic data, "water budget" or "water balance" equation of the hydrologist was used. This method is also referred to as the "moisture depletion method" by irrigation scientists.

Considering the field plots where these experiments were carried out the water balance equation can be solved as follows:

The Water Balance Equation

Inflow - Outflow = Change in storage.

Inflow: $R + I + R_s + R_{ss}$.

Outflow: $E + O_s + O_{ss}$.

Change in Storage: $\Delta S_{grw} + \Delta S_{sm}$.

E = Evapotranspiration. The equation will be solved for that component.

O_s = Surface outflow from the area. $O_s = 0$ accepted by not letting water out of field plots.

O_{ss} = Subsurface outflow from the area. Accounts for the amount of water flowing out as well as percolating below root zone. $O_{ss} = 0$ and $P=C$.

$\pm\Delta S_{grw}$ = Change in groundwater storage. For the experiment sites low water table areas are usually selected. Since it is assumed that groundwater table is at a safe depth we are not interested in ΔS_{grw}. It is possible to determine:

$$\Delta S_{grw} = p\Delta h$$

where p = effective porosity, h = change of elevation observed in water table.

$\pm\Delta S_{sm}$ = Change in soil moisture storage. This component is rather easy to determine by taking frequent readings or samplings of the soil profile.

For the unsaturated zone, the zone above water table or root zone

$$P = C$$

can be considered equal. Where:

P = Vertical flow downward from unsaturated zone to saturated zone

C = Vertical flow upward from saturated zone to unsaturated zone.

With these assumptions, water balance equation for the unsaturated zone simplifies to:

$$(R + I) - (E) = \pm\Delta S$$

solving for E

$$E = (R + I) \pm \Delta S.$$

Substituting,

$$(R + I + R_s + R_{ss}) - (E + O_s + O_{ss}) = \Delta S_{grw} + \Delta S_{sm} .$$

R = Precipitation. A measurable component.

I = Irrigation water. A measurable component

R_s = Surface inflow from joining areas. A measurable component. But field plots surrounded by dikes prevent R_s. Therefore $R_s = 0$.

R_{ss} = Subsurface inflow from joining areas. Rather difficult to measure quantitatively. In field experiments this is assumed $R_{ss} = 0$.

Experimental Results

The hydrological water balance equation (equation 2) was simplified with the assumption made in this paper (equation 5) and was used to estimate monthly evapotranspiration values for various crops for various locations in Turkey.

The monthly ET values of crops is an important component for the hydrologists' water balance equation and an essential datum for irrigation engineers.

The experimental results are presented in Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12 for wheat, alfalfa, sugar beets, cotton, potatoes, beans, melon, tomatoes, and sesame respectively.

The experimental values for a specific crop at one location are given for individual years instead of an average of these years. We feel it is safer to give individual years instead of averages for the irrigation engineers' or hydrologists' use.

Table 4. MONTHLY ET VALUES FOR WHEAT AT ANKARA AND ESKİŞEHİR

Months	Ankara				Eskişehir		
	1967-68	1968-69	1969-70	1969-70	1963-64	1964-65	1965-66
October	37.0	-	12.0 (8)	12.0 (8)	7.0 (27)	22.0 (25)	25.0 (27)
November	37.0	33.0	46.0	50.0	6.0	26.0	25.0
December	39.0	60.8	40.0	51.0	6.0	4.0	6.2
January	39.0	57.2	49.0	50.0	44.0	6.0	72.8
February	35.0	51.0	80.5	46.0	41.0	3.0	73.0
March	39.0	41.0	46.5	51.0	43.0	110.0	10.0
April	126.0	55.0	184.0	186.3	104.0	130.0	10.0
May	128.0	152.0	193.0	83.7	139.0	136.0	151.0
June	68.0	97.0	51.0	45.0	139.0	133.0	159.0
July	14.3 (16)	28.0 (27)	12.8 (14)	11.9 (14)	76.0 (4)	15.8 (22)	87.1
TOTAL ET (mm.)	562.3	575.0	714.8	586.9	605.0	585.8	619.1
Days	289	279	264	264	283	289	287

Number in parentheses indicate the number of days of the month the ET value represents. Months with no number in parentheses represent the total days of these months.

Table 5. MONTHLY ET VALUES FOR ALFALFA FOR ANKARA, ESKİŞEHİR, MENEMEN AND KONYA

Months	Ankara				Eskişehir				Menemen	Konya	
	1968	1969	1970	1970	1961	1962	1963	1964	1963	1966	1968
March			22.0 (18)	26.0 (8)	15.0 (11)	52.0 (26)	63.0 (26)	8.0 (11)			28.1
April	78.0 (19)	12.0 (5)	80.0	84.0	50.0	87.0	72.0	74.0	96.0	72.2	81.0
May	70.0	117.0	146.0	98.0	190.0	185.8	90.0	188.0	171.0	50.5	100.5
June	148.0	182.0	195.0	229.0	210.0	234.2	212.0	205.0	222.0	186.4	188.8
July	158.0	171.0	339.0	248.0	329.0	147.1	261.0	195.0	246.0	102.9	198.8
August	140.0	143.0	222.0	234.0	271.0	290.9	168.0	140.0	108.0	74.5	331.9
September	98.0	77.0	39.2 (28)	95.0	56.0 (12)	35.0 (4)	91.5 (16)	102.6 (15)	152.4	93.9	132.1
October	16.8 (11)	23.0 (10)		182.7 (15)					292.8		17.8
TOTAL ET (mm.)	708.8	725.0	1,043.2	1,196.7	1,121.0	1,032.0	957.5	912.6	1,288.2	580.4	1,079.0
Days	183	168	199	206	176	183	195	179	214	183	245

Table 6. MONTHLY ET VALUES FOR SUGAR BEETS AT ANKARA, ESKİŞEHİR, TOKAT AND KONYA

Months	Ankara				Eskişehir			Tokat				Konya	
	1968	1969	1970	1970	1959	1960	1961	1967	1968	1969	1970	1965	1968
March										26.0 (15)	2.0 (4)		
April	44.0 (19)		50.0 (25)		3.0	45.0 (15)	84.0 (28)	30.0 (20)	34.0 (28)	54.0	56.0	33.6	27.4
May	63.0	78.0 (26)	89.0	5.0 (21)	8.0	84.0	97.0	138.0	244.0	90.0	80.0	124.2	53.5
June	69.0	175.0	160.0	130.0	115.0	125.0	91.0	266.0	357.0	220.0	205.0	100.2	126.2
July	126.0	185.0	124.0	253.0	454.0	276.0	308.0	357.4	493.0	280.0	216.0	157.2	199.0
August	175.0	189.0	144.0	298.0	240.0	267.0	295.0	338.0	250.0	153.0	169.0	179.0	251.0
September	194.0	141.0	59.2 (17)	207.0	173.0	125.0 (20)	73.0 (11)	125.9 (28)		15.3 (5)	105.0	85.0	83.9
October		63.6 (15)		92.2 (19)	10.5 (1)						18.6 (7)		15.3
TOTAL ET (mm.)	671.0	831.6	262.2	985.2	1,003.5	922.0	948.0	1,255.3	1,378.0	838.3	851.6	679.2	756.3
Days	172	163	165	162	184	158	162	171	149	173	194	183	214

Table 7. MONTHLY ET VALUES FOR COTTON AT TARSUS AND VARIOUS LOCATIONS IN THE AEGEAN REGION

Months	Tarsus (Acala)		Tarsus (Acala)		Tarsus (Coker)	Menemen (Acala)	Manisa (Acala)		Aydın (Coker)	Denizli (Coker)
	1959	1960	1961	1962	1962	1962	1962	1963	1966	1966
April	25.0 (28)	28.0 (24)	22.0 (21)	68.7 (24)	42.0 (22)					10.0 (4)
May	49.0	107.0	108.0	55.3	52.0	52.2 (21)	37.0 (29)	85.0		98.3
June	167.8	114.1	144.0	180.0	144.8	135.8	54.0	107.0	115.4	121.7
July	187.2	153.0	173.0	192.0	184.1	260.0	327.4	190.0	239.6	234.0
August	66.0	60.0	56.0	70.1 (20)	41.3 (21)	253.5	203.6	230.0	200.6	336.0
September	29.2 (18)	7.0	22.1 (16)			93.0	87.0	75.0	81.4	75.0
October		1.1 (7)				180.0	89.0	69.0	78.0	26.0
November						2.4 (1)				
TOTAL ET (mm.)	524.2	470.2	525.1	566.1	424.2	976.9	798.0	756.0	705.0	901.0
Days	169	184	160	136	135	175	182	184	153	188

Table 8. MONTHLY ET VALUES FOR POTATOES AT ANKARA

Months	1968	1969	1970
April			15.0 (7)
May	57.0	7.0 (6)	65.0
June	140.0	131.0	237.0
July	142.0	174.0	214.0
August	87.0	128.0	231.0
September	32.0	78.0	155.7 (15)
October	11.3 (11)	4.5 (3)	
TOTAL ET (mm.)	469.3	522.5	917.7
Days	164	131	145

Table 9. MONTHLY ET VALUES FOR BEANS AT ANKARA, TARSUS AND KONYA

Months	Ankara		Tarsus	Konya	
	1969	1970	1962	1965	1968
May	12.0 (6)	86.0	100.0	78.3	46.9
June	90.0	129.0	230.0	174.0	95.7
July	109.0	212.0	94.0 (12)	111.7	130.2
August	114.0	121.0		41.8	137.1
September	79.4 (23)	17.1 (15)		30.3	17.0
October					13.3
TOTAL ET (mm.)	404.4	565.1	424.0	436.1	440.2
Days	121	146	73	153	184

Table 10. MONTHLY ET VALUES FOR MELON (HONEYDEW) AT ANKARA AND KONYA

Months	Ankara	Konya
	1968	1963
May	50.0	41.0
June	55.0	48.8
July	99.0	134.2
August	79.0	32.1
September	52.0	9.4
TOTAL ET (mm.)	335.0	265.5
Days	153	153

Table 11. MONTHLY ET VALUES FOR TOMATOES AT TARSUS AND KONYA

Months	Tarsus			Konya	
	1961	1962	1963	1966	1968
April	55.0 (7)	126.6 (29)			
May	190.0	107.4	123.0 (19)	31.0	31.7
June	206.4	153.0	152.0	115.6	148.9
July	136.6	160.0	137.0	130.0	164.3
August	38.6 (5)	88.1	82.0 (22)	99.4	227.9
September				42.7	7.9
October					6.2
TOTAL ET (mm.)	626.6	635.1	494.0	418.7	586.9
Days	104	152	102	153	184

Table 12. MONTHLY ET VALUES FOR SESAME AT MENEMEN

Months	1958	1961
May	17.4 (20)	19.0 (19)
June	82.2	13.2
July	168.2	173.8
August	134.3	182.0
September		30.3 (7)
TOTAL ET (mm.)	402.1	418.3
Days	112	118

To further emphasize the natural deficiency of water at each location for each one of the crops, evapotranspiration (ET), precipitation (P), irrigation water (I) amounts are given in Tables 13, 14, 15, 16, 17 and 18 for Ankara, Eskişehir, the Aegean region, Konya, Tarsus and Tokat respectively.

By comparing the seasonal ET and R values in these tables, one can decide that without irrigation most crops listed in these tables, maybe with the exception of wheat, could not possibly be grown profitably.

For most of these locations the total annual R values are much higher than the seasonal R values given here. Especially the coastal areas have pretty wet spring and winter seasons. It becomes evident, therefore, that the hydrologists' definition of drought as the exceeding of outflow to inflow during the calendar or hydrological year does not define the natural moisture supply or deficiency of most of the crops in Turkey.

Table 13. SEASONAL ET, R AND I VALUES FOR WHEAT, ALFALFA, SUGAR BEETS, POTATOES, BEANS AND MELON FOR ANKARA

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Wheat	1967-68	562.3	401.7	117.2	428.0
	1968-69	575.0	441.2	85.7	496.4
	1969-70	714.8	312.0	356.9	313.1
	1969-70	586.9	322.0	196.8	313.1
Alfalfa	1968	708.8	180.4	492.8	532.2
	1969	725.0	150.3	606.9	443.2
	1970	1,043.2	96.7	837.1	342.2
	1970	1,196.7	102.4	956.7	342.2
Sugar beets	1968	671.0	175.6	539.5	532.2
	1969	831.6	95.8	688.0	443.2
	1970	626.2	80.3	525.6	342.2
	1970	985.2	48.0	915.8	342.2
Potatoes	1968	469.3	135.5	295.5	532.2
	1969	522.5	31.1	448.1	443.2
	1970	917.7	54.8	780.0	342.2
Beans (seed)	1969	404.4	30.1	283.6	443.2
	1970	565.1	54.8	445.4	342.2
Melon	1968	335.0	127.4	169.6	532.2

Seasonal R values are for the period of seeding--harvest or late frost--early for that year for that specific crop.

Annual R values for wheat are October through July of the next year, and January through December for other crops.

TABLE 14. SEASONAL ET, R AND I VALUES FOR WHEAT, ALFALFA AND SUGAR BEETS FOR ESKİŞEHİR

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Wheat	1963-64	605.0	303.3	290.0	354.7
	1964-65	585.8	346.5	150.0	365.7
	1965-66	619.1	388.2	150.0	416.5
Alfalfa	1961	1,121.3	225.4	878.0	341.0
	1962	1,032.0	148.2	828.0	346.9
	1963	957.5	217.4	516.0	482.6
	1964	912.6	145.0	674.0	294.3
Sugar beets	1959	1,003.5	175.1	783.0	354.6
	1960	922.0	145.5	601.0	463.6
	1961	948.0	208.2	679.0	341.0

Table 15. SEASONAL ET, R AND I VALUES FOR COTTON, ALFALFA AND SESAME FOR VARIOUS PARTS OF THE AEGEAN REGION

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Cotton (Menemen)	1962	976.9	259.4	268.1	826.5
Cotton (Manisa)	1962	798.0	90.6	378.9	1,044.8
	1963	756.0	191.3	257.0	703.4
Cotton (Aydın)	1966	715.0	43.4	380.0	1,233.9
Cotton (Denizli)	1966	901.0	125.2	440.0	599.8
Alfalfa	1963	1,288.2	415.0	645.0	487.9
Sesame	1958	402.1			
	1961	418.3		289.0	

Table 16. SEASONAL ET, R AND I VALUES FOR ALFALFA, SUGAR BEETS, BEANS, MELON AND TOMATOES FOR KONYA

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Alfalfa	1966 1968	580.4 1,079.0	105.5 106.6	278.6 980.8	263.9 397.8
Sugar beets	1965 1968	679.2 756.3	51.2 80.9	589.0 668.3	234.0 397.8
Beans	1966 1968	436.1 440.2	94.0 69.3	143.1 396.3	263.9 397.8
Melon	1963	265.5	133.8	100.0	371.8
Tomatoes	1966 1968	418.7 586.9	94.0 69.3	209.2 530.4	263.9 397.8

Table 17. SEASONAL ET, R AND I VALUES FOR COTTON, BEANS AND TOMATOES FOR TARSUS

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Cotton	1959 1960 1961 1962 1962	524.2 470.2 525.1 566.1 464.2	77.6 73.4 46.6 47.8 48.1	320.0 300.0 375.0 375.0 300.0	575.0 443.4 916.0 614.9 614.9
Beans (green)	1962	424.0	20.4	409.3	614.9
Tomatoes	1961 1962 1963	626.6 635.1 494.0	28.7 65.6 70.8	323.1 553.5 364.0	916.0 614.9 647.7

Table 18. SEASONAL ET, R AND I VALUES FOR SUGAR BEETS FOR TOKAT

Crop	Year	Seasonal values (mm.)			Annual R (mm.)
		ET	R	I	
Sugar beets	1967	1,255.3	152.7	1,011.6	498.5
	1968	1,378.0	147.3	1,136.3	474.9
	1969	838.3	138.8	609.8	374.0
	1970	851.6	124.6	684.9	424.0

POSSIBILITIES OF SUPPLY AND PROPER USE OF WATER IN THE GARMSAR AREA

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BACKGROUND

Since Iran is located in an almost arid zone, with an insufficient rate of precipitation to face crop needs, irrigation is essential.

Possibilities of a water supply from different sources and strictly controlled use of such water in a proper use condition are vital. This report defines the results obtained from studies that have been carried out in the Garmsar area with the cooperation of the Food and Agriculture Organization of the United Nations.

Location and Extent

The Garmsar area is an existing farming district, about 120 km. southeast of Tehran between 35.13°N latitude and 52.22°E longitude. It

lies at the foot of the Alborz Mountains. It covers part of the alluvial fan, which has an area of about 50,000 hectares. Due to the shortage of water only a part of this area can be irrigated. The southern part of the area merges into the great salt desert of central Iran.

Climate

The climate is continental, semi-arid to arid, with low rainfall and humidity. The summers are dry and hot, and the winters are cold. Most of the rain and snow falls in the high northern slopes and very little manages to reach the plain to the south.

Temperature

AVERAGE MONTHLY TEMPERATURE IN C°

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
4	7.1	11.2	17	23	26	30.6	28.8	25	10	11.1	5.2

The maximum air temperature during the period was 42.7 C°(July) and the minimum was 14.5 C°(Jan.). The maximum amount of precipitation falls in the winter and spring months. The mean monthly rainfall is as follows:

MEAN MONTHLY RAINFALL IN MM.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
23.6	19.3	17.3	9.7	6.8	0	0	0	0.5	5.5	5.7	11
Total: 99.4											

MEAN MONTHLY AIR HUMIDITY %

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
67.8	59.8	51	49.8	42	37.9	36.1	34.8	40	44.8	58.1	69.6

Agriculture suffers from the wind, which dries up the soil in summer. Northern, northeastern and southwestern winds predominate.

