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AN ASSESSMENT OF RESEARCH NEEDS AND PRIORITIES FOR RAINFED AGRICULTURE IN J O R D A N

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FOREWORD

The dryland areas of the Near East Region Area are a major source of food and fiber for millions of people. However, current yields are extremely low, compared with yields in developed countries. Existing technologies to improve dryland production are not in widespread use. Also, economic climates often fail to encourage the adoption of improved soil, water, and crop management practices.

To assist developing countries improve the productivity and stability of their dryland agricultural areas, the U.S. Agency for International Development (AID) organized the Technology for Soil Moisture Management Project (TSMM) in 1983. TSMM is being implemented through a Participating Agency Service Agreement (PASA) between the Agricultural Research Service (ARS) of USDA and the Science and Technology Bureau (S&T) of AID. ARS has addressed problems of dryland agriculture in the U.S. Great Plains for more than 50 years. Through TSMM, the skills of scientists in ARS and in land-grant universities are being applied to arid and semi-arid regions of developing countries.

The overall objective of TSMM is to assist developing countries and donor agencies to assess soil moisture and relate soil fertility problems and establish national strategies for increasing the long-term productivity of dryland areas. Through a series of activities, TSMM assists with research, technology transfer, economic analysis, planning, and assessment of policy needs.

TSMM's basic approach involves three steps:1) compiling data bases or syntheses of relevant in-country research; 2) conducting workshops to assess findings and establish priorities; 3) planning and implementing regional research and economic case studies on priority problems. In the long run, TSMM hopes to contribute to the development of regional research networks in dryland soil and water management.

In January 1986, TSMM and the International Center for Agricultural Research in the Dry areas (ICARDA) cosponsored a workshop on "Soil,Water, and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region." The workshop was held in Amman , Jordan, January 18-23 . Approximately 70 participants from six countries attended the sessions. Participants included ICARDA , the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) , the University of Jordan , Jordan University of Science and Technology , the Jordanian Ministry of Agriculture , the Food and Agriculture Organization (FAO) , the German Technical Assistance Agency (GTZ),the Arab Organization for Agricultural Development (AOAD) , the Jordan-Australia Dryland Farming Project, Jordan Cooperative Organization (JCO), and the Water Authority of Jordan.

The proceedings of this workshop will be published in early 1988. However, a strong consensus of the workshop participants was that countries of the Near East Region should compile databases of past research on soil, water, crop, and livestock management systems and assess their relevance to current problems. Too often in developing countries, the lack of communication and exchange of research data among international donor organizations and national scientists has led to irrelevant research and duplication of effort.

Following the Jordan workshop, TSMM asked Dr. Abdullah A. Jaradat, Jordan University of Science and Technology at Irbid, to compile a database on soil, water and crop management research for dryland/rainfed agriculture in Jordan. The resulting database document is this publication which is entitled, "An Assessment of Research Needs and Priorities for Rainfed Agriculture in Jordan." The database reviews recent and ongoing research, examines results, assesses recommendations, and identifies future research needs and priorities. It includes information on government policies in dryland areas, soil resources and conservation, agroclimatology, cultural practices, and crop rotations.

This publication represents a monumental effort on the part of Dr. Jaradat who served as the editor and who also wrote most of the chapters. His task was particularly difficult because so many different agencies and organizations have been involved in generating the data which now resides in various files, libraries, and documents at many locations around the country. TSMM is pleased to have provided support for compilation of this Jordan Database.

It should be a valuable reference for both national and international agencies in developing strategies and priorities for future research and as a national planning document for the development, conservation, and management of limited natural resources. We would hope that other countries in the Near East region will use the document as a model in compiling their own such databases.

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The preparation of this monograph on rainfed agriculture in Jordan has proved to be a valuable learning experience for me. In undertaking the assignment which was requested by Dr. J. F. Parr, Coordinator USDA/USAID Dryland Agriculture Project, I found much of the material required was not readily available. Different agencies and organizations have been involved in generating the data compiled in this monograph. I tried to review all published and unpublished work to provide a comprehensive coverage of the subject. I trust that the information presented in this monograph will help researchers,administrators and policy makers to get a full assessment of research needs and priorities for rainfed agriculture in Jordan.