AVERAGE MONTHLY WIND VELOCITIES IN M./SEC.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0.98	1.23	1.6	1.5	1.38	1.37	1.45	1.32	0.97	0.97	0.93	0.93

AVERAGE MONTHLY EVAPORATION IN MM.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
58	85.8	171.1	267	384	440	514	466	344	242	115	61
Total Annual 3,147.9											

Average monthly evapotranspiration (ETP) was calculated from six different formulas and the results are as follows:

AVERAGE MONTHLY ETP IN MM.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Penman formula	15.9	27.2	66	93	143.8	175	187.3	166.6	123.4	71	24.5	14.3
Penman E.Pan A.	24.2	36	86.8	130.7	216.8	246.5	288	261	168.5	118	48.2	23.8
Cyclic formula	13	25.2	74.4	136.4	225	225.6	294.8	243.6	161.4	82.9	27.3	10.8
Day degree formula	26.6	42	74	109	151	180	203	193	158	128	67	34.8
Turc formula	22.3	46	80	113	181	235	242	227	172	115	54.9	30.3
Criddle-Blaney formula	70	78	110	140	178	104	218	201	162	133	90	72
Average	28	43	82	120	183	216	239	215	157	108	52	31

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Hydrology

The Hablehrud River and its tributaries are the main sources of water for irrigation purposes. Total available water of the Hablehrud on the Garmsar Plain cone is 247.7 m.c.m. (7.85 $m.^3$/sec.) in an average year.

In the wettest year 508.46 m.c.m. (16.12 $m.^3$/sec.) and in the driest year 118.74 m.c.m. (3.8 $m.^3$/sec.).

CLASSIFICATION OF THE HABLEHRUD RIVER WATER FOR IRRIGATION

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
C_3S_1	C_3S_1	C_3S_1	C_3S_1	C_3S_1	C_3S_1	C_3S_2	C_4S_2	C_4S_2	C_3S_1	C_3S_1	C_3S_1

The class C_3S_1 = high saline water and low sodium hazard. The water can be used on permeable soils if they are adequately leached, drained and irrigated, and very salt-tolerant crops are grown. During 8 months of the year the water is highly saline with low sodium hazard, and during 4 months the water is very high saline and with medium sodium danger. Electrical conductivity of the Hablehrud River is 1,700 micromhos (in flood free water).

Groundwater

The groundwater originates mainly through seepage from the river beds, irrigation canals and from the field percolation losses.

According to available data the annual groundwater extraction is 35 m.c.m.

The salinity of the groundwater is higher than that of the river water. Electrical conductivity of the water in deep wells varies between 1,500 - 5,000 micromhos and that in the shallow wells ranges between 2,000 - 20,000 micromhos.

On the basis of the hydrogeological surveys and studies it was found that the best quality of groundwater is in the northeast part of the area and new wells will be dug there for the combined use of surface and groundwater.

The groundwater balance in the Garmsar Plain in a normal year is as follows:

River water at diversion point: 260 x 10^6 $m.^3$

Inflow		Outflow	
Subsurface inflow (Hablehrud)	5m.c.m.	Well and qanat extraction	35m.c.m.
Flood recharge in fan head	8m.c.m.		
Recharge from main flood channel	3m.c.m.	Qanat water discharged across outflow boundary	5m.c.m.
Recharge from rainfall	2m.c.m.		
Seepage from canals	80m.c.m.	Subsurface outflow	99m.c.m.
Irrigation percolation	41m.c.m.		
	139×10^6 m.^{3}		139×10^6 m.^{3}

Soil Types and Land Classification Origin

The soil of the Garmsar Plain originated from the Hablehrud River and sediment from the foothills.

The calciferous sediments prevail, but in addition salty and gypsiferous material is also present.

Drainage Conditions

The soils included in the layout area are I and II class soils. The depth of the water table varies between 60 and 10 metres and the capillary fringe depth in the soils lies from 2 to 6 metres, and if proper irrigation is applied, the danger of the water table rising does not exist.

Land Classification

Land classes are as follows:

	Area (hectares)	%
Class I	2,794	6.3
Class II	18,748	42.7
Class III	4,094	9.3
Class IV	4,531	10.3
Class V	10,493	23.9
Class VI	3,314	7.5
	43,974	100

EXISTING IRRIGATION AND CANALS

Diversion of the water

Easy diversion (very wide river bed, little depth of water) of the river water and its steady flow has enabled the farmers since ancient times to use the river water for irrigation of their lands in the Garmsar Plain. The farmers cultivate the middle part of the fan, where the groundwater is deep, soil is permeable and of medium to fine texture.

Existing Canals

The method of diversion and the conveyence of the water have always been very primitive. The river is tapped at about 70 places and the water is then conveyed through 70 irrigation canals with a length of about 920 km. into the cultivated area. The canals are wide in relation to the carried discharge, and very winding. In general they are not engineered, and none of them has a regulating headworks. The abstraction of the water from the river bed is by means of gravel. All this results in heavy losses by evaporation and seepage and makes impossible any proper system of water control and distribution.

The Garmsar irrigation development has some limitations from its nature: very little rainfall (about 100 mm. per year), low river discharge in the summer, rather high salinity of the river and groundwater, and the occurrences of saline soils and alkaline patches scattered over the whole plain.

TOTAL IRRIGATION CANAL LOSSES IN THE PLAIN

Hydrological year	Available water in m. c. m.	Total loss m. c. m.	Losses in % of available water
1344-45	173.34	83.69	48.2
1345-46	151.10	74.86	49.5
1346-47	275.42	101.42	36.9
1341-42	118.74	71.17	60.0
1332-33	508.46	139.43	27.4

During an extremely dry year the total losses are 60 percent of available water, and in an average year 36.9 percent and in the wettest year 27.4 percent.

Existing Irrigated Agriculture

At present a variety of different crops is cultivated; however, wheat and barley occupy about 60 to 70 percent of the cultivated area, cotton 18 to 20 percent, melon 12 to 22 percent, gardens 6 to 9 percent, vegetables about 1.5 percent and alfalfa 1 to 3.5 percent. The cultivation methods are not as developed as they should be.

RESULTS OF TWO CROP SURVEYS
(in hectares)

	Barley	Wheat	Cotton	Melons	Gardens	Vegetables	Alfalfa	Total
Years 1958-63	1,440	8,100	3,700	4,360	1,700	250	700	20,250
Years 1966-67	546	6,555	2,243	1,413	682	-	84	11,523

Gross water use at the diversion per hectare was measured as 17,940 m^3./ha.

Improvement of Irrigated Area

At present agricultural production in the Garmsar Plain is low because of:

* Insufficient and irregular water supply for irrigation
* High salinity of the soils and water, both surface and ground
* High silt-clay content in the Hablehrud River water
* Unstable diversion of the river water
* Insufficient development of irrigation practices, including insufficient leaching
* Excessive water use in upstream river valleys and lack of good roads.

The irrigation development plan aims to improve land and water management in the following respects:

* Increase the available amount of water for irrigation purposes by reducing the canal seepage (lining of the canals), and replacing the old wells in a better location (more water and less saline)

* Introduce regular leaching for each crop, especially in the wet years, to reduce the soil salinity

* Reduce the amount of harmful silt and clay from floods by better control of the water use, (diversion weir, sand trap, gates and sluices at the head of the main canals)

* Fix the location of the irrigation canals, by lining and construction of the necessary structures

* Improve irrigation through even distribution of the available water in the necessary amount and time

* Improve irrigation practices

The irrigation development includes, besides the lined irrigation canal, the following:

* Diversion dam

* Improvement in flood protection

* Necessary local recharge system around the new well fields

* Groundwater development with 35 new deep wells

* Road network

* Reclamation of saline and alkaline soils.

THE AGRICULTURAL DEVELOPMENT PLAN

Agricultural development for the Garmsar region has been projected with a view to the long-term target of economical and social development through:

* Construction of a new irrigation system

* Improvement of farm techniques

* Introduction of adequate institutions to insure, assist and accelerate the development process.

With the proposed investment in the irrigation sector, together with other related investments and activities, it is expected that the cultivated area can be increased from 14,000 hectares to 18,000 hectares in an average year (20,000 hectares in a wet year, and 16,500 hectares in a dry year) and a higher production per unit of cultivated land can be achieved. This will result in higher productivity of the production factors, higher income and better contribution to national income. The introduction of new crops has not been recommended; instead it has been found more beneficial to change only the present cropping pattern by expansion of high income earning melons and expansion of fodder crops required for improvement of the livestock sector. Special emphasis has been given to the available water supply and the water demand of crops month by month, which leaves only a limited scope for changes and modifications. After full implementation of the project, the cropping pattern will consist of 45 percent wheat, 17 percent barley, 8 percent cotton, 22 percent melons, 3 percent alfalfa and 5 percent orchards in an average year.

According to present practices farmers will partially or totally cut out cotton cultivation (and also some barley) during a dry year and expand the cultivation of this crop during wet years.

Projections of future yields have been based on existing achievements and feasible growth rates on average farms. With favourable climatic, soil and market conditions, the highest benefits are expected from melon cultivation and orchards, if the present fruit trees are replaced by new ones and managed properly. The introduction of new orchard plantings requires availability of credits and special assistance of the extension service.

WATER DEVELOPMENT PLAN

Surface Water Available

The Hablehrud has the advantage of good natural regulation, and it delivers a well sustained discharge even in the late summer and fall. Both the long-term and the short-term fluctuations are relatively small, and these two facts make it very suitable for irrigation use with a minimum of regulation. On the other hand, the river is saline, with an average electrical conductivity value of about 1,700 micromhos/cm., and this has two effects:

1) Accumulation of salt in the plain has affected both the soil quality and the groundwater.

2) To grow reasonably satisfactory crops, the amount of irrigation water applied should be increased by about 27 percent above the normal, to provide leaching to wash the salts out of the surface soil.

Two favourable factors will aid this process:

1) The main problem is salinity, not alkalinity, and the salts are soluble, and can, therefore, be removed by leaching. However, scattered patches of alkalinity also occur, and may need chemical treatment.

2) The soil in general possesses good natural vertical drainage.

Salt Reduction Schemes

The main defect of the Hablehrud is its high salt content. About 55 percent of the salt in the Hablehrud enters below the Dalichai Junction, and 44 percent of it in seven tributaries, which contribute only 2.2 percent of the total water. After full and careful investigation, two types of schemes have been worked out for reducing the amount of salt entering the plain. The first type is aimed at collecting and disposing of the water from the seven most saline tributaries, and evacuating it to the desert.

The two methods that have been investigated are:

* Retention basin scheme

* Constant flow diversion scheme.

The capital expenditure for the first method is Rls. 45 million and the second is Rls. 67.2 million. Both methods should be capable of reducing the salt content by 30 percent.

The preliminary economic appraisal shows that the best way to use the better quality of water produced by these schemes is to increase the irrigable area (by about 1,000 hectares) rather than to apply more water to a smaller area.

Groundwater Available

In the Garmsar Plain large quantities of groundwater are available, and it would be physically possible to abstract about 100 m.c.m. per annum. However, in most parts of the area the groundwater is too saline to be suitable for irrigation, and it is mainly in the east, centre and northeast that usable water can be developed by deep wells at a reasonable depth. Therefore, it is clear that the groundwater should be used to only a limited extent to supplement the river flow.

Through the use of a suitable crop pattern it will be possible to reduce the use of groundwater to less than 10 percent of the irrigation demand, and even that will be drawn from deep wells (which give a better quality of water) and from the best parts of the area.

Recharge

With the limited amount of groundwater that is required, it is considered that only local artificial recharge measures near the new well fields are needed. Usable natural recharge will also take place through river subsurface flow, natural spreading of flood water over the wide gravel areas in the north, canal seepage, and irrigation percolation in the upper area.

FUTURE GROUND WATER BALANCE NORMAL YEAR
IN M. C. M.

Inflow		Outflow	
Subsurface river inflow	5	Abstraction from deep wells	18
Flood recharge in fan head	8	Abstraction from shallow wells	3
Recharge in main flood channels	3	Abstraction from qanats	4
Artificial recharge	5	Qanat water discharged across outflow boundary	5
Rainfall recharge	2	Subsurface outflow	90
Canal seepage	45		
Irrigation percolation	52		
	120		120

WATER SUPPLY INTEGRATION IN M. C. M.

Months	Mean Year 18,000 hectares				Dry Year 16,500 hectares				Wet Year 19,500 hectares			
	Demand at field	River water at field	Surplus	Pumping from wells	Demand at field	River water at field	Surplus	Pumping from wells	Demand at field	River water at field	Surplus	Pumping from wells
Mehr	10.8	11.8	1.0	-	10.8	8.6	-	2.2	10.8	11.4	0.6	-
Aban	14.8	17.1	2.3	-	14.8	13.8	-	1.0	14.8	16.4	1.6	-
Azar	12.2	15.0	2.8	-	12.2	12.6	0.4	-	12.2	12.2	-	-
Dey	12.9	14.4	1.5	-	12.9	12.4	-	0.5	12.9	10.6	-	2.3
Bahman	16.6	14.4	-	2.2	16.6	12.6	-	4.0	15.4	11.4	-	4.0
Esfand	20.5	17.8	-	2.7	20.5	16.6	-	3.9	21.7	19.4	-	2.3
Farvardin	22.5	18.5	-	4.0	21.9	19.1	-	2.8	23.1	26.1	3.0	-
Ordibehesht	20.8	17.3	-	3.5	18.8	15.6	-	3.2	22.8	25.4	2.6	-
Khordad	15.8	16.1	0.3	-	12.3	9.4	-	2.9	19.5	22.5	3.0	-
Tir	11.2	12.3	1.1	-	6.0	6.9	0.9	-	16.4	21.4	5.0	-
Mordad	9.9	9.1	-	0.8	3.8	5.3	1.5	-	16.0	18.3	2.3	-
Shahrivar	10.6	10.5	-	0.1	6.5	6.5	-	-	14.7	15.4	0.7	-
TOTAL	178.6	174.3	9.0	13.3	157.1	139.4	2.8	20.5	200.3	210.5	18.8	8.6

SUMMARY OF MAIN CONCLUSIONS

The Garmsar area has the full use of the Hablehrud River, which possesses good natural regulation, but is somewhat saline.

Most of the existing 30 deep wells are too saline for beneficial use, and it is proposed to replace them by 35 new wells drawing on the best groundwater area. The existing unlined canals have heavy seepage losses (about 80 m.c.m. or 37 percent), so the unlined canals should be replaced by a system of concrete lined canals. This will save about half of the present losses, and with the integrated use of new wells, will provide a properly controlled and regulated supply of water whenever the crops require it. A special cropping pattern has been worked out to fit in with the fluctuations of river flow and to reduce the use of groundwater to less than 10 percent of the total. These measures will enable the irrigated area to be increased to 18,000 hectares in the average year, dropping to 16,500 hectares in dry years and rising to 19,500 or 20,000 hectares (out of 21,500 hectares of good soil available) in the wet years. It has been found unnecessary to go in for the expensive land levelling and village irrigation programme, and also concrete sublaterals. Thus the cost of development has been kept to a minimum, with the result that the benefit cost ratio is 4.4:1 at 7 percent interest.

The cost of each cubic meter of water at field is calculated at 0.21 Rls.

EVALUATION OF THE HYDROLOGICAL ASPECTS OF THE AGRICULTURAL STUDIES IN ARID AND SEMI-ARID ZONES OF TURKEY

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INTRODUCTION

Planning of water and land resources development projects may be defined as the necessary steps to foresee future requirements. The technical and economical feasibility for the development of land and water resources may be investigating the possibilities of meeting requirements and solving problems related to the development of water, land and the other related sources. The plan should consider floods, irrigation, drainage, domestic water supply, power production, etc.

Hydrological and meteorological data are the main and vital items required for such a plan.

For each purpose of usage, in general, it is necessary to know about the dependable annual yield and yearly variations of surface water resources, necessary water supplies, the characteristics of surface water floods, sediment characteristics of surface water, the quality of water, water requirements of crops, irrigation water requirements, adequate irrigation deliveries, necessary storage capacities in project reservoirs, quantities of water available in underground storage, artesian water supplies, and various additional items, and the meteorological characteristics of the project area, such as precipitation, evaporation, temperature and some other refined data depending on project purposes and area. Hydrological and meteorological data should be based on long range records and should be dependable.

Hydrological aspects of the agricultural studies should include all of the water problems related to a soil, plant and environmental complex involved in developing and maintaining profitable crop production. They should also include such items of information as may be required in designing project structures in agricultural areas. Since "drought" is a phenomenon characterized by shortness of water and as it has vital importance for arid zones, this subject should be one of the main hydrological studies for arid zone agriculture and should be discussed in detail. For the areas where crop requirements are not satisfied by rainfall, controlled application of water to the arable lands through irrigation provides the best possible means of satisfying crop water requirements. For this reason, the hydrological aspects of irrigation should also be studied. Hydrological factors have always been important in the development of irrigation enterprises. They became more and more important as choice areas of land became fully developed and natural water resources became fully utilized.

When we talk about subjects like drought or hydrological aspects of irrigation in arid and semi-arid zones, one important question arises, that of defining and drawing the boundaries of these zones.

In this paper, first of all, hydrological and related activities in Turkey, including the definition of climatic zones, the classification used for defining the arid and semi-arid zones and hydrological activities which have been carried on in Turkey, will be discussed.

In the second part of this study, agricultural drought studies with respect to hydrology and a proposal for drought studies in the agricultural areas of arid and semi-arid zones will be summarized.

HYDROLOGICAL AND RELATED ACTIVITIES IN TURKEY

When we talk about the arid or semi-arid zones, the first task is naturally to define the concepts and problems to be dealt with. It is necessary to define what is meant by arid and semi-arid zones in order to classify them, and to fix their boundaries.

This kind of work immediately raises a number of questions and controversies which suggest lines of research to be investigated. To give an example, the somewhat academic work concerned with the classification of arid regions very soon led to extremely practical applications in agroclimatology, where yields and agricultural possibilities were linked with definite climatic factors.

Defining the Climatic Zones

"Climate is one of the basic elements in descriptive and comparative geography or the regional and local description of the earth. It governs plant associations, crops, water resources, and through these, nearly every phase of human activity. The bare facts of climate, as represented by a series of observations of the various climatic elements are an unwieldy mass of statistical data."[1] Climatological data are indispensable to agriculture and various phases of engineering. They can be used for planning and design purposes.

Climate has been classified on the basis of temperature, precipitation, humidity, prevailing winds and some other factors such as location with respect to ocean, topography, native vegetation and various other conditions or combinations of conditions.

The geographer, climatologist, agriculturist and the hydrologist alike have been attempting to organize climatic data into coherent systems for their special usages. Thus a number of climatic and regional classifications have been devised.

Before describing any of these schemes, a few remarks on their validity and scope are needed:

"It is essential to stress that it is not possible to provide a taxonomy of climate comparable to that of plants and animals. The main reason is that there are few, if any, sharp dividing lines between various climates. There is a gradual shading from one type to the other. Hence, the lines of separation are essentially arbitrary, and in almost all climates there are always broad transition zones."[2]

This does not preclude that one can arrange climates into entities. But all these entities are arbitrary. They may serve a very useful purpose, yet the purpose itself dictates the class limits.

Hence there can be as many climatic classifications as there are purposes. For example, one can define climates in terms of suitability for certain crops, the need for irrigation, or for broad geographical

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1. Landsberg 1969, p. 361.
2. Ibid, p. 362.

descriptive purposes, etc.

From the hydrological point of view, the existing climatic classifications mostly used in Turkey do not mean too much for agricultural purposes.

Since agricultural subjects like soil, plant, water and climatic relationships are very complex and closely related to each other, some more detailed study should be undertaken on the hydrological aspects of agricultural studies in relation to climatic classifications.

Classification Used for Defining the Arid and Semi-Arid Zones in Turkey

The following is a list of several climatic classifications which have been widely used for the description of broad zones in Turkey from the viewpoint of the meteorologist, the geographer and partly by the engineer.

Köppen's climatic classification in Turkey

Köppen's climatic classification is based mainly on temperature and precipitation. Not that other climatic elements are unimportant, but these two have the most obvious effects. They are also the factors used for the best and longest series of observations available.

The mean values of these elements alone are not sufficient, but their variation during the course of the year cannot be neglected if we desire to arrive at a useful climatic system. In fact, Köppen s climatic classification is based on the monthly and annual mean temperatures and the annual precipitation with the times of its maximum. The main classification is closely related to the geographical latitude. From the combination of the five major classes with the subclasses and the distribution of precipitation, 11 main climatic divisions are derived as enumerated in Table 1.

Two combinations, As and Ds, have been omitted because of their unimportance; a third letter can be added to the classification for further characterization of the climate. It is mainly concerned with temperature values. Table 2 gives these additional symbols and their explanation.

According to Köppen's climate classification, the areas in percent of the climatic zones of Turkey are given in Table 3. As can be seen from Table 3, C group climate covers a somewhat larger area than the others and constitutes about 70.4 percent of the whole area.

Table 1. KÖPPEN'S CLIMATIC TYPES AND MAIN CLIMATIC PROVINCES

Class	Symbol	Type of Climate	Symbol
(1) Tropical Rainy	A	(1) Tropical rainforest (hot and rainy in all seasons)	Af
		(2) Tropical savanna (hot and winter dry)	Aw
(2) Dry Climates	B	(3) Desert	Bw
		(4) Steppe	Bs
(3) Humid Mesothermal	C	(5) Moderate oceanic (without dry season)	Cf
		(6) Moderate, winter dry	Cw
		(7) Moderate, summer dry	Cs
(4) Humid Microthermal	D	(8) Continental climate, even precipitation through the year	Df
		(9) Continental, winter dry	Dw
(5) Polar Climates	E	(10) Tundra	EF
		(11) Glaciation	EF

Table 2. THIRD SYMBOL LETTERS OF KÖPPEN'S CLIMATE CLASSIFICATIONS

Symbol	Conditions
a	Mean temperature of warmest month $> 22^{\circ}C$
b	Mean temperature of warmest month $< 22^{\circ}C$ but at least 4 months with mean temperatures above $10^{\circ}C$
c	Mean temperature of less than 4 months above $10^{\circ}C$, but coldest month $> -38^{\circ}C$
d	Temperature of coldest month $< -38^{\circ}C$
h	Annual temperature $> 18^{\circ}C$
k	Annual temperature $< 18^{\circ}C$

Table 3. AREAS OF THE CLIMATIC TYPES OF TURKEY, ACCORDING TO KÖPPEN'S CLASSIFICATION

Group	Type	Percent of Whole Area	
B	BSk	5.5	
	Csak	39.9	
	Csah	3.4	
C	Csb	21.8	70.4
	Cfa	2.1	
	Cfb	3.2	
	Dfb	2.8	
D	Dsa	5.3	23.5
	Dsb	15.4	
E	ET	0.6	

The climate of Turkey, according to Köppen's classification, has been prepared on the basis of long and short range observations made in the meteorological stations of Turkey, together with annual and monthly temperature and precipitation distribution analysis.

As can be seen from the explanations of the symbols of the classification, this type of taxonomy does not mean too much from the standpoint of agricultural hydrology. It can be used only for comparative purposes of the climatic zones.

In this classification, the aridity boundaries are very broad. Therefore when we apply this classification as an example to some areas such as Kars and Lüleburgaz, it results that these areas would be the humid climate areas. In fact there are great differences between the two areas from the standpoint of aridity.

De Martonne climatic classification in Turkey

The De Martonne Climatic Classification is based mainly on annual mean temperature and annual precipitation.

De Martonne, by using a drought index, classified the various climates of the world, and as a result he has defined five different types of climatic zones (Table 4).

The De Martonne "drought index" is given by the following formula:

$$Ik = \frac{H}{T + 10}$$

in the formula

Ik = Drought index
H = Annual precipitation (mm.)
T = Annual mean temperature (C^o)

Table 4. DE MARTONNE CLIMATIC CLASSIFICATION

Drought Index	Type of Climate
5 >	Desert
5-10	Very arid (There are very few stream flows.)
10-20	Arid (Irrigation is needed and useful. Sometimes dry farming is applicable.)
20-30	Semi-humid (There is no need for constant irrigation.)
30 <	Humid (Abundance in stream flows)

The De Martonne Climatic Classification scheme has been widely used in Turkey, but for the use of this formula some adaptation has been made for Turkey. The boundaries of the zones have been changed somewhat by the authorities of the Turkish State Meteorological Service, as shown in Table 5.

Table 5. ADAPTATION OF DE MARTONNE CLIMATIC CLASSIFICATION FOR TURKEY

Drought Index	Type of Climate
0-10	Very arid
11-15	Arid
16-20	Semi-arid
21-40	Semi-humid
40 <	Humid

In 1964, a second adaptation was made in the boundaries of Turkey's climatic zones by the Agricultural Meteorological Office of the Turkish State Meteorological Service, and according to this new classification new maps of Turkey have been prepared. These changes are shown in Table 6, plus the percentage of each climatic zone of the whole area. The climatic data used for calculating the drought index for different areas are averages of climatic factors occurring between 1954 and 1964.

Table 6. SECOND ADAPTATION OF DE MARTONNE CLIMATIC CLASSIFICATION FOR TURKEY

Drought Index	Type of Climate	Percentage of Whole Area
0-19.9	Very arid	28.6
20-30	Semi-arid (cold) *	2.6
20-30	Semi-arid (warm)	55.2
30.1-40	Semi-humid	9.5
40 <	Humid	4.1

* In semi-arid cold zones, during the accepted agricultural growing season months of October, November, March, April, May and June, the average monthly temperatures are less than zero, and in semi-arid warm zones the opposite is true.

For showing the annual rainfall amounts which will be a boundary for humid and arid zones, a further study has been carried on for almost every province of Turkey accepting the index of 20 as the boundary of an arid zone and putting it in the De Martonne formula.

$$20 = \frac{H}{T + 10}$$

$$H = 20\ (T + 10) \text{ can be found}$$

Then all the annual amounts of rainfall for each station for delineating the arid zone have been calculated. It can be concluded from the results that the boundary rainfall between arid and semi-arid zones in Turkey should be between 282 mm. and 598 mm.

Thornthwaite classification

The Thornthwaite classification is primarily based on the water balance and the concept of potential evapotranspiration. The latter is empirically defined by:

$$e = 1.6\ (10\ t/I)^a$$

where:

e = the monthly total evapotranspiration in cm.

t = the mean monthly temperature in ^oC

a = constant determined by locality

I = heat index obtained by sum for 12 months $(t/5)\ 1.514$

According to the value of the evapotranspiration, Thornthwaite distinguishes the thermal classes listed in Table 7.

Thornthwaite further divides climates on the basis of water availability (Table 8). If the precipitation (P) at any time of the year exceeds the plant water need (n), the climate is humid and defined by an index of humidity:

$$I_h = \frac{100\ (P-n)}{n}$$

Conversely, if there is a deficiency of water at any time, an aridity index is used:

$$I_a = \frac{100\ (n-P)}{n}$$

In practice an index is determined for each part of the year, I_h or I_a, depending on whether the month has a water surplus or deficiency.

The overall moisture index I_m for the locality is then calculated by using one of each following relation:

$$I_m = I_h - 0.6\ I_a \qquad \text{or}$$

$$I_m = \frac{100s - 60d}{n}$$

where:

s = annual sum of the monthly water surpluses

d = annual sum of the monthly water deficit

n = annual plant water need or annual potential evapotranspiration

Table 7. THORNTHWAITE'S CLIMATIC TYPES, BASED ON POTENTIAL EVAPOTRANSPIRATION

Type	Potential Evapotranspiration in cm.
Frost	< 14.2
Tundra	14.2
Microthermal	42.7
Mesothermal	99.7
Megathermal	114.0

Table 8. THORNTHWAITE'S CLIMATIC TYPES BY MOISTURE PROVINCES

Type	Moisture Index
Humid	100
Humid	100 to 20
Moist subhumid	20 to 0
Dry subhumid	-20 to 0
Semi-arid	-40 to -20
Arid	-60 to -40

Thornthwaite's scheme is closely related to the earth's plant cover.

"Since the Thornthwaite formula calculates the potential evapotranspiration, it has some limitations for application. It applies

quite well to humid, vegetated areas. Increased errors are observed in low humidity areas." [3]

Thornthwaite's formula has been used in Turkey from time to time for the classification of the areas according to their climate, but especially it is used for the calculation of consumptive use of all crops through potential evapotranspiration for large irrigation project areas and for determination of water deficits, and water surpluses of those areas.

Here again, it has some limitations for its usage as explained above.

Classification of climate on the basis of precipitation

One of the widely used climatic classifications in Turkey in the past was the well known classification based on annual precipitation.

Since irrigation is practiced principally in regions of low rainfall, this classification of climate is basically from the viewpoint of irrigation. Humid regions are those receiving more than 760 mm. of precipitation annually; semi-arid regions are those receiving from 360 to 760 mm.; and arid regions are those receiving less than 360 mm.

One other type of classification according to precipitation is given in Table 9.

Table 9. CLIMATIC CLASSIFICATION IN RELATION TO PRECIPITATION

Annual Precipitation in mm.	Climatic Classification
Less than 250	Arid
250-500	Semi-arid
500-1,000	Subhumid
1,000-1,500	Humid
1,500-2,000	Humid
More than 2,000	Very wet

3. Israelsen and Hansen 1962, p. 248.

It can be easily understood that these kinds of classifications give a very rough estimation of climate, since they do not take into account the yearly distribution, duration, intensity, frequency of rainfall or water-plant-soil relationships. In recent years they have not been used in Turkey.

There are no relevant data for the areas of Turkey, in percent, according to these classifications.

Hydrological Activities in Turkey

In the following section, hydrological activities in general and hydrology related activities in arid and semi-arid zones of Turkey will be summarized.

Hydrological activities in general

The responsible government agencies for hydrological and related activities in Turkey are:

* The General Directorate of State Hydraulic Works (DSI)

* The General Directorate for Power Investigations (EIEI)

* The General Directorate of State Meteorological Works (DMI)

* The General Directorate of Soil Conservation and Farm Irrigation (TOPRAKSU)

Education and hydrology: Basic hydrology courses designed to serve as a basis for hydrocivil engineering are given in Istanbul Technical University and Ankara Middle East Technical University. The three agricultural faculties that are located in Ankara, Erzurum, and Izmir teach elementary hydrology to agricultural engineers.

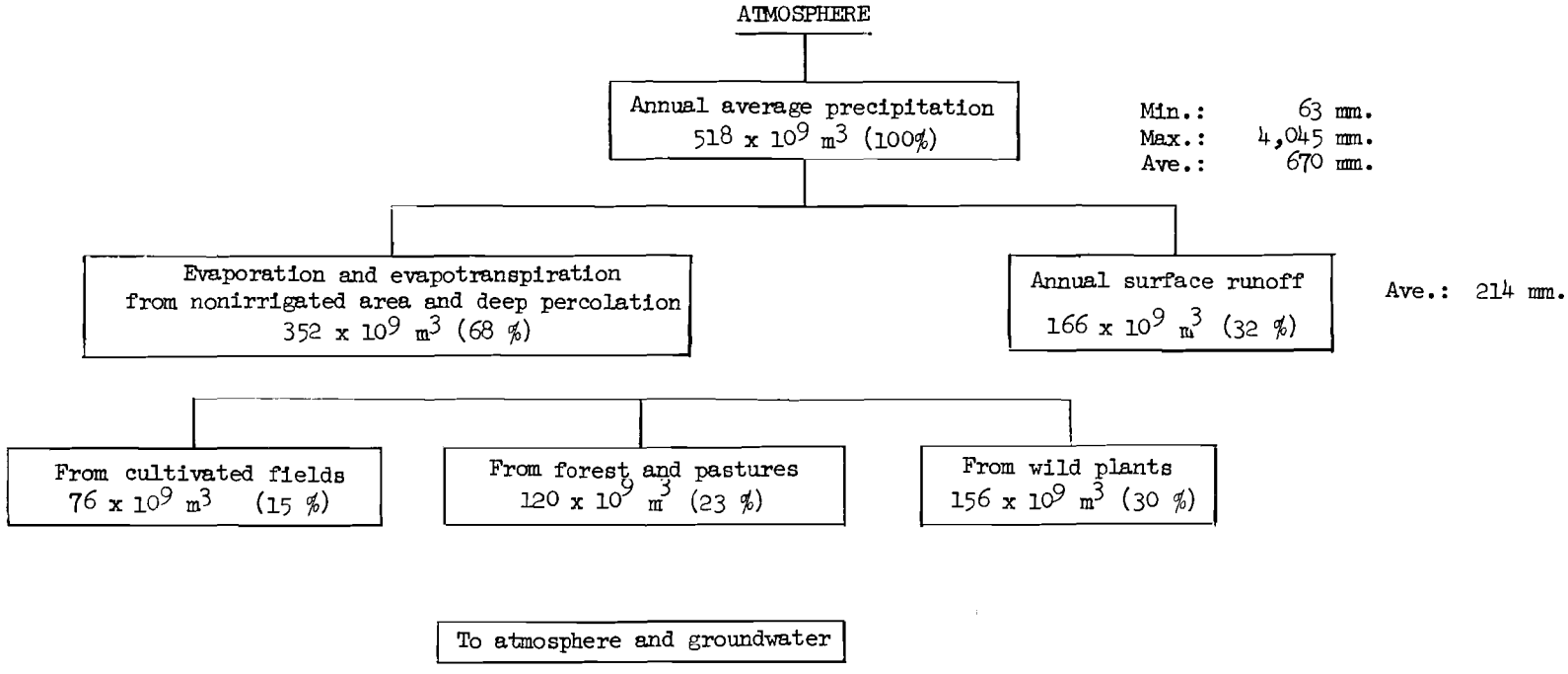
Hydrological Studies: The hydrological cycle and the estimated usage and consumption of water in Turkey are given in Charts 1 and 2.

The overall mean annual rainfall in Turkey is about 670 mm., corresponding with a water potential of 518 billion m^3. From this amount, only 214 mm., or 166 billion m^3 is surface water runoff, and the mean ratio of runoff to rainfall is 0.32.

The runoff values decrease in the summer months, in almost every region of Turkey, in accordance with the low volume of rainfall in these months.

CHART 1

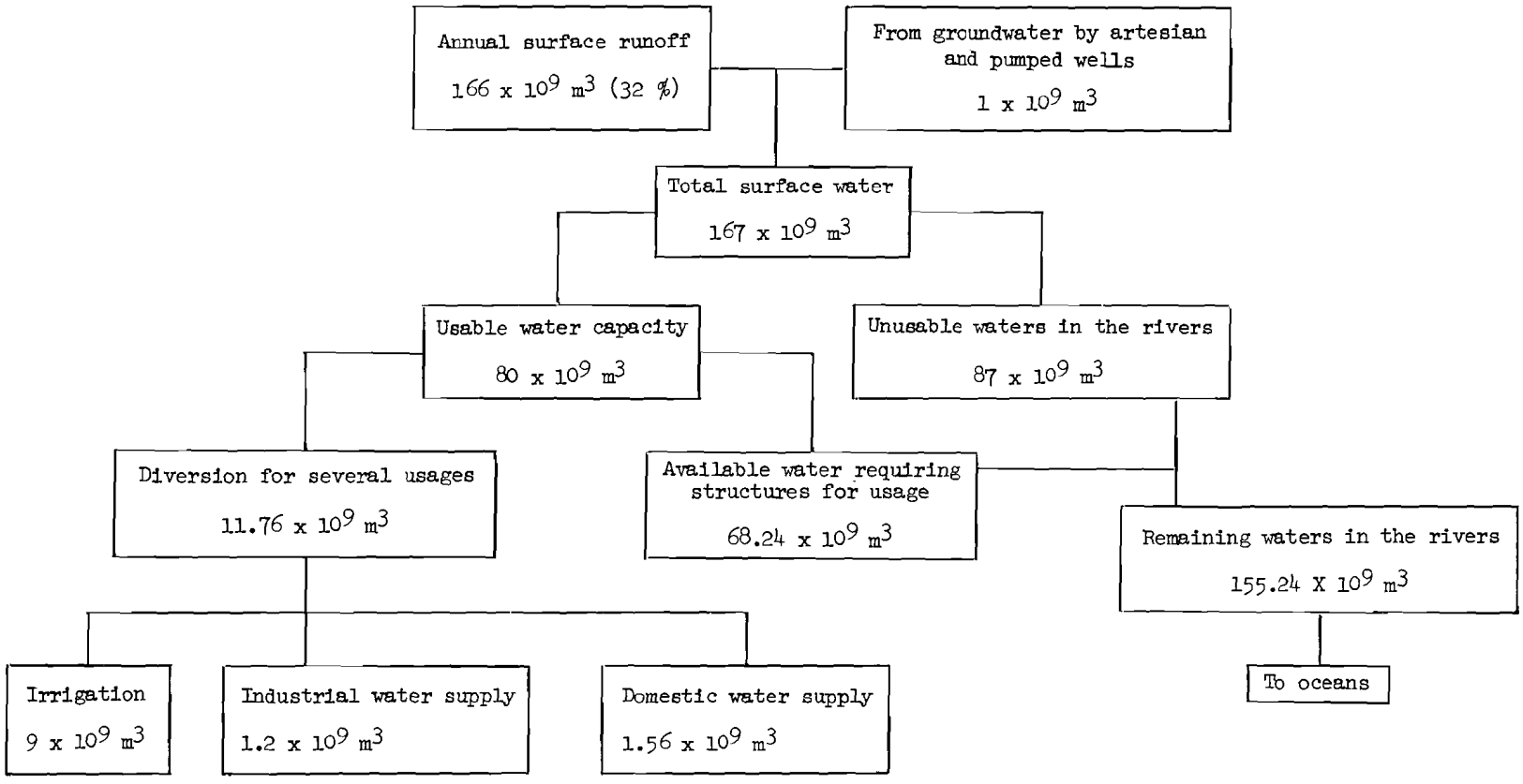
HYDROLOGICAL CYCLE AND WATER USAGE IN TURKEY



Revised from Kılıç et al (1966, p. 70) according to data given by DSI (1970, pp. 12 - 13)

CHART 2

WATER USAGE IN TURKEY



Revised from Kılıç et al (1966, p. 70) according to data given by DSI (1970, pp. 12 - 13)

Rainfall regions of Turkey can be considered in five groups:

1) In central and southeast Anatolia, annual rainfall is generally low. Most of the precipitation falls in the spring and winter months.