Several people have rendered invaluable assistance in making this publication possible and I thank them all. The help of F.A. Kofahi and T.T. Jaradat is highly appreciated. I would like to thank B. Qudah for providing part of the material in chapter 3 on soil resources. Also, thanks are due to J. Abu Mushrif for providing part of the material and unpublished data for chapter 4 on soil and water conservation. Chapter 10 was authered by I.J. Stewart , and chapter 11 was authered by H.M. El-Hurani. I thank them for their permission to publish these two chapters in this monograph.

I thank Dr. Carol E. Whitman for meticulously going through the manuscript and providing special editorial assistance. I thank the art and photography unit of the Scientific and Technical Information Program of ICARDA for providing the photographs at the begining of each chapter. Grateful thanks are due to Drs. J.F. Parr and R.E. Meyer for their encouragement and financial support through TSMM. Finally, it hardly needs saying that this monograph would have been much less fun to put together without the enthusiastic participation of my family.

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Irbid , Jordan

June 1988 .

RAINFED AGRICULTURE IN JORDAN: AN OVERVIEW

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RAINFED AGRICULTURE IN JORDAN: AN OVERVIEW

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1-1. INTRODUCTION

Arable land in Jordan is a limited resource with an area of a little over 0.7 million hectares. The climate in the country is basically a Mediterranean climate characterized by dry hot summers and mild wet winters and extreme variability in rainfall within and among years.

In spite of a number of adverse factors, rainfed agriculture still remains an important component in Jordan's economy. On the average , it contributes about 12% of the gross domestic product (El-Hurani,1988).

Jordan is importing more than 70% of its food requirements due to an imbalance between its agricultural production and food demand(FAO , 1985) . This problem is a serious one because:

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(i) The average increase of population is over 3% per annum which will push the population to about 4 million by 1990, and

(ii) The land area which can be used for food production is limited (Table 1.1).The total arable rainfed area is expected to reach a maximum of 565,000 ha by the end of this decade (FAO, 1980), if no more land is lost to desertification, erosion or urbanization.

Dryland regions of Jordan are characterized by low and highly variable rainfall . Unreliability and variability of rainfall increases as the amount of rainfall decreases. Potential evapotranspiration exceeds precipitation for at least seven months during the year in most parts of the country. Finally , occasional high-intensity rainstorms lead to runoff and hazardous soil erosion.

The rainfed area in Jordan is essentially a fixed resource (Fig. 1.1) , and any future additions to the cropped lands must come either from conversion of natural grazing lands or from reclamation of areas that are , at present, not used for agricultural production(MOA ,1974).

The conversion of natural grazing lands to cropped lands in the low rainfall zone (< 250 mm) resulted in soil erosion and expansion of the desert during the last 2-3 decades (World Bank , 1981).

Table 1.1 : Profiles of agroecological zones in Jordan, (MOA, 1974).

Agroecological Zones	Long-Term Average Annual ppt.*(mm)	Total Area (hectare)	% of Total Population
Arid Zone	0 - 200	8,456,900	31
Marginal Zone	200 - 350	563,400	41
Semiarid Zone	350 - 500	135,900	19
Semihumid Zone	500 - 800	98,900	9

* : Annual Precipitation.