2) In the Aegean Sea region, Marmara and the western part of middle Anatolia, most of the precipitation falls in the winter and spring months.

3) In eastern Anatolia there is considerable rainfall every month, especially in the winter and spring.

4) In the basins of the Mediterranean coast and part of southeastern Anatolia, winter months are very rainy and there is no rain in the summer.

5) On the Black Sea coast and in Thrace, there is considerable rainfall almost every month of the year.

In the following paragraphs the hydrometrical network, the meteorological network, groundwater investigation, sediment measurement, quality analysis and snow surveys which were carried out by responsible government agencies are briefly summarized.

a) *Hydrometrical Network*: The establishment of gauging stations and systematic measurements in Turkey was initiated in 1935. The network at the beginning of 1970 consists of gauging stations on 1,124 streams. There is one station per 691 km.^{2} in the country as an average. DSI and EIEI operate 816 and 308 stations respectively. Of these, 481 stations have reliable rating curves.

b) *Hydrometeorological Network*: The establishment of meteorological stations and systematic measurement of precipitation in Turkey started in 1926. The present network of meteorological stations consists of 1,628 precipitation stations making daily observations. The majority of stations is operated by the DMI, which has 1,197. The rest are operated by other government agencies.

According to a recommendation made by the World Meteorological Organization, the maximum area for one rain gauge is 250 km.^{2}. The density of the network in Turkey is approximately one station per 550 km.^{2} and for this reason the density of the network should be at least doubled in the coming years.

About 200 stations in Turkey are equipped with recording gauges. At 396 climatic stations included in the network, other meteorological factors such as temperature, soil temperature, humidity, atmospheric pressure, evaporation, and wind speed direction are also observed. The majority of the stations makes precipitation and temperature observations only.

c) *Groundwater Investigation Network:* The groundwater investigation (hydrological) network of Turkey is operated by DSI, the only responsible organization in this field. According to extensive DSI groundwater investigations, through the end of 1970, it was estimated that the groundwater reserve capacity of Turkey is 8×10^9 m^3 per year and approximately 400,000 - 450,000 hectares of land can be irrigated by using these reserves.

Among the above stated network activities, sediment measurement, water quality analysis and their evaluation for different purposes, and surveys of snow courses are carried out by the responsible government agencies.

The data obtained from sediment measurements up to 1970 are not adequate to establish sound relationships between runoff and sediment loads of the rivers.

Water quality investigations on a large scale were initiated by DSI in 1957. About 100,000 samples from groundwater, springs and different major streams have been analyzed and most of them were found suitable for irrigation purposes.

Hydrological Characteristics of Water Resources: Turkey is divided into 26 river basins for water resources investigation purposes. These can also be grouped according to similarities of their hydrologic features, although necessary data for establishing the hydrologic character of water resources are somewhat limited. Some attempts have been made to define the basic hydrologic features of different regions of Turkey, but they were not adequate.

Drainage areas, average annual rainfall, average evaporation and estimated surface and groundwater potentials of these 26 river basins are shown in Table 10.

A close look at this table shows the differences of river potentials among the coastal and inland regions because of the different climatological features of the regions. Precipitation is generally low and insufficient for natural watering of the crops during the vegetation.

Table 10. HYDRAULIC POTENTIAL OF TURKEY

Basin No.	Name of Basin	Area in sq. km.	Average Precipitation in mm.	Average Evaporation in mm.	Estimated Water Potential: Surface Water 10^9 cu.m.	Estimated Water Potential: Ground water 10^6 cu.m.
1.	Meriç-Ergene	14,560	500	427.5	1.06	-
2.	Marmara	24,100	800	557.4	5.85	-
3.	Susurluk	22,399	600	414.1	4.16	-
4.	Ege	10,003	650	476.8	1.74	27
5.	Gediz	18,000	600	474.0	2.27	21
6.	K. Menderes	6,907	650	498.8	1.04	-
7.	B. Menderes	24,976	600	474.0	3.15	250
8.	W. Mediterranean	20,953	900	572.0	6.86	45
9.	Antalya	19,577	1,100	608.6	14.33	80
10.	Burdur Gölleri	6,374	600	458.2	.90	61
11.	Akarçay	7,605	500	380.3	.91	56
12.	Sakarya	58,160	450	380.7	4.10	133
13.	W. Black Sea	29,598	800	485.0	9.32	17
14.	Yeşilırmak	36,114	500	374.0	4.57	185
15.	Kızılırmak	78,180	400	327.5	5.66	178
16.	Konya Kapalı	53,850	400	327.5	3.91	319
17.	E. Mediterranean	22,048	900	490.5	9.03	84
18.	Seyhan	20,450	880	590.2	5.92	-
19.	Asi	7,796	900	711.0	1.47	95
20.	Ceyhan	21,982	950	619.2	7.25	66
21.	Fırat	125,540	700	479.5	28.35	427
22.	Eastern Black Sea	24,077	1,400	705.6	11.34	-
23.	Çoruh	19,872	600	354.3	4.88	-
24.	Aras	27,548	500	292.1	5.71	60
25.	Van	19,405	700	517.3	3.54	16
26.	Dicle	57,614	850	513.2	19.49	14
	Total	777,688	670	438.0	166.81	2,134

Hydrology related activities in arid and semi-arid zones of Turkey.

In general, programs have been prepared for large dams and reservoirs to irrigate the large plains located generally at the lower end of the watersheds. EIEI and DSI are concerned with the hydrological studies of these types of works.

Because of the topographical and economic conditions of Turkey, the land in the upper watershed is also cultivated and may need irrigation. Irrigation water for the land in the upper watershed can be obtained by diverting or pumping water from small creeks and spring-fed ponds into small reservoirs. TOPRAKSU is developing programs for the construction of a large number of small earth dams. At the present time the graph established by the Soil Conservation Service of the USA is generally used to determine the hydrological aspects of these dams, especially the direct runoff from rainfall.

In central Anatolia, which has arid and semi-arid climatic conditions, the recently established Ankara Soil Conservation Research Station has started some preliminary work to solve soil conservation problems of the region, including the hydrological aspects of the zone, such as the precipitation-runoff relationship, and to provide reliable data for the local TOPRAKSU organizations.

There is no institute in Turkey which covers all the problems, including hydrological aspects of arid and semi-arid zones. However, there are some institutes in Turkey which study some aspects of arid and semi-arid zones. These are listed below. The last two have been recently established.

* The University of Ankara, Faculty of Agriculture and Botanical Institute of the Faculty of Science

* The University of Istanbul, Faculty of Forestry and Geographical Institutes

* Agricultural Experiment Stations of Ankara and Eskişehir

* Arid Zone Irrigation Institute of Middle East Technical University

None of these institutes are directly related to the hydrological aspects of the arid and semi-arid zones of Turkey. They usually carry on some research work related to crop production on dry weather conditions, or they conduct basic research on the rainfall-temperature-crop yields relationships, etc.

Meanwhile, in addition to the above stated studies, additional re-

search work is being done on the different aspects of drought in Turkey.

At present, there are some research institutes in the world which are specifically studying the problems of regional arid and semi-arid zones, including the hydrological aspects of these zones. In fact, an arid zone research institute including a hydrology division and regional substations should be established in Turkey, as decided by the Scientific and Technical Research Council of Turkey (TBTAK).

AGRICULTURAL DROUGHT IN RELATION TO HYDROLOGICAL ACTIVITIES

Definition of Drought

Drought is a phenomenon characterized by shortness of water accompanied frequently with dry weather and high temperatures.

From the viewpoint of the meteorologist, drought is defined as a rainless situation in a period during which a certain amount of rainfall is expected in that zone. For the agricultural engineer drought means less water that a certain crop requires. This concept implies a fall in surface and groundwater levels to the hydrologist, whereas to the economist a drought is the deficiency of water which affects the present economy of the region directly.

Considering the definitions above, it can be concluded that drought is not a definite but a completely relative situation, and it is very difficult to agree on a common definition of drought.

For example, it can be said that a drought period in a humid region may correspond to a very wet period in a semi-humid region. At the same time, an artificial drought can be created if more water is required than the available amount during the development of a certain region. These artificial droughts created by humanity should be carefully distinguished from natural droughts.

In general, we are interested in agricultural droughts. Contürk defines a drought as "an incident during which the available water is less than the expected or required." Any studies made on available water or water requirements or their relations would therefore constitute a "drought study." All drought studies, especially in agriculture, rest primarily on the selection of most suitable variables and time units. A thorough understanding of the soil-plant-environment complex helps in obtaining better results.

Frequently, intensity and length of the drought are the most important aspects to be investigated.

From the agricultural engineering point of view, any study on an agricultural drought should cover some or all of the subjects listed below:

* Available water
* Water requirements
* The water budget
* Drought and crop yield relationships
* Soil-water-plant-environment relationships

A Proposal for Drought Studies in the Agricultural Areas of Arid and Semi-Arid Zones

The focal point of the drought problems is the lack of suitable soil moisture conditions for plant growth that occurs during the drought periods. Occurrences of these undesirable conditions vary with geographical location, soil properties, cropping systems, and in particular, weather conditions. In the latter category, distribution of rainfall and consumptive use of water by crops are of principal significance.

It would obviously be of value to know what soil-moisture conditions may be expected to occur in a given area, as determined by the factors listed above. Such information should be given in terms of probabilities, because of the extreme seasonal variability in rainfall distribution.

When a description of the incidence of soil-moisture deficits and excesses can be given, even if it is on an approximative base, much can be concluded with respect to the suitability of certain types of crop production in given areas and under given soil conditions. The needs for irrigation and drainage also become evident as well as certain design factors needed in the engineering of irrigation, if there are available water resources.

Such information for any part of Turkey is not yet available to the agronomist, the agricultural engineer or the economist.

However, many detailed research works have been carried out by Van Bavel and associates, and by others, to provide estimates of soil-moisture conditions or to estimate the agricultural drought for Virginia, North Carolina, South Carolina, Georgia, Alabama, the Dakotas, the Tennessee Valley, the Northeastern states, and the lower Missisippi Valley areas of the USA.

Van Bavel and associates computed daily soil-water balances for 25 years of records in their studies. These balances were based on recorded amounts of daily precipitation and on estimated values of daily evapotranspiration. Furthermore, the soil was assumed capable of retaining certain maximum amounts of water available to plants. These amounts ranged from 25 mm. to 125 mm.

Five steps make up the procedure for estimating soil moisture conditions from climatological data. These are:

1) Procurement of daily rainfall data

2) Estimation of daily evapotranspiration

3) Estimation of the moisture-storage capacity of the soil in a form available to plants

4) Computation of the daily soil-moisture balance

5) Classification of the resulting data.

The data as reported enable one to determine for a given section and time of year the probability for occurrence of deficits and excesses of soil moisture of given severity. In cases of deficits, the required amounts of irrigation water have also been estimated.

The data thus serve multiple purposes. One may ascertain the severity of drought incidence in a location for certain soil conditions. The recurrence value of a drought as it happened may be determined and related to the plant response in an irrigation or fertilizer trial. The demand for irrigation water may be anticipated for long range planning.

The common objective in these kinds of studies is to obtain a reliable estimate of prevailing soil moisture conditions for large areas in spite of the absence of direct observations of soil moisture content for almost all areas and conditions. The results of these estimations give valuable information and can be used for several purposes as explained above.

For the daily soil-water balance calculations, the procedure can be carried on by using IBM machines, as Van Bavel and associates have done.

For this reason, as far as drought studies are concerned, we should start similar studies, encompassing at least 25 years of daily rainfall and other required data for calculating the monthly evapotranspiration on the arid and semi-arid zones of our countries.

CONCLUSIONS

From these discussions a number of conclusions can be drawn and these may be summarized as follows:

1) An arid zone research institute, including a hydrology division and regional substations, should be established in Turkey, and then hydrological aspects of the arid and semi-arid zones should be studied extensively by means of this institute. The hydrology division should have the recording and data collection services for hydrology, climatology and hydrometeorology. Since statistics are closely associated with the hydrological research work, this research institute should develop its own statistical service.

2) The hydrological surveys, especially those related to the agricultural point of view, should be further intensified for the arid and semi-arid zones of Turkey by means of this new research institute. These surveys should include:

   a) integrated surveys, data gathering, and evaluations of climatic factors and natural resources related to hydrology, such as frequency and intensity of rainfall, temperature and its variations, land, soils, water and vegetation, to be taken up on a comprehensive basis

   b) definition of arid and semi-arid zones of Turkey, according to the results and evaluations of the above mentioned surveys; classification and deliniation of arid and semi-arid zone boundaries.

   c) estimation of the water requirements of various crops, water needs for irrigation, industrial domestic and livestock consumption, and comparison with the available surface and groundwater resources in arid and semi-arid zones, plus determination of quality in the available water resources

   d) investigation of the most efficient use of rainfall for crop production

   e) investigation of the drought frequency and occurrence expected to occur in different arid and semi-arid areas as determined by geographical location, soil properties, cropping systems, weather conditions (distribution of rainfall, consumptive use of water by crops), using the method described previously.

3) Investigations on organic compounds for the control of evaporation from soil and water surfaces should be emphasized.

4) Saline water and its use in the production of crops, and selection of species which tolerate high temperatures and salinity should be studied.

5) Studies on basic problems of arid lands such as soil-plant-water energy- relationships should be included in the curriculum of the above mentioned institute.

6) The efficient distribution and utilization of irrigation water and the selection of the most suitable irrigation systems for crop production should be investigated for the different land types of arid regions.

7) Other problems of arid and semi-arid zones related to low soil-moisture conditions which might be a subject for hydrology should be studied extensively, such as:

   a) the wild species of plants with respect to water deficiency and adaptation to an arid environment

   b) the germination of the cultivated and the wild species of plants under drought conditions

   c) the techniques for nutrient uptake for cultivated plants under low soil-moisture conditions.

GENERAL REPORT ON DEVELOPMENT AND UTILIZATION OF SALINE SOILS IN IRAN

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INTRODUCTION

The Empire of Iran, which is located between 25° and 40° N latitude and covers an area of about 1,650,000 square kilometers, is located in the arid part of the Middle East. The country is very complicated in the sense of specific natural conditions. First, Iran is a country of mountains and plateaus uplifted more than a thousand meters. These plateaus are not the residual eroded type, but are covered with alluvial and colluvial deposits of tertiary or quarternary types. Between the highest mountains, the natural geography of this country has relatively deep lowland and intermountain valleys, probably of mostly tectonical origin. This is very important for the penetration of artesian and simple groundwater which drains naturally into the valleys. Secondly, there are typical alluvial plains along the Caspian coast and the Persian Gulf.

Furthermore, the country is tectonically active and some parts are

still experiencing earthquakes. It should be emphasized that many blocks of the country are uplifting and forming steplike systems of terraces and long, flat inclined slopes.

These main peculiarities of orography and geomorphology are followed by the production of soluble salts. Distribution and composition of these salts are very complicated and are accompanied by the processes of natural leaching, transitional transport, and accumulation, depending on the conditions of different regions. Generally, there is a strong and permanent generation of concentrated and diluted salt solutions migrating into the slopes, the lowlands and deltaic areas.

Another factor that contributes to the salinity problem in Iran is climate. For example, evaporation is extremely high in the country, while the rainfall in most areas is low and it is restricted to the winter season. On the northern part of the plateau the average annual rainfall is above 200 mm. and it decreases to less than 120 mm. in the southern part. The general distribution of rainfall is shown in the following table.

RAINFALL DISTRIBUTION IN IRAN

Annual Rainfall (mm.)	Recipient Area (millions of hectares)	Ratio of Recipient Area to the Total Area of the Country (in percent)
Less than 100	22	13
100-250	100.5	61
250-500	28	17
500-1,000	13	8
Over 1,000	1.6	1

Considering the above mentioned conditions of orography, geomorphology and climate in Iran, it can be readily realized that the conditions are favourable for the accumulation of soluble salts in the upper soil layer and on the surface. In this paper, an attempt has been made to study the causes of salinity in the Iranian plateau from the following two angles:

1) Development of salinity due to natural processes which are completed with time and can continue

2) Development of salinity due to the improper practice employed by the farmers.

NATURAL SALINIZATION

Geologic Factor

This factor is responsible for the transportation of sea salts and their deposition on lands and probably it started its effects in the middle of the Miocene period when the Iranian Plateau was uplifted and there was no longer any connection between the "lakes" developed from the Miocene seas and the oceans.

These lakes were no longer fed from the oceans and the amount of water they received from the surface runoff was relatively small. Further, the development of hot arid conditions gradually decreased the size of these lakes, and finally there was nothing left except large deposits of soluble salts and gypsum. These types of salts are found in different parts of the country and are one of the most important problems. This type of salt deposition is still in progress in some areas like Khuzistan, due to the reflux of the Persian Gulf, and to some extent in the eastern part (Turkmen desert) of the Caspian coast.

Geochemical Factor

In some parts of the country, there are huge masses of salts, which form the salt mountains on the surface of the land and cover large areas. They are valuable sources for salt mining because their main constituent is sodium chloride with some sodium and magnesium sulfate. The salt content of these masses is transported to the surrounding areas by the surface runoff, precipitation and wind. Moreover, in some parts of the country there are saline groundwater reservoirs. In some areas, due to the high evaporation rates, the salt content of these groundwaters is brought up to the surface soil. In some other parts, the saline groundwater runs on the surface through the cracks of rocks (saline springs) or forms salt marshes upon the upward movement of water in the soil.

Geomorphology

Considering the climatic conditions of Iran and the fact that during most periods of the year evaporation is more than precipitation, it will be obvious that geomorphological conditions of the country play an important role in the accumulation of salts in soils. Accordingly, the problem of salinity is mostly encountered in lowlands, alluvial plains, valleys, low terraces, and deltas. On the other hand, in elevated areas like hills and sloping lands, salinity is not a problem. This difference is mainly due to the rapid accumulation and stagnation of water, and also the "feeding" of the groundwater accompanied by high evaporation rates.

Surface water

Transportation of salts and salinization by means of surface water flows, in the form of rivers or otherwise, is very common in Iran. In this respect, the surface flows which end up in sandy areas, salt deserts, and closed basins are particularly important. The rivers flowing in some regions of the country dissolve different salts and transport them to the plains and, consequently, cause salinity in these areas. Generally, the salt content of rivers in Iran is high, ranging from a few hundred milligrams to a few grams.

It should be mentioned that the seasonal floods which divert the direction of river flow and deposit salt and silt content on the lowlands, to some extent increase the salinity of some regions.

Wind Effect

In Iran wind has been one of the factors increasing the degree of salinity by transporting the powdered salts or dust containing salt from one area to another. Some researchers have shown that the annual amount of salt transported by wind is between 200 kg. and 50,000 kg. per hectare. Accordingly, a nonsaline soil close to a saline area with powdered salts can in a few years become saline due to the effect of wind. The rate of salinization caused by wind depends on the amount of salt and the form in which it is present and also the ability of wind to transport it.

Biological Factors

Different crops also affect the rate of movement and accumulation of salts in the soil in different degrees, depending on the type and variety. Plants are able to adjust the quantity and quality of mineral composition of their roots and other parts to the salt content of different soil layers and groundwater. This adjustment results in a change of the form and quantity of salts present in the soil. Usually, the typical halophytic plants increase the salt content of the surface layer of soil. On the other hand, grasses and legumes decrease the salt content of surface soil. The halophytic plants are able to take up about 0.2 to 1 ton of salt per hectare and after the growing season deposit this amount of salt at the soil surface. The amount of salt in the roots of these plants can be as high as 1.5 to 2.0 tons.

It can be concluded that plants affect the salinity situation in different ways. First, they can increase the salinity of the area where they are grown by bringing the salts from the lower depths of the soil to the surface. Secondly, the salt deposited from the plants on the soil surface can be transported to other areas by wind or surface flows.

SECONDARY (MANMADE) SALINIZATION

In certain areas of the country, employment of improper cultural practices by the farmers, accompanied by a lack of drainage, has intensified or caused the development of a salinity problem. Secondary salinization, which is caused mainly by the incorrect use of water on lands, is very common in Iran as the natural conditions of the country are also favourable for its development. In the USA, USSR, Pakistan and Turkey many areas are abandoned because of the presence of salinity brought about by man. In Iran, secondary salinization is quite common where extensive irrigation projects were in operation. The province of Khuzistan is in one of the areas where big irrigation projects have been conducted. It is located in the southeast of Iran and bounded by the Persian Gulf and the Zagros chain of mountains, and has a hot and relatively humid climate. This province will be considered in some detail in order to clarify the factors which give rise to the condition of secondary salinization. The province is one of the hot areas of the world with the maximum temperature going over 50°C and a minimum temperature of about 0°C. The average annual temperature of the area is 24-28°C, relative humidity about 50 percent, and the rainfall amounts to 150-300 mm., which is very low compared with the annual evaporation of over 2,000 mm.

With the above mentioned climatic conditions of the area, the salinity condition is quite common and, to some extent, it is expanding. The main factors responsible for the natural salinization of Khuzistan are as follows:

1) Miocene deposits, whose salts are transported from the Zagros Mountains to the Khuzistan Plain by surface flows

2) The continous deposition of salts because of the intrusion of water from the Persian Gulf

3) The action of wind and rivers

Moreover, large areas of high fertility have turned into saline soils upon irrigation, because of the gradual increase in the salt content of the soil. The main factors which have been recognized as the ones responsible for the development of salinity conditions in the area are groundwater conditions, salt-containing layers, irrigation water, transpiration environment, and agricultural activities.

EFFECTS OF GROUNDWATER

The conditions of groundwater in Khuzistan are the main factors causing salinity of the soil. In most areas of the plain, the groundwater surface is high, mainly because of improper irrigation. Generally,

the areas close to the irrigation fields and cities have a higher water table than others.

There is almost no movement in the groundwaters of Khuzistan. The salt concentration of the groundwater was checked in several locations and was found to vary between 1 and 110 gr./lit. In some areas, the highly saline groundwater has brought about saline marsh conditions on the soil surface. The critical depth of groundwater for Khuzistan as determined by field studies is 2.5 - 3.5 meters. However, evaporation is also taking place at depths lower than this, down to about 4.5 meters. If the depth of the water table is less than 2.5 - 3.5 meters, the overlying soil can become saline. Shallow water tables are developed either through the upward movement of water from lower depths or the application of excessive amounts of irrigation water.

Effects of Salt Containing Layers

Salt-containing layers are developed in various ways such as the gradual lowering of the water table or direct transportation of soluble salts to a certain depth of the soil.

These layers are either in the form of soil horizons or layers of geological material with a salt content of a few thousandths to a few percent. In areas where salt-containing layers are present below a non-saline soil, the gravitational water coming from irrigation will dissolve the salts. Then, through the capillary movement of deep water to the soil surface, the soluble salts are brought up and, upon evaporation, they will be deposited on the surface soil. The critical depth of these layers is estimated to be 1 - 1.5 meters. However, depending on the type of soil, the crop grown, cultural practices, and the method of irrigation, the critical depth can vary between .5 and 1.5 meters.

Effects of Irrigation Water

Irrigation of the fields by application of river water can cause salt accumulation in the soil. In Khuzistan, this is true even for the rivers with a low salt content, such as the Karon. The reason for this is that a high evaporation rate decreases the amount of water penetration, and because of the low infiltration rates and the presence of impermeable soil layers water movement in the soil profile is slow. Consequently, a high amount of irrigation water is evaporated. It has been found that the application of 500 - 1,000 mm. of Karon water has resulted in the accumulation of 1.5 - 4 tons of salt per hectare.

Although leaching can help in the removal of salts from the root zone, the application of excessive amounts of water necessary for leaching can cause the development of a local high groundwater or bring up the old water tables.

Transportation Environment and Agricultural Activities

Eradication of the transpiration potentials of an environment and intensifying the evaporation of the soil surface not only increases the salinity of the soil but it also affects the degree of aridity of the area. This is one of the important factors causing the salinity of many areas throughout the country.

This condition is observed in areas where vegetative cover has been eradicated by overgrazing, excessive clearance of forested areas, removal of bushes, use of improper crop rotations, late planting, and other poor management practices including incorrect use of machinery and lack of soil conservation.

ECONOMIC ASPECTS OF SALINITY

Salinity is one of the limiting factors in the development and economic expansion of agriculture in Iran. In many areas of the country some percentage of the soil is saline and when agricultural activities are expanded in different areas, this percentage is generally increased.

Although the seriousness of the salinity problem has been recognized by national experts, the farmers' awareness of the situation is rather limited and they would benefit by more guidance on proper water management practices.

Recommendations

Considering the economic possibilities and availability of water supply in Iran, the following points are recommended:

1) The causes and degrees of salinity in each area should be studied carefully. The quantity and quality of the salts present in the soil or irrigation water should be determined in order to design reclamation projects on a scientific basis. Also, different natural factors which favor the expansion of the problem should be determined, before deciding on control measures.

2) In areas where the degree of salinity is such that salt-tolerant fodder crops (including some grasses and legumes) can be grown with relative success, it is better to continue the planting of these crops rather than implementing a hurriedly designed reclamation project. In this way, not only economic returns may be obtained from the crops, but also the degree of salinity will be decreased so much that, after some seasons, the salt-tolerant crops can be grown successfully. In areas where salinity is accompanied by a high water table, the best

crops to be grown include alfalfa, eucalyptus, and, where soil salinity is severe, date palms. This is usually considered a biological method of amelioration.

3) In soils which have a soluble salt content of more than one percent, the salts must be removed before any successful growth can be expected. The most effective method of removing salts from soils is by leaching, and this should be accompanied by sufficient drainage of the area. Other methods include biological and mechanical practices but they are not as effective as leaching. It is recommended that the main leaching should be done in fall and winter when the temperature is low and precipitation is higher than in other seasons.

   In areas where exchangeable sodium ion is high, the best method of amelioration is through the use of gypsum. Generally, PH alkalinity is not much of a problem in Iran.

4) In cases where salinity is readily recognized, control measures should be taken in order to prevent the development of secondary salinization. As mentioned in previous sections, the factors involved include groundwater transpiration environment and agricultural activities. The control measures of these factors are briefly discussed below:

   a. When salinity is caused by the shallow depth of the water table, the problem can be solved in a number of ways. First, the water table depth may be lowered by implementation of a drainage system which includes horizontal drainage canals, collector wells and vertical drains. This method is employed where the root zone is under the influence of the groundwater. Obviously, before designing the drainage system, the type of crop and its "resistance" to the depth of the water table should be determined. Various crops do not have the same degree of tolerance to the depth of the water table. Moreover, the relationship between the critical depth of groundwater and its quality varies and should be carefully studied.

      For example, in a loamy soil overlying groundwater with a salt content of 0.1 - 0.3 gr./lt. the critical depth of the water table is about 1 meter, while under the same conditions but with a salt concentration of 3 gr./lit., the critical depth is considered to be 2.5 meters or more.

      In areas where the depth of the water table is sufficiently below the soil surface and there is no need for implementation of a drainage system, measures should be taken to con-

trol the capillary rise of water. These include protection of the transpiring environment, proper tillage practices, and use of biological "drains." With respect to the latter method the best crop is alfalfa, which is able to take up and transpire more than 10,000 cubic meters per hectare per year. Some trees can also take up an amount of more than 5,000 cubic meters per hectare per year. Among these, eucalyptus is most suitable for the conditions of the country.

b. If the salinity of the soil is due to the presence of salt-containing layers, the control measures should aim at the prevention of the back "flow" of gravitational water reaching these layers or employ irrigation practices which will not result in the formation of gravitational water or saturation of the salt-containing layers. To achieve this purpose, the amount of irrigation water should be determined on the basis of the water required for bringing the moisture content of a certain depth of soil up to an amount which is less than field capacity (FC) (about 75 percent of FC).

c. In areas where salts have accumulated in the soil due to the poor quality of irrigation water, the amelioration methods should be based on the results of studies conducted to determine the exact quality of irrigation water, the physical and chemical properties of soils, the microclimate of the area, especially the rainfall pattern, the type of crop, and topography of the area.

To decide on the suitability of water for irrigation purposes, the following criteria should be determined:

i. sediment in the river water

ii. amount of soluble salts or degree of salinity

iii. ratio of soluble salts

iv. pH

Most rivers flowing in Iran have a high content of sediment which is beneficial or harmful for agricultural purposes, depending on its chemical characteristics. A high content of soluble salts in the water, however, is one of the main problems of Iranian farmers. The critical concentration of the hazardous salts is thought to be between .3 and .5 gr./lit. This value can be considered higher, depending on the

physical and chemical properties of soils, and the growing season of the crop. To remove the extra amounts of salts from the soil, a periodical leaching programme, accompanied by a drainage system, should be used. Compared with the amount of soluble salts, the ratio of different soluble salts to water is less serious. Moreover, the pH content of most water sources in Iran is not detrimental for agricultural purposes.

5) Protection of vegetative cover and, generally, prevention or lowering of the evaporation from the surface of agricultural lands is very effective in the conservation of the fertility of soils crop cover prevents both the salinization of the soil and the development of aridity conditions in an area. Fortunately, a lot of attention is given to the protection of vegetative cover in Iran. It is necessary in some cases to develop new varieties of crops which are resistant to salinity and drought.

Finally, it must be emphasized that successful prevention of the development of salinization, which is an important problem for all the countries in the Middle East, to a large extent depends upon the awareness and knowledge of the farmers about the problems.

EFFECT OF RATE AND TIME OF APPLICATION OF NITROGENOUS FERTILIZER ON THE EFFICIENCY OF NITROGEN UPTAKE BY WHEAT

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With the increasing use of fertilizers in the production of wheat grown under nonirrigated and irrigated conditions in Turkey, it is inevitable that not only the amount of a particular fertilizer, but also its time of application will receive greater attention.

Time of fertilizer application may affect crop yield and quality in a number of different ways. Efficiency of a known amount of fertilizer may be more in terms of growth response in two or more split applications than in one single application. Such a difference, if it exists, may be because, with a single large application, a greater loss of soluble nutrients may occur. It may also be that a greater proportion of a nutrient element may convert to a less available form when applied in a single rather than multiple treatment. Also, the period during which a crop may make a large demand for a nutrient may not coincide with the time of fertilizer application.

Practical methods for realizing high efficiency of nitrogen use would seem to depend on good soil aeration and drainage, incorporation of nitrogen fertilizers in the soil rather than application at the surface, and the addition of nitrogen at such times and in such amounts that the crop can utilize it rather promptly.

It is well known that the soil nitrogen may be increased by fertilizer additions, and gains in the total nitrogen content may occur through various microbial fixation processes. On the other hand, nitrogen may be lost from the soil in different ways, i.e. by volatilization, leaching, erosion, burning, and crop removal. In particular, fertilizer nitrogen is susceptible to losses; in agricultural practice crop uptake of fertilizer N is relatively inefficient, often amounting to less than half the quantity applied.

It is desirable to know the relative efficiency of fertilizer use resulting from times, methods and rates of application. Use of 15N-tagged fertilizer has made it possible to obtain more detailed information on the behavior of fertilizer N in soil and its assimilation by growing plants. In addition, it is possible to obtain much better estimates of N losses and the residual effect of fertilizer N than is possible with conventional techniques. The behavior of soil N in the presence of fertilizer N can also be examined. Allison has recently made a comprehensive review of findings of tracer N experiments.

The present investigation was conducted to obtain further information on the efficiency of nitrogen and phosphorus uptake by wheat as a function of rate and time of application of nitrogeneous fertilizer.

MATERIALS AND METHODS

The field experiment with 15N and 32P-labelled fertilizer was conducted on an alluvial soil located at Tarsus Irrigation Research Institute in the Mediterranean region of Turkey.

The soil of the experimental site is a silty clay loam with a pH of 7.7 (in water paste); low in available phosphorus, organic matter and total soluble salts; low to medium in inorganic nitrogen; and high in exchangeable K and lime content. Moisture characteristics of different depths of the soil profile were almost identical within the depth of 120 cm., and the available water-holding capacities ranged between 15 and 17 percent. Moisture content of the soil at seeding time was adequate.

In a randomized block design, 12 treatments were replicated five times. Fertilizer treatments used in the experiment are given in Table 1. It can be seen from Table 1 that 20, 60 and 120 kg. of nitrogen per hectare were applied in one single application at seeding time, or the

Table 1. FERTILIZER TREATMENTS

Treatments	N-fertilizer application kg. N/ha. ($^{15}NH_4$ $^{15}NO_3$) Applied at				P - fertilizer application kg. P/ha. (0-50-0)
		Growth Stages			
	Seeding[1]	I Tillering	II Stem Extension	IV Boot	Seeding[1]
A	20[xx]		100		30[x]
A-1	20		100[x]		30
A-2	20[xx2]		100		30[x]
B	20[x]		40[x]		30
C	20[x]				30
D	60[x]				30
E	120[x]				30[x]
F	60[x]				30
G	20[x]	50[x]		50[x]	30
H	Control				Control
I	40	80			30
K	80	40			30

Note : xx Labelled with 2 % excess N - 15
x Labelled with 0.7 % excess N - 15 **or** P - 32
(1) N and P carried banded together and placed approximately 2 cm. below the seed for all treatments **except** A - 2.
(2) N and P carriers banded with the seed.
(3) 60 kg. N/ha. applied and worked into the surface soil prior to seeding. [sic]

total amounts were topdressed at appropriate rates in two or three dates of application at tillering, stem extension and boot stages. Usually a small "starter" amount of nitrogen, 20 kg. N/ha., was given at seeding time and the rest applied at the stem extension stage.

Ammonium nitrate with both the ammonia and nitrate labelled, and monocalcium phosphate (0-50-0) labelled with 32P were used as sources of N and P respectively.

Plot size was 1 x 5 meters, in which 1 x 1 meter was used for labelled fertilizers. Five V-shaped furrows about 8 cm. deep were made in each plot 20 cm. apart. The required amounts of N and P fertilizers were banded at the bottom of the furrow and the furrow was then partially filled by moving soil into the furrow. Wheat seed was sown by hand and covered with the soil.

The experiment was located in an area where wheat is in rotation with cotton. After the cotton was picked from the field, the land was plowed to a depth of 25 cm. and disked to a depth of about 10 - 15 cm. prior to seeding.