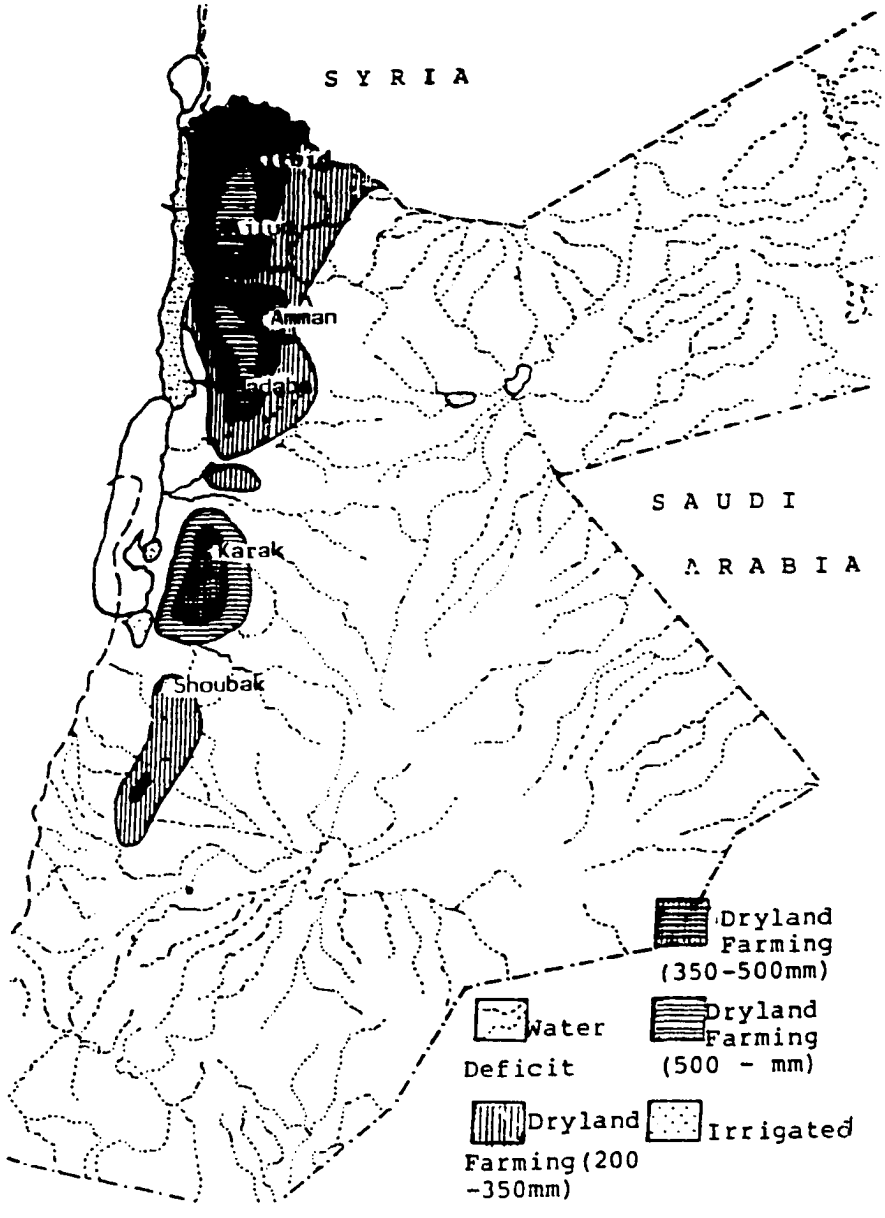

Fig.1-1. Dryland farming regions of Jordan according to their average annual rainfall.

1-2.AGRICULTURAL ZONING

The drylands of Jordan have been divided into five agroecological zones (MOA , 1974). The division was based on factors such as : rainfall, topography, temperature patterns, altitude, natural vegetation and soil groups. The five agroecological zones are :

1 - The arid zone , where rainfall does not exceed 200 mm.

2 - The marginal zone , where rainfall ranges from 200 to 350 mm.

3 - The semiarid zone , where rainfall ranges from 350 to 500 mm .

4 - The semihumid zone , where rainfall exceeds 500 mm, and

5 - The irrigated highlands , parts of the arid zone where groundwater is available for irrigation.

A sixth zone, the Jordan Valley, was included in the original MOA report. This area is under intensive agriculture due to the availability of irrigation water.

Over 90% of Jordan's area is included in the arid zone. Cultivation is prohibited by law in this area, however,

cultivation took place during years of above normal rainfall and the natural vegetation was destroyed(Tadros,1984). The arid zone , traditionally , serves as natural pasture land for sheep, camels and goats.

The marginal, the semiarid and the semihumid zones comprise, together, less than 10% of the country's area. A large part of Jordan's population (~41%) lives in the marginal zone, while a smaller part (~ 31%) lives in the arid zone. The remaining 28% of the population is living in the semiarid and semihumid zones (Dept. of Statistics , 1981).

1-3.THE AGRARIAN SECTOR

Heterogeneity is the main characteristic of Jordan's agrarian structure (Lanzendorfer, 1985). This is mainly due to the different production potentials in different parts of the country. The dryland agriculture is dominated by cereals (wheat and barley) . However, in areas of moderate to high rainfall (350-500 mm) ,other crops (e.g., lentils, chickpeas, summer vegetables and tobacco) are grown. Besides these , some drought-tolerant tree crops (e.g., olives, grapes and almonds) are grown in some parts of the dryland regions of the country.

Agriculture in Jordan accounts for about 12 % of the gross domestic product (GDP), while employment in the

agricultural sector has been constantly and steadily declining, reaching a low level of 15 % in the early 1980s (El-Hurani , 1988).

The public and private sectors invested heavily in irrigated agriculture during the 1970s, while the development of rainfed and arid areas has received lower priority. However, the government of Jordan , during the 1980s is directing major efforts towards the development of the rainfed areas to maximize local production and reduce the rising food imports(Ministry of Planning , 1986).