Due to some delay in receiving labelled fertilizers the experiment was seeded on December 9, 1969, and after 164 days of growth, the crop was harvested on May 21, 1970. A high yielding wheat variety, Penjamo 62, one of the Mexican dwarf wheat varieties which shows greater response to a high amount of nitrogen, was seeded at a rate of 130 kg. seed per hectare.

In order to determine the efficiency of the nitrogen uptake in different stages of growth, plant samples collected at stem extension stage and at final harvest were dried at 65°C, ground and analyzed for total N, P, 15N and 32P.

Climatic conditions of the experimental site were convenient for wheat through the whole growing season. The average annual rainfall of this area is about 640 mm., and a total of 470 mm. of rain was recorded during the experimental period. The crop was not irrigated, although very little rain fell during the last two months before the final harvest.

RESULTS AND DISCUSSION

Total yields of dry matter and the results of the chemical and isotopic analyses of the plant samples obtained from the stem extension stage are given in Table 2. An increase in the level of fertilizer application has resulted in an increase in the amount and nitrogen content of dry matter obtained from the stem extension stage. Consequently, the total N absorption by wheat at this stage of growth was also increased significantly.

Table 2. DRY MATTER: N, P CONTENT OF PLANT SAMPLES; % N DFF, % P DFF;

N, P ABSORPTION BY WHEAT AT STEM EXTENSION STAGE

Treatments	Dry matter kg./ha.	% N in dry matter	Total N absorbed by plants kg./ha.	% N derived from fertilizer	N dff kg./ha.	% P in dry matter	Total P absorbed by plants kg./ha.	% P derived from fertilizer	P dff kg./ha.
A	1,729	2.27	39.3	12.8	5.03	0.219	3.8	37.7	1.4
A-1	1,762	2.06	36.3	-	-	0.208	3.7	-	-
A-2	1,634	2.11	34.5	12.2	4.21	0.250	4.1	39.5	1.6
B	1,495	2.40	35.9	12.6	4.52	0.225	3.4	-	-
C	1,584	2.23	35.3	13.3	4.69	0.204	3.2	-	-
D	2,079	2.34	48.6	38.9	18.91	0.185	3.8	-	-
E	2,572	2.48	63.8	47.9	30.56	0.253	6.5	49.7	3.2
F	1,744	2.55	44.5	28.6	12.73	0.192	3.3	-	-
G	1,950	2.55	49.7	40.0	19.88	0.213	4.1	-	-
H	879	2.54	22.3	-	-	0.224	2.0	-	-
I	2,147	2.70	58.0	-	-	0.216	4.6	-	-
K	2,174	2.65	57.6	-	-	0.196	4.3	-	-
LSD 0.01	780	0.34	20.3	11.0	7.7	0.34	2.3	8.4	1.2
0.05	584	0.26	15.1	8.2	5.7	0.25	1.7	5.8	0.8

Using 15N and 32P-labelled fertilizers made it possible to determine the percentage of N and P in the composition of plant samples. Percent N derived from fertilizer was affected by amount rather than the time of application of nitrogenous fertilizer. These values ranged from 13 percent in the case of 20 kg. of nitrogen application to 39 and 48 percent in the case of 60 and 120 kg. of nitrogen application per hectare. Therefore, total fertilizer nitrogen absorbed by plant (kg./ha.) at the stem extension stage was also increased significantly by increasing rates of fertilizer nitrogen.

The rates and time of application of nitrogenous fertilizer did not have much effect on the phosphorus content of the plants, but percent P derived from fertilizer was significantly affected by the amount of fertilizer nitrogen. The higher rate of nitrogen stimulates the uptake of fertilizer phosphorus by plant. The percent P derived from fertilizer was increased from about 38 to 50 percent by the application of 20 and 120 kg. of N per hectare. Total absorption of fertilizer phosphorus by plants was also increased significantly with applied nitrogen. It has been found that fertilizer N stimulates plant use of fertilizer P throughout a wide range of soil conditions.

The straw and grain data are presented in Tables 3 and 4. Fertilizer treatments used in the experiment had great effect on grain and straw yields. Nitrogen applied at the tillering stage seems to be more effective in increasing grain and straw yields than nitrogen applied at the stem extension stage. In a recent field experiment using 15N-labelled fertilizers, identical results were found. In addition to 30 kg. of P, the application of 20, 60 and 120 kg. of N per hectare increased the grain yield about 1.1, 1.9 and 2.6 tons per hectare respectively.

The nitrogen content of grain and straw increased with increasing rates of fertilizer. Nitrogen applied at the stem extension stage may be considered to be more effective in increasing the percent N in both the grain and straw than nitrogen applied at tillering. Total N absorbed by grain and straw increased about two or threefold in control by application of 60 and 120 kg. of nitrogen per hectare. Rate of application rather than time of application of nitrogenous fertilizer influenced the total nitrogen absorption by plants.

The percentage of N derived from fertilizer in grain and straw samples was in close agreement. Those values were affected by both the time and rate of nitrogenous fertilizer applications. The later dates of applications at the boot and stem extension stages were more effective in increasing the percentage of fertilizer nitrogen in grain and straw than the earlier applications at tillering and seeding times. The percent N derived from fertilizer generally changed from 5 to 25 to 45 percent when 20, 60 and 120 kg. of N per hectare were applied. Consequently, total N absorbed by wheat from the added fertilizer was nearly proportional to the nitrogen applied.

Table 3. YIELD AND N, P CONTENT OF STRAW, % N DFF AND

N, P ABSORPTION BY STRAW

Treatments	Straw kg./ha.	% N in straw	Total N absorbed by straw kg./ha.	% N derived from fertilizer	N dff kg./ha.	% P in straw	Total P absorbed by straw kg./ha.
A	7,183	0.509	36.6	5.7	2.09	0.053	3.81
A-1	7,163	0.563	40.3	27.4	11.04	0.055	3.94
A-2	7,096	0.504	35.8	5.3	1.90	0.053	3.76
B	6,816	0.413	28.2	29.5	8.32	0.044	3.00
C	5,155	0.322	16.6	9.9	1.64	0.050	2.58
D	6,616	0.381	25.2	24.0	6.05	0.047	3.11
E	7,350	0.493	36.2	45.4	16.43	0.049	3.60
F	7,537	0.375	28.3	27.8	7.87	0.044	3.32
G	7,934	0.440	34.9	50.5	17.62	0.049	3.89
H	3,921	0.376	14.7	-	-	0.060	2.35
I	8,224	0.390	32.1	-	-	0.052	4.28
K	8,084	0.480	38.8	-	-	0.049	3.96
LSD 0.01	1,787	0.09	9.2	-	-	0.001	1.0
0.05	1,337	0.07	6.9	-	-	-	0.7

Table 4. YIELD AND N, P CONTENT OF GRAIN, % DFF AND

N, P ABSORPTION BY GRAIN

Treatments	Grain kg./ha.	% N in grain	Total N absorbed by grain kg./ha.	% N dff	N dff kg./ha.	% P in grain	Total P absorbed by grain kg./ha.
A	4,555	1.87	85.2	5.3	4.52	0.227	10.34
A-1	4,335	1.84	79.8	42.1	33.60	0.235	10.19
A-2	4,562	1.85	84.4	3.9	3.29	0.225	10.26
B	4,168	1.73	72.1	33.0	23.79	0.236	9.83
C	3,281	1.20	39.4	8.0	3.15	0.269	8.26
D	4,015	1.66	66.6	23.7	15.78	0.244	9.80
E	4,562	1.81	82.6	37.8	31.22	0.213	9 72
F	4,648	1.71	79.5	26.7	21.23	0.219	10.18
G	4,855	1.80	87.4	47.0	41.08	0.229	11.12
H	2,154	1.58	34.0	-	-	0.278	5.99
I	5,255	1.66	87.2	-	-	0.225	11.82
K	5,095	1.82	92.7	-	-	0.221	11.26
LSD 0.01 0.05	1,080 808	0.15 0.12	22.6 16.9	12.0 8.9	8.9 6.6	0.03 0.02	2.3 1.7

Table 5. % UPTAKE OF FERTILIZER N BY PLANTS AT STEM EXTENSION STAGE AND AT FINAL HARVEST

Treatments	Time of N fertilizer application	Total N applied kg./ha. (N-15 labelled)	% Uptake of fertilizer N			
			At stem extension stage	At final harvest		
			Dry matter	Straw	Grain	Straw + grain
A	Seeding	20	25.0	10.5	22.5	33.0
A-1	Stem extension	100	-	11.0	33.6	44.6
A-2	Seeding	20	21.0	9.5	16.5	26.0
B	Seeding	20	22.5	-	-	-
	stem extension	+ 40	-	-	-	-
	Total	60	-	13.8	39.7	53.5
	Seeding	20	23.5	8.0	16.0	24.0
D	Seeding	60	31.5	10.2	26.3	36.5
E	Seeding	120	25.5	13.7	26.0	39.7
F	Seeding	60	21.2	13.2	35.3	48.5
G	Seeding	20	-	-	-	-
	Tillering	+ 50	-	-	-	-
		70	28.4	-	-	-
	Boot	+ 50				
	Total	120	-	14.7	34.3	49.0

The phosphorus content of grain and straw differed significantly according to the amount of nitrogen used. The percentage P in the plants from control plots was highest and decreased with increasing yield.

Since the amounts of straw and grain were greatly affected by the rates of nitrogen applied, the total P absorbed by both the straw and grain was also increased with increasing nitrogen application.

Percent uptake of fertilizer N by wheat at the stem extension stage and at final harvest is given in Table 5. Wheat at the stem extension stage used about 20 to 30 percent of the nitrogen added. Percent uptake of fertilizer N by straw was not greatly affected by the fertilizer treatments used in the experiment and it changed between 10 and 15 percent. On the other hand, percentage of nitrogenous fertilizer used by grain was about 15 to 25 percent when fertilizer was applied at seeding time, and increased to about 35 to 40 percent when applied at the stem extension stage or the fertilizer was given in split application at seeding, tillering and boot stages.

Data obtained by combining the fertilizer N absorbed by grain and straw indicated that the percent uptake of fertilizer N by wheat (straw + grain) was changed from about 25 to 40 percent when fertilizer was applied at seeding time, while it increased to about 45 to 54 percent when fertilizer was applied at the stem extension stage or split into two or three applications at seeding, tillering and boot stages.

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SYSTEMS ANALYSIS : A DECISION-MAKING TOOL FOR ARID LAND DEVELOPMENT

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INTRODUCTION

From the dawn of civilization man has been concerned with the management of the waters of the earth for subsistence, for protection against the elements and for transportation. In many instances, he went to great lengths to secure this essential ingredient in his fight for survival, as witness the qanats here in Iran, the Roman aqueducts, the bamboo-drilled wells of China, and many other such examples. The ancient worlds in both hemispheres were no strangers to the complex physical, economic and social problems which still characterize man's never-ending battle against aridity, flood, drought, and pollution.

Water resources development is related to other national development needs and should be viewed as a complete system covering the many

uses for which water is employed--domestic, agricultural, industrial, waste disposal, forests, wildlife, natural beauty and transportation. The planners and designers of water resource management systems must often choose among a number of alternative plans for the location and design of structures, land and water management systems, and institutional arrangement for effecting the acceptable plan. In a similar fashion, farmers must choose the right combination of water, fertilizer, labor, etc. for a variety of crops to maximize their returns. Much of the research and analysis applicable to such systems has dealt only with bits and pieces of the system. Lack of adequate data and the laboriousness of methods of analysis have severely limited the number of alternatives that could be compared and prohibited a clear choice among a set of alternatives.

In our preoccupation with identifying problem areas in the broad and complex systems of water management, we sometimes fail to consider that adoption of a slight change may cause undue stress elsewhere in the entire system. Too frequently our approach to problem solving is to accept the problem as it exists and work directly towards a solution. This can be a too narrow process and may lead to a workable but still unsatisfactory solution. We allow our conventional concepts to guide us. Instead, we should turn our attention more to an analysis of the problem itself to determine whether it can be broken down into component parts. We should consider the possibility that the end of a problem may come through the development of new means.

Systems analysis is a tool that can permit a view of the entire problem. It takes into account means and ends, choices and alternatives. It makes use of prediction and advanced testing to suggest objectives and courses of action. It provides a method for more thorough consideration of alternatives.

Systems analysis may be viewed as a formalization of interactions. It contains few new concepts; it makes use of newly developed tools. Its application is by no means restricted to the planning of large-scale water resource management schemes. It can have a significant role in the decision-making processes of individual farmers.

The development of better data, together with the development of high-speed computers, and the availability of newer analytical techniques have opened the way to more comprehensive analyses of relevant alternatives in the design of water management systems and the benefits which can be derived from those systems.

There is no universally accepted definition of systems analysis nor is there any standardized method that can be presented as a general mathematical model for selecting the optimal alternative. It should be kept in mind that while systems analysis may be a powerful tool, the tools of operations research as applied to water resources systems can only assist the decision-making process. In addition, by itself systems

analysis is useless; a knowledge of water resources systems is essential. The purpose of this discussion is to take a brief look at selected examples in which some form of systems analysis may be used to advantage.

THE SYSTEMS CONCEPT IN WATERSHED MANAGEMENT

Watershed management is a relatively new science as evidenced by a lack of a large body of solidly established facts and well-proven relationships. There are several definitions of watershed management, one of which is the administration and regulation of all the available resources of a watershed for the production of water, control of erosion, regulation of streamflow and the control of floods. However, watersheds are generally of the multiple-use type in that they are used not only for the production of water but for timber, forage, wildlife habitat and for outdoor recreation purposes. While watersheds are flexible in that they may be managed to serve these various purposes, there is almost always some kind of tradeoff in manipulating a watershed. That is, altering the vegetation to increase streamflow, for example, may result in erosion as well as reducing the benefits to be derived from the watershed's uses other than for water.

In the water-short areas of the world, the management of water-source areas for the purpose of producing beneficial changes in the hydrologic regimen is a subject of increasing concern. The vegetative manipulation of forests to alter both the quantity and timing of streamflow has been under study in the United States for over 50 years. In studies of this type, attention is usually given to the harmful effects of a vegetative treatment such as erosion and sedimentation. However, no attention is given to the entire water system, from its source to its storage to its eventual use. For example, suppose a treatment produces water yield increases only in the very wet years and in those years the available storage facilities are not adequate to control the natural flows. This type of treatment would have no beneficial use as the storage facilities would simply be forced to spill the increased flow and hence the water would be wasted. Conversely, in the dry years when the added flow would be highly beneficial, the treatment may result in insignificant increases.

The following briefly illustrates a procedure for evaluating the effects of a watershed treatment designed to increase the water yield by looking at the entire water system, from its source to its use.

The planning for most water resources management systems normally starts with an analysis of precipitation to determine, among other things, its distribution in time with respect to the probable occurrence of drought periods. In our particular example, a study would be made on how a watershed transforms precipitation into streamflow. The results should be sufficiently sensitive to determine the effects of a

watershed treatment on streamflow. Finally, an investigation is needed to obtain the required storage to meet the downstream needs for water.

Available precipitation records are analyzed for the purpose of predicting what might happen in the future. Too often our analysis implies that the historical record will repeat itself. If hundreds of years of records are available, we may very well rely completely on historical records to predict the future. However, since this is not too frequently the case, some means of generating sequences of precipitation is needed. Stochastic models of precipitation, with all degrees of sophistication are currently available which will produce a synthetic time series that preserves the statistics (mean, standard deviation, etc.) of the available historical records. Hopefully, this simulated record can account for all the variability found in these historical records.

To convert precipitation into streamflow, computerized, mathematical watershed models are used. This simulated hydrologic response of a watershed coupled with a stochastic precipitation model results in a synthetic streamflow record. Then, using this simulated streamflow as inflow into a reservoir, a storage-draft analysis can be made for any kind of demand schedule, such as water for irrigation, municipal use or power.

The storage-draft relationship is simply a means for determining the size of the reservoir or storage needed to produce a firm outflow from the reservoir to meet specific downstream water requirements. Looking at this another way, the relationship can be used to determine the *dependable* supply of water that can be obtained from a given river system with its storage facilities. The supply can also be determined for those cases where users are willing to accept a certain amount of risk in receiving a greater quantity of water.

With the system thus defined, various watershed treatments under a variety of site conditions can now be evaluated to determine their potential usefulness to the ultimate consumer. The use of operations research or systems analysis is practically a necessity to determine both the optimal combination of treatments and their scheduling within the many constraints confronted by land managers. The physical constraints are only one aspect of the problem. Consideration must also be given to the budgetary, legal, social and political factors involved in water resources management.

SYSTEMS ANALYSIS IN AGRICULTURE

In this section two examples will be presented to illustrate the use of operations research techniques to select from a number of alternatives that particular course of action which will best accomplish the overall objectives.

Let us assume that a farmer wants to raise two crops. From past experience, he knows that his net profits are four and three units of money per unit of land. Naturally, he wants to maximize his profits. However, he has only 200 units of water and crop A requires two per land unit while crop B needs only one per land unit. An additional constraint is placed on the farmer in that he only has 150 land units.

The above problem could be solved quite easily to determine the number of acres that should be planted to each crop in order to maximize profits. Stated mathematically, the optimization problem is to maximize

$$V = 4A + 3B \text{ (objective function)}$$

subject to the constraints

$$2A + B \leq 200$$

$$A + B \leq 150$$

$$A \geq 0, \quad B \geq 0$$

If we replace the inequality signs by equal signs it is apparent that A should be planted on 50 land units and B on 100 units to maximize profits.

However, with as few as four crops and three constraints, the solution is far from obvious. If the objective function in this case is a simple linear algebraic equation and if the constraints also can be expressed as linear algebraic equations or inequalities involving nonnegative decision variables, the result is a particular type of optimization problem known as the linear-programming problem.

A possible four-crop problem that can be solved by linear programming is presented in the following table.

Requirement	Crop				Total Availabilities
	A	B	C	D	
Labor	1	1	1	1	$\leq$ 15
Water	7	5	3	2	$\leq$ 120
Fertilizer	3	5	10	15	$\leq$ 100
Unit Profit	4	5	9	11	Maximize
Acreage Planted	x_1	x_2	x_3	x_4	

The problem can be stated as follows:

$$\text{Maximize profit} = \text{maximize } (4x_1 + 5x_2 + 9x_3 + 11x_4)$$

subject to the constraints

$$1x_1 + 1x_2 + 1x_3 + 1x_4 \leq 15$$

$$7x_1 + 5x_2 + 3x_3 + 2x_4 \leq 120$$

$$3x_1 + 5x_2 + 10x_3 + 15x_4 \leq 100$$

$$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0,\ x_4 \geq 0$$

The solution to the above problem turns out to be

$$x_1 = 50/7 \qquad x_3 = 55/7$$

$$x_2 = 0 \qquad x_4 = 0$$

In addition to wanting optimal values, farmers may also want to know how profit would be affected by increasing each input (labor, water, fertilizer, etc.) or by a change in the cost of the raw materials--and consequently a change in the unit profit. In many real applications of linear programming models, these considerations are even more important than finding exact optimal values.

In many instances, time is an important consideration such as in dealing with sequential-decision processes. The farmer's concern about when to irrigate--at what soil moisture level? or at what stage of growth?--is such a process.

Certain semi-arid regions are continually faced with water shortages, especially for irrigation. Farmers should be advised not only on the most efficient methods for applying water but also on those practices that will result in the greatest return per unit of water.

Suppose experiments on a given crop were conducted to determine the effect that a given moisture stress at a particular stage of growth had on crop yield. Let us assume that these effects can be indicated by the use of yield coefficients, and that the following table is a result of these experiments:

YIELD COEFFICIENTS

Deficiency, Moisture units	Stage of growth			
	A	B	C	D
0	.9	1.0	1.1	1.0
1	.8	.7	.8	.9
2	.7	.5	.7	.8
3	.5	.3	.2	.6
4	.3	.2	.1	.3

If an additional assumption is made that these yield coefficients are additive, then it is readily seen that the total seasonal coefficient for no soil moisture deficiency is 4.0. This would represent the maximum yield obtainable for a given climate and no other limiting factors.

To illustrate a particular example, suppose a farmer is faced with a 25 percent shortage in irrigation water, and that he has the option of using the water at any time throughout the growing season. The question is, then, when should he choose to short his crop to have the least effect on crop yield.

The problem can be simplified by choosing the stages of growth such that they all require the same amount of water, say four moisture units each. This particular type of problem is readily solved through the use of dynamic programming techniques.

The usual procedure in such problems is to work backwards. For growth stage D, the yield coefficients are shown in the last column of the above table. That is, if we arrive at this stage with a given deficiency, the choice is obvious.

Now, let us look at stage C. If we arrive in time at this stage with no deficiency, the required four deficient units will have to be selected from some combination of those occurring in both stages C and D. For example, the farmer may choose to have the entire deficiency in stage C and none in D, or three in C and one in D, or two in each and so on. It turns out, that for this situation, the best choice as indicated by the highest combined yield coefficient would be to hold back two moisture units in each stage.

Still looking at stage C, a similar calculation is made assuming that a deficiency of three moisture units has to be allocated to both

stages C and D. This is repeated for one and two deficient units. The following illustrates the procedure:

If four units are to be allocated to stages C and D:

Combined yield coefficients	Selection
1.1 + 0.3 = 1.4	
0.8 + 0.6 = 1.4	
0.7 + 0.8 = 1.5	use 2 units in C
0.2 + 0.9 = 1.1	
0.1 + 1.0 = 1.1	

If five units (three deficient) are to be allocated:

Combined yield coefficients	Selection
1.0 + 1.7 = 2.7	use 0 units in C
0.7 + 1.9 = 2.6	
0.5 + 2.0 = 2.5	
0.3 + 2.1 = 2.4	

If six units (two deficient) are to be allocated:

Combined yield coefficients	Selection
1.0 + 1.9 = 2.9	use 0 units in C
0.7 + 2.0 = 2.7	
0.5 + 2.1 = 2.6	

If seven units (one deficient) are to be allocated:

Combined yield coefficients	Selection
1.0 + 2.0 = 3.0	use 0 units in C
0.7 + 2.1 = 2.8	

The same process is repeated at stage B with the same result. Stages B and C should have no moisture deficiency.

Thus, the final result of this particular analysis indicates that for the situation here 75 percent of the required water is available for irrigation (four units deficient out of 16 required), the highest yield would be obtained by supplying stages A and D with 50 percent

(two moisture units) of their requirement and 100 percent for stages B and C.

A similar analysis can be made for any other deficiency. The farmer can then go one step further. He may find out that the greatest return can be obtained by applying less than the total amount of water required.

While the above methodology is correct, there are several drawbacks to this procedure. Few or no data are available to determine the yield coefficients. The additive nature of these coefficients which implies that a moisture stress at one stage has no effect on another stage of growth may not be true. There are other problems, too, such as the interrelationship between water and other crop variables. Nonetheless, more and more research efforts are being directed along these lines because of the importance of the problem.

DISCUSSION AND SUMMARY

Since arid land development is intimately associated with water resources systems, procedures that aid in the management of such systems is of relevant concern to all seminar participants. From the examples presented, systems analysis may be defined as the *art* and *science* of selecting from a large number of feasible alternatives that particular set of actions which will best accomplish the overall objectives within the constraints of law, economics, resources and political and social pressures. Perhaps a more appropriate term would be *decision analysis.*

The intent of using examples in this paper is not to discuss the procedures themselves but rather to illustrate the type of problems that can be dealt with using these techniques. In the first example, the idea of a system was presented in that plans for treating a watershed to induce more runoff should be looked at from the standpoint of both the damaging effects resulting from such an action and the ultimate recipient of such action. Thus, if the watershed treatment produces reservoir-filling sediment or increased water supplies come only at times when there is no available storage space then this action would have little or no economic value.

The use of an important systems analysis tool, simulation, was used in this example. To account for the variable nature of streamflow, a stochastic precipitation model was coupled with a deterministic watershed model to generate a synthetic series of streamflow both for the treated and untreated watersheds. Other systems analysis techniques would have to follow to determine a detailed course of action--what type, where and when the treatments should be applied.

To emphasize the point that systems analysis can be used not only

for large-scale water resources systems, two types of optimization problems of concern to individual farmers were illustrated. In the first case, the aim was to maximize profits by selecting the area to be planted to each crop. Crops have different requirements for labor, water and fertilizer and each yields a different return to the farmer. Since there are obvious limitations to the land, water and finances that are available, the selection has constraints as well as many alternatives. This first instance is an example of linear programming.

However, since all objective functions or constraints do not have linear relationships, other techniques have to be used in these cases. Also, the time element is difficult to introduce into a linear programming problem. Many water resources problems concern the optimization of a sequential-decision process. For example, scheduling irrigation water applications for the sake of water conservation or for maximizing net profits are problems that can be solved using the techniques of dynamic programming.

Farmers are continually confronted with such questions as--How much fertilizer should I use?--When should I apply it?--When should I irrigate considering that I have a limited water supply?--How much land can I irrigate with an occasionally deficient supply? Questions such as these can apply either at the farmer or project level. The procedures used to obtain solutions to these problems are not necessarily difficult. However, they may be impractical or even impossible to attain because of the type of data they may require. In the optimal irrigation timing example, the yield coefficients are simply not available for most crops. Research, however, is currently being directed to obtain the necessary data and relationships.

In summary, the techniques of *operations research, systems analysis,* or *decision analysis* are relatively new and hence are usually a mixture of art and science. Attaining improved decision making still involves a considerable amount of ingenuity on the part of the manager. Not all parts of the problem can be solved with mathematical models and high-speed computers. Man's experience is still an essential ingredient in decision-making processes. Systems analysis has, on the other hand, demonstrated an important principle. An action program, whether or not instituted by systems analysis, cannot be undertaken in isolation from the surrounding managerial environment. It is readily apparent, for example, that intensifying the agricultural development upstream will affect the quality and quantity of water available to a downstream irrigation project. Other action programs, however, may result in much more subtle changes to another aspect of the environment. Thus, a systems analysis or operations research project should be regarded, at least in part, as a systems effort.

IRRIGATION WATERS OF THE INDUS PLAINS AND THEIR SALT LOAD *

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SUMMARY

This paper is concerned with the optimum salt load and quality of the irrigation waters required for intensive scientific agriculture in the arid and semi-arid Indus Plains. The surface and groundwater of the area have been classified on the commonly used quality criteria for water quality standards and classification applied in the United States and Pakistan. The river waters used for irrigation in the Indus Plains are of high quality, having a salt content of only 200-300 ppm. The quality of groundwater presents a variable picture. The salt content and the alkalinity hazard generally increase with depth and with distance from the source of recharge, viz. the rivers and the canals. The concentration of various ions varies between different ranges of salt concentration. There are three general zones of groundwater quality--the fresh water zone, the mixing zone and the unusable saline water zone. The groundwaters having less than 1,000 ppm TDS are classed fresh, and those in the range of 1,000-2,000 ppm TDS in the southern zone as marginal; these waters can be used by mixing them with canal

* This paper was prepared for the seminar, but not read.

water. Waters having a salt content of more than 3,000 ppm in the northern zone and 2,000 ppm in the southern zone are classed as unusable. The alkalinity hazard indicated by the SAR value and the RSC further restricts the usability of groundwaters. The gypsum requirements for the amendment of high SAR and RSC waters are considered to be beyond the farmers' means.

The most economical method of exploitation of groundwater for irrigation use is pumping by tubewell. However, the recirculation of pumped water used for irrigation involves the hazard of deterioration in its quality. A certain proportion of the pumped water has to be exported to keep the quality under control. Where the depth of sweet groundwater is shallow, deep and high-capacity tubewells cannot be used and the concept of a compound tubewell pumping two streams of water, one of inferior quality in the bottom and the other one of the overlying fresh water has been introduced.

Monitoring studies on the tubewells operating in Salinity Control and Reclamation Projects 1 and 2 have revealed that the deterioration is more serious than indicated by the earlier forecasts. This underlines the fact that only waters of low salinity and alkalinity hazard should be exploited for irrigation use.

A general picture of research on soil and water quality carried out in the country to date is presented. Some of the problems which need more intensive research in the future are:

1) The effects of different qualities of water under different soil conditions

2) The pumpage by deep versus shallow tubewells

3) The effect of the depth of the water table and its quality on crops under different soil conditions

4) The measures by which the groundwater quality can be maintained as usable or improved

5) The criteria for mixing groundwater with surface water for irrigation

6) The irrigation practices required for use of waters of variable quality.

INTRODUCTION

West Pakistan covers a land area of about 311,000 square miles. The climate is in general tropical or subtropical. Summer temperatures are high and exceed 120°F in the upper Sind. At the other extreme, the

minimum winter temperatures are several degrees below zero in the Quetta region in Baluchistan and the high mountain valleys of the north. The natural precipitation decreases from the north towards the south. Along the foothills of the Himalayas in the north, the average rainfall is more than 26 inches. In the submontanes and the upper parts of Bari and Rechna Doabs it is about 18 inches. Proceeding to the south in Bari, Rechna and Thal Doabs and Bahawalpur, the average rainfall is 12 inches or less. In the northern part of Sind and in Baluchistan the average rainfall is less than 5 inches; towards the southwest, as the tropical coastland is approached, it increases to about 10 inches.

West Pakistan is divided into three distinct hydrological units. These are the Indus Basin, the basin of the Kaharan Desert and the Makran coastal streams discharging directly into the Arabian Sea. The area of the Punjab and the Sind Plains, containing the principal canal irrigation systems, comprises the Indus Plains.

Due to the high temperatures prevailing in the plains, evaporation is high. The theoretical lake evaporation varies from 57 to 75 inches in a year in the northern areas and from 72 to 87 inches in a year in the southern areas. The highest evaporation occurs during the summer season from April to September. As a consequence, agriculture in the arid and semi-arid Indus Plains, some 204,000 square miles in area, is almost entirely dependent upon irrigation.

The Indus River and its tributaries--the Jhelum, Chenab, Ravi and Sutlej, pass through Pakistan territory but the waters of the Ravi and the Sutlej have gone to the share of India. About 140 million acre feet of water crosses the border into Pakistan from the Indus, Jhelum and Chenab Rivers, 84 percent of which is received in the summer and 16 percent in the winter months. At the present stage of development about 98 million acre feet of this water is being diverted for irrigation use and the rest goes into the sea. About 44 million acre feet of the diverted water is delivered at the watercourse heads and the rest seeps underground from the irrigation canals and their offtakes or evaporates on the way from the diversion headworks to the field. The gross area within the canal system is about 37 million acres and the arable area about 33 million acres. In this arable commanded land, water is provided for about 21.5 million acres in the summer as well as in the winter, and for about 11.5 million acres in the summer only. The area actually irrigated in a year is about 24 million acres. The water supply provided by the canal systems is far from adequate to crop the whole area in the summer or in the winter. Even in the area irrigated, the water applied does not meet the full consumptive use requirements of the crops. As a result, the maximum crop production cannot be obtained. This deficiency of water also results in an upward movement of salts in the soil, which makes the soil saline.

Seepage from the existing irrigation system has built up a huge

reservoir of groundwater in the Indus Plains. Before the construction of the canal system the groundwater depths ranged up to 100 feet. Over the past 100 years or more since the first canal system came into operation, the water table has been steadily rising. According to the Colombo Plan Survey, by 1953-54 an area of about 11.3 million acres was severely affected by waterlogging and poor drainage. The rise of the water table within 10 feet resulted in an appreciable upward movement of subsoil water to the surface by capillary action. With the evaporation of capillary moisture the salts contained in the water and dissolved from the soil profile are deposited at the surface. Supplemental irrigation water is now required not only to meet the consumptive use requirements of crops but also to depress the salts accumulated in the soil. Also, to maximize agricultural output it is necessary to raise the intensity of cropping. Crop cover, by reducing evaporation from the soil surface, checks the capillary rise of moisture and salts to the surface.

The water table has to be lowered to and maintained at a safe depth and the full water requirements for crop production and leaching of salts have to be provided. For this purpose pumping from the groundwater storage has been undertaken in the valley. In 1969 there were about 8,500 tubewells (with an average capacity of about 3 cusecs), installed by the Government, pumping about 5 million acre feet of water and about 80,000 private tubewells (with an average capacity of about one cusec), installed by farmers pumping about 14 MAF of water per year.

The government tubewells are being installed under a programme for salinity control and reclamation. The total number of irrigation tubewells will be 28,280 in the Punjab (the northern zone of the Indus Plains) and 9,658 in the Sind (the southern zone).

This paper is concerned with the salt load and the quality of the irrigation waters already being used and those planned for future development in the Indus Plains.

WATER QUALITY CRITERIA AND STANDARDS

Criteria

For successful crop production, the irrigation water has to be of such quality that it does not injure plant growth. The important criteria for water quality classification commonly used are:

1. Salt Content

The total concentration of salts, named total dissolved solids (TDS), in water is expressed either in parts per million (ppm) or by the electrical conductivity in micromhos per centimetre at 25°C

(Ec). These two have the relationship:

$$TDS = K \times Ec$$

The value of K varies from 0.62 to 0.64 for different salts.

2. Sodium Adsorption Ratio (SAR)

The injury to plant growth is caused not only by concentration of salts, but also by the concentration of sodium ions which causes base exchange in the soil and results in the formation of sodium soils. Sodium soils are alkaline in reaction and impermeable to water. This sodium hazard is expressed by the relative concentration of sodium and calcium plus magnesium, termed as Sodium Adsorption Ration (SAR). The relationship is defined by the following empirical equation wherein the ionic concentration of sodium, calcium and magnesium is expressed in milliquivalents per litre:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

3. Residual Sodium Carbonate (RSC)

Apart from the excess of sodium ions as shown by the SAR value, an excess of carbonate and bicarbonate over calcium and magnesium can result in precipitation of the divalent ions of calcium and magnesium as carbonates which causes an excess of sodium ions in the water. The hazard is expressed by the Residual Sodium Carbonate (RSC) value suggested by Eaton. It is indicated by the equation:

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

4. Boron Concentration

The concentration of minor elements like boron in the water may be toxic to plant growth. Boron is essential to plant growth, but exceedingly toxic at concentrations only slightly above the optimum.

Standards

1. Salt content

The water quality standards for the salt content adopted by the

U.S. Salinity Laboratory are the following:

Class	Total Salts (ppm)	Fitness for Use
C1	Less than 250	Can be safely used; the required leaching occurs in normal irrigation practices
C2	250 - 750	Can be used with moderate amount of leaching
C3	750 - 2,250	Cannot be used on soils with restricted drainage; appreciable leaching required
C4	Above 2,250	Not suitable in ordinary conditions

The advisers of the former Ground Water Development Organization of the Irrigation Department, and later the general consultants of the West Pakistan Water and Power Development Authority (WAPDA) connected with development of groundwater for irrigation in the Indus Plains, suggested the following standards:

Class	Total salts (ppm)	Fitness for Use
a	Less than 1,000	Can be used directly
b	1,000 - 3,000	Marginal; requires mixing with canal water
c	Above 3,000	Unfit

2. SAR value

For the alkalinity hazard, the Punjab Irrigation Research Institute had arrived at the following formula for expressing the quality of irrigation water. The value given by this formula was named Salt Index (S.I.):

$$S.I. = (\text{Total Na} - 24.5) - \left[(\text{Total Ca} - \text{Ca in } CaCO_3) \times 4.85\right]$$

The quantities in this formula are in parts per 100,000. The Salt Index is negative for all good waters varying from 24.5 to zero and positive

for those unsuitable for irrigation ranging from 0 to any value. In the absence of calcium salts in water, more than 620 ppm of sodium chloride or 750 ppm of sodium sulphate will result in the gradual replacement of calcium in soil by the sodium in water. With the presence of calcium salts in waters, to be on the safe side, the concentration of sodium chloride must not exceed 1,170 ppm.

The U.S. Salinity Laboratory, in later years developed the concept of the SAR value. The standards adopted are the following:

Class	SAR Value	Fitness for Use
a	Less than 10	Excellent
b	10 - 18	Good
c	18 - 26	Fair
d	Above 26	Poor

3. RSC

The following standards have been suggested by the U.S. Salinity Laboratory:

Class	RSC	Fitness for Use
a	Less than 1.25	Probably safe
b	1.25 - 2.5	Marginal
c	Above 2.5	Not suitable

The standards suggested by the WAPDA's consultants for the Indus Valley groundwaters are:

Class	RSC	Fitness for Use
a	Less than 2.5	Usable
b	2.5 - 5.0	Marginal
c	Above 5.0	Not suitable

4. Boron

The permissible limits of boron concentration range from 0.33 ppm to 3.00 ppm for different crops. Toxic concentrations of boron have not been met with in the Indus Valley waters.

QUALITY OF INDUS VALLEY SURFACE AND GROUND WATERS

Surface Water

The river flows of the Indus and its tributaries are derived from snow melt on the Himalayas and the monsoon precipitation. Analysis of samples of the Indus, Jhelum and Chenab waters collected at the rim stations at Attock, Mangla and Marala show that the mineral content commonly falls in the range of 150-250 ppm TDS and consists mainly of alkaline earths and bicarbonates. As the higher value represents low supplies in the winter and the lower value high flow conditions in the summer, the average mineral content of the water at the rim stations is less than 200 ppm. Near the outfall of the combined waters of the Indus and its tributaries into the sea, the average salt content is about 300 ppm. In planning studies for the integrated use of the surface and groundwaters, it is assumed that the surface waters have about 250 ppm TDS.

The SAR values of these waters are all below 1.0, and the RSC is nil. According to the accepted criteria, these surface waters are of excellent quality and no restrictions apply to their use for irrigation.

Groundwater

Extensive groundwater quality surveys have been carried out both in the northern and the southern zones of the Indus Plains. These plains are underlain by saline groundwater below variable depths. Seepage from rivers, the canal system and surface runoff from natural precipitation has imposed better quality water upon the saline subaquifer. The data indicate a gradual increase in mineralization with depth and with distance from the fresh water recharge source. Local variations of the quality of shallow supplies (up to 50-100-foot depths) are of about the same magnitude as the regional variations. However, the quality of water data for the shallow supplies tends to have a regional pattern similar to that of the deep groundwater.

The mineral content of the deeper groundwater of the northern zone (the Punjab) ranges from less than 200 to more than 10,000 ppm. In general, the mineral content increases with distance from the rivers which are the principal source of natural recharge. This transition from low to higher ranges in quality is gradual.

The groundwaters of the Punjab are characterized by their evolution from calcium, magnesium bicarbonate waters near their source of recharge to waters containing a dominant proportion of sodium. Groundwaters containing from 500-1,000 ppm are commonly of the mixed type, having about equal proportions of the common anions--bicarbonate, chloride and sulphate. With increasing mineralization, from 1,000 -3,000 ppm, the relative proportion of chloride and sulphate increases and these waters are generally of the sodium chloride or sodium sulphate type; in the Punjab area sodium chloride predominates.

The general pattern of groundwater distribution in the southern zone is one of a band of good quality water immediately adjacent to the river and of increasing salinity away from the river. A lesser quantity of good water is available on the right bank of the river. This is due to the proximity of the limestone hills on the right bank and to the poor aquifers associated with piedmont soils. Another feature that is apparent is the complete absence of useful groundwater in the delta area south of Hyderabad except for some shallow pockets in the fairly recently abandoned river channels of the Gaja Command. Some of the most saline groundwaters of the area are found in the delta where samples with salinities twice as high as seawater and more have been recovered. Throughout the area the salinity of groundwater increases with depth and no case has been recorded of saline water overlying fresh water.

INTEGRATED USE OF SURFACE AND GROUNDWATERS

Mixing Criteria in Use

According to the standards which had been recommended by the regional consultants of WAPDA for the northern zone, in the integrated water resources development planning, the groundwater supplies have been classified under three heads on the basis of the mineral content of the water. Groundwater containing less than 1,500 ppm TDS is classified as nonsaline and safe for use under accepted irrigation and water management practices which implies that about one-third of the applied irrigation water is derived from canal supplies. Under those conditions the maximum concentration of applied water would be about 1,100 ppm of total dissolved solids. Groundwater containing 1,500 to 4,000 ppm TDS is classified as intermediate; use of the intermediate quality groundwater requires dilution with canal supplies or special water and soil management practices. Water with a concentration of more than 4,000 ppm TDS is classified as saline and unsuitable for economic development for irrigation supplies under present conditions.

In the southern zone the classification of groundwaters recommended by the regional consultants of WAPDA has been based on their salinity and alkalinity. After a study of a large number of samples of groundwater it was concluded that water with salinity in excess of 1,500 ppm TDS and water with SAR values above 7.5 should not be used. Waters that are more saline and more alkaline can be used only after

mixing with river water so that the resultant mixture meets the criteria laid down above. For this purpose it is considered that mixing of more than two parts canal water to one part saline water is impracticable below minor canal level.

IACA's Views on Quality Criteria for Integrated Use

The Irrigation and Agriculture Consultants' Association (IACA), consultants to the World Bank, have also given particular attention to the requirements for the quality of irrigation supplies in order to establish criteria for groundwater development. They considered that water with the following properties could be used directly for irrigation:

1) Ec of less than 1,500 micromhos per cm. at 25°C; this is approximately equivalent to 1,000 ppm TDS.

2) SAR of less than 10.

3) RSC of less than 2.5 meq per litre.

Eventually it might be possible for water of higher salinity to be used directly on the crops, but that would require an increased application of water and a degree of control which IACA did not regard as feasible at present or in the near future.

They classified the groundwaters in terms of the following general zones:

1) Fresh groundwater zones, i.e. areas with deep groundwater quality, have TDS less than 1,000 ppm. Tubewell waters can be applied directly to the crops in these zones.

2) Mixing zones, i.e. areas where tubewell water has to be diluted with surface water before being used for irrigation, deep groundwater quality is of intermediate salinity 1,000 to 3,000 ppm TDS, in all areas except the southern region, where a limit of 2,000 ppm TDS is applied. The lower limit in the southern region allows for the more rapid increase of salinity with depth of the aquifer than in the northern region and for the higher salinity of the river water after it has received the drainage effluent.

3) Saline groundwater zones, where the ground would not be used for irrigation, deep groundwater has more than 3,000 ppm TDS in the northern region and more then 2,000 ppm TDS in the southern region. The proposed criteria for use of groundwater for irrigation are summarized in the following table.

PROPOSED MIXING RATIOS FOR OVERALL BASIN PLANNING

Groundwater Quality Zone	All Except Lower Indus		Lower Indus Region	
	Deep Groundwater Quality (ppm TDS)	Average Mixing Requirements, (Surface Water to Groundwater)	Deep Groundwater Quality (ppm TDS)	Average Mixing Requirements, (Surface Water to Groundwater)
Fresh	Less than 1,000	No restriction	Less than 1,000	No restriction
Mixing	1,000-2,000 2,000-3,000	1 : 1 2.5 : 1	1,000-2,000	1 : 1
Saline	More than 3,000	Not used	More than 2,000	Not used

It is not only necessary to dilute the groundwaters having TDS between 1,000 and 3,000 or 2,000 ppm, but it is also necessary to provide the leaching requirements to keep the salt concentration of the soil solution within safe limits for plant growth. This leaching requirement applies also to waters classed as good quality waters having TDS below 1,000 ppm. Even the river water having TDS in the range of 200-300 ppm has about 10 percent leaching requirements which increase to 37 percent for waters having TDS in the range of 500-1,000 ppm. The intermediate quality of groundwater having TDS of 1,000-3,000 and 2,000 ppm when mixed with river water in the ratios given in the preceding table will, therefore, have its leaching requirement dependent upon its salt content. Beyond the limit of 3,000 and 2,000 ppm, mixing with canal water will require a higher ratio of canal water, and this is not available.

IACA, in proposing the above mixing ratios, did not take the SAR value and RSC content into account. The hazard involved in both these values can only be counteracted by the use of gypsum by which the exchangeable sodium can be replaced by calcium ions. Working out the gypsum requirements of the well waters in Chaj and Rechna Doabs, Ghulam Mohammad has shown that the sodium hazard of water having a salinity content of 3,000 ppm, after mixing with canal water in the ratio of 1:1, requires about 1.2 tons of gypsum per acre foot of water applied. If a 3-acre foot delta is applied in a year the requirement would be about 3.6 tons per acre, which costs about Rs. 300. Such a recurring cost is beyond the poor farmer's means.

CHANGES IN THE GROUNDWATER QUALITY WITH PUMPAGE

Tubewell pumpage can result in changes in the hydrologic environment, which in turn can influence the quality of water of the aquifer. The important factors that can affect the salt balance of the groundwater are:

1) Leaching of salts present in upper soil layers

2) Recirculation of aquifer salts

3) Salt accretions from irrigation with surface water

4) Salt accretions from canal and river seepage

5) Reduction of groundwater volume with mining

6) The amount of groundwater removed by drainage.

The rainfall can improve the quality of water but its effect is very small in the Indus Plains because the component of rainfall recharge is low.

The Water Resources Group of Harvard University conducted studies for the Revelle panel of U.S. scientists, who visited Pakistan in 1962-63, to investigate the rate of increase of groundwater salinity with pumpage and use. A mathematical model, called the "salt-flow model" for digital computer simulation was developed and investigated. The effect of many important design parameters such as tubewell depth and pumping rate relative to surface flow was analyzed.

It was assumed in these studies that leaching of upper soil layers, recirculation of aquifer salts, salt accretions from irrigation with surface water and salt accretions from canal and river seepage are operative uniformly over the whole area and that uniform mixing of saline components occurs. However, the seepage from larger canals and rivers, which constitutes a significant portion of the recharge balance is localized. In spite of these assumptions, the study gave some indication of the average rate of salinization. The conclusions reached are listed below:

1) Tubewell spacing has no effect on the salt buildup characteristics of irrigation water.

2) Tubewell depth: a) increases the rate of buildup inversely proportional to the depth, and b) increases concentration of the irrigation water due to salt on the surface of the earth inversely proportional to depth.

3) Drainage is necessary up to 10 to 15 percent of the tubewell effluent.

4) The rate of salt buildup is directly proportional to the pumping rate.

5) Initial groundwater concentration raises or lowers the entire buildup curve in proportion to the initial concentration.

6) Deep wells (250 ft. or more) should be employed in all areas where there are 60 or more tons per acre of salt on the ground surface and in the upper layer of the soils.

The conclusions of the Harvard University Water Resources Group are important to long-term development plans. They affect area development plans and the amount of saline water disposal that must be provided. With mining, groundwater salinization will be more rapid than would follow from the above study. Increased surface water recharge will enhance the quality of the groundwater. Groundwater salinization will be slower near large canals and rivers. It appears desirable to arrange for the export of some tubewell water when the salt load is greater than, say, 2,000-3,000 ppm. In areas of low salinity ground-

water this can be delayed till the salt concentration rises to that level.

In the light of this study, the Revelle panel in their report and subsequent discussions estimated that with recycling of groundwater to supply additional irrigation water and at the same time prevent a further increase in waterlogging, the groundwater will within 5 to 10 years of pumping, have become too saline for further use. The catastrophe can be guarded against only by following the suggestion that only water of low salt content should be pumped.

In addition to the above factors, which essentially involve mobilization of salts during pumping and use of groundwater, there are also hazards of lateral intrusion of saline water into fresh water zones. A primary objective of the development plan is to lower the water table first in the nonsaline zones. Drainage benefits in the saline zones are a major byproduct of groundwater development in the nonsaline and intermediate zones. The resulting pattern of groundwater movement will inevitably cause lateral movement of the saline water. WAPDA's consultants were of the view that this is not a matter which warrants immediate action as the velocities of lateral movement are extremely low and change in quality, if any, occurs very slowly.

Monitoring Studies

Monitoring studies on the tubewells operating in Salinity Control and Reclamation Projects 1 and 2 in the northern zone have revealed that the deterioration hazard is more serious than indicated by the Harvard study. In Scarp 1, during the 5 to 7-year period of operation between 1960-62 and 1967, the area of groundwater containing less than 1,500 ppm TDS decreased from 1.09 million acres to 1.07 million acres with a corresponding increase in area of TDS above 1,500 ppm. During the same period the area in which tubewells were providing groundwater of SAR values less than 10 was reduced from 900,000 to 867,000 acres. There was naturally a corresponding increase in the area from which groundwaters of SAR values greater than 10 was pumped. Similarly, the area having RSC content of less than 1.25 meq/l decreased from 265,000 acres to 121,000 acres. The area having RSC between 1.25 and 2.5 meq/l increased slightly from 274,000 to 280,000 acres. The area having RSC content exceeding 2.5 meq/l increased from 700,000 acres to 840,000 acres.

In the monitored part of the Scarp 2 area similar data are available by number of wells for the period 1964-70. The distribution of wells falling under permissible limits of TDS, SAR and RSC is tabulated below:

Year	TDS		SAR		RSC	
	0-500 ppm	500-1,000 ppm	0-5	5-10	0-1.25 meq/l	1.25-2.50 meq/l
1964	71	27	88	10	84	4
1970	64	27	79	12	75	16

These observations highlight the deterioration hazards in the water quality of irrigation tubewells. Dependence on the studies under controlled conditions conducted by the Harvard University's Water Resources Group will not suffice. Therefore, intensive investigation under field conditions are urgently called for.

Pumpage of Usable Water Overlying Brackish Water

The most economical method of exploitation of usable groundwater for irrigation is pumpage by tubewells. The depth of usable water overlying saline water varies widely. In areas having usable water up to 200-300 feet in depth it is possible to install deep tubewells of high capacity. But where the layer of usable water overlying brackish water is relatively shallow the deep tubewells cannot serve the purpose. For such areas a compound well has been proposed to eliminate the saline water from being pumped with the upper good quality water by the maintenance of two separate discharge streams, the main one of fresh water from the aquifer and the minor one of the saline water from the well bottom.

Where the aquifer conditions do not permit pumpage by tubewells the only economical drainage measure possible is tile drainage. Tile drainage has its own advantage. It will drain only the upper 4-6 feet of the soil profile. When the salt content to this depth has been drained out by leaching, the drainage outflow from the tiles will be of a usable quality of water. A number of such areas falls in the southern zone; a small number also exists in the northern zone.

Drainage of Pumped Water

As pointed out by the Revelle panel, it is necessary to export some of the pumped water to save groundwater from deterioration by an increase in the salt concentration due to recirculation of pumped water. The export of saline groundwater is of special concern to the

irrigated lands of the southern zone. For the export of this drainage water as well as for the disposal of surface runoff from rainfall and of the excess of water applied in rice areas, WAPDA's consultants for the southern zone (Hunting Technical Services) had proposed two outfall drains for the southern zone--the Right Bank Outfall Drain for the area on the right side of the Indus, and the Left Bank Outfall Drain for the area on the left. The Right Bank Outfall Drain will outfall into the Indus while the Left Bank Outfall Drain will outfall into the Rann of Kutch. IACA has given high priority to the Left Bank Outfall Drain, as the bulk of the nonrice growing areas lies on the left bank. The spinal outfall drain will start in the Khairpur area and running along the irrigation boundaries will outfall into the Rann of Kutch. It will be about 270 miles in length and will have three main drains with their branches.

RESEARCH ON WATER QUALITY

Investigations and research on scientific land and water use in the Indus Plains are as old as the present system of weir controlled canals. Intensive and pioneering research work on the effect of irrigation with river waters started about half a century ago. The Irrigation Research Laboratory established at Lahore in 1924 rose to the status of a full fledged Research Institute by 1931-32. Scientists like Mackenzie Taylor, Puri, Asghar and Mehta devoted themselves to research on the problems of soil salinity and water use. Standards of soil and water quality were established and the means of reclamation of deteriorated soils fond. The implementation of these research findings in the field started in the late thirties and in the mid-forties a separate Directorate of Land Reclamation was established. Valuable work on the movement of moisture and the salts in soil was initiated before Independence by means of lysimetre studies which continued after Independence. Till then the river supplies diverted were the only source of irrigation.

The development of groundwater as a source of supplemental water supply for irrigation had just made a start before Independence. A group of 22 tubewells was installed in 1939 in a small area near Lahore called Karol. In 1945 a project for the installation of some 1,800 tubewells along the main canals in Rachna and Chaj Doabs was undertaken with the aim of checking the rise of the water table by seepage from the canal system and to add the pumped water into the canals to supplement the water supply for irrigation and reclamation. This work was completed in 1954. In this connection investigations and research on groundwater quality were initiated. During the fifties private farmers also started installing tubewells for irrigation. As a result of the severity of the problems of salinity and waterlogging, more intensive research on groundwater quality started by the end of the sixth decade. The installation of tubewells for the control of waterlogging and salinity by the government agencies was undertaken on a larger scale and from 1962 the era of WAPDA's scarps started.

Thanks to the extent of the problems of waterlogging and soil salinity, soil and groundwater surveys and investigations have had to be carried out in the Indus Plain on a scale unequalled anywhere else in the world. Abundant data have become available during the last 50 years, most of it during the last two decades. Very useful studies on these problems including water quality for irrigation have remained in progress over all these years. However, there is no end either to problems or to research. Some of the topics which eminently appear to need further research in connection with salt load or quality of irrigation water are named below:

1) The classification of surface and groundwater as well as of soils is available but much remains to be known on the effect of different qualities of water under different soil conditions; the moisture-holding capacity of soil determines the quality of water available to plants.

2) The question of pumpage of shallow versus deep waters is still under debate. The final answer is yet to be found.

3) The effect of the depth of the water table and its quality on crops under different soil conditions needs to be concretely determined. At what depth groundwater of what quality affects crop production is the question to answer.

4) The hazards of groundwater deterioration and the measures by which the good water quality can be improved need intensive research.

5) The feasibility of the usage of mixed surface and groundwaters is limited by the availability of surface waters. With this limitation the criteria for mixing groundwater of different qualities have been tentatively adopted but much more detailed research on the topic is called for.

6) The ultimate result of usage of water of different salt loads will be determined by the irrigation practices. Work is, therefore, needed on irrigation practices.

The most useful assistance for these and other such investigations and research can be provided by a systematic and scientific monitoring of tubewells already installed and the use of their water actually made.

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