1-4.THE CHALLENGE

Farmers in the dryland regions of the world , historically, have been ingenious in devising ways of managing and manipulating difficult environments within the constraints imposed by soil and climate (Arnon , 1972). However, the problem now facing these farmers, especially in developing countries, is that traditional methods of coping with the risks and hazards of dryland agriculture (e.g., fallow, sowing methods, plowing etc.) are breaking down under population pressure , while modern technology has not yet produced acceptable alternatives.

The challenge facing farmers , agriculturists and policy makers in Jordan is how to raise productivity of the dryland farming areas in the country. Areas which merit the

greatest attention of the above mentioned groups are : increasing the biological efficiency of the cropping systems; managing soils to conserve moisture and fertility ; and a better integration of livestock and crop production.

A well-organized program for the development of rainfed and arid areas is essential and is expected to bring about considerable economic and social benefits, particularly as more than 85 % of the farming population lives in the rainfed areas and most of the livestock depends to varying degrees upon grazing over the arid rangelands. Any further delay in providing investment support to developing these areas poses the following hazards (FAO ,1980):

(i) Progressive erosion resulting in loss of soil and soil productivity;

(ii) Threat of desertification ; and

(iii) Low farm income leading to migration of the rural population to urban centers.

1-5.FUTURE PLANS

The current five - year plan for economic and social development (Ministry of Planning, 1986) stressed the importance of increasing productivity in the agricultural sector, in general, and in the rainfed sector, in

particular. This increase in productivity is planned to be achieved through introducing modern production techniques, applying research findings and developing extension services.

One of the major projects to be implemented during the current five - year plan is the Jordan Highlands Agricultural Development Project. One aim of the project is to conduct agricultural research on different aspects of rainfed agriculture in the highlands of Jordan . Another is to develop agricultural extension services through the training of qualified staff for this purpose. The extension services will be the vehicle of disseminating research results and findings to the farming community in the highlands.

The soil survey and land classification project will be implemented during the first three years of the plan. The project calls for a complete survey of potential agricultural lands in the country and decisions regarding their optimum use.

A number of soil conservation projects will be continued during the current plan. The Zerqa River Catchment Project aims to develop and increase agricultural productivity in the lower Zerqa River catchment area of about 82,000 ha.

Suitable soil and water conservation measures will be

built on farmer's lands as needed. In addition, the project will work to developing rangelands in the catchment and increase their productive capacity.

Other major projects, which will be initiated and /or continued during this plan, are :

(i) Soil conservation and fruit tree planting on lands unsuitable for cereal production;

(ii) Seed improvement and multiplication project. Foundation and certified seed of cereal and legume crops will be produced through cooperative efforts of the Ministry of Agriculture and the Jordan Cooperative Organization;

(iii) Introducing grain legumes and forage crops in the crop rotation. It is hoped that this will lead to a better integration of crop production and animal husbandry in the rural areas of the country; and

(iv) Mechanized Agricultural Services. The Jordan Cooperative Organization will further develop two of its Agricultural Machinery Stations in Irbid and Madaba, complete the one at Karak and start a new station at Shoubak. The services offered by these stations are expected to increase crop yields in the rainfed sector through the use of modern machinery and cultural practices for crop production.

1-6.AGRICULTURAL RESEARCH

National research efforts in the rainfed agricultural sector started in the 1950s . In addition to these efforts, a number of international agencies have assisted the Ministry of Agriculture in improving dryland cereal production. The UNDP/FAO involvement was primarily on soil conservation (see chapter 3 ,for more details). A program which was carried out by USAID/OSU (Goetze , 1976) focused on the evaluation of a package of production practices under Jordanian conditions. This package was developed earlier in the Pacific Northwest of the United States.

Other agencies such as ICARDA,Ford Foundation,the Australian government and GTZ, were also involved in research on several aspects of rainfed agriculture in the country.

It is generally accepted that research in agriculture is slow and costly. However, research is the only reliable means of achieving any progress in agricultural production. Recently, many researchers feel that technology transfer could solve many agricultural problems in the developing world without the need of lengthy and costly research. However, this procedure requires thorough testing before any recommendations are given to the farmers .

In spite of the considerable efforts which have been spent to improve rainfed agriculture in Jordan, the results

so far have been disappointing. However, the opportunities , in Jordan, are wide open to raise agricultural production and land productivity through agricultural research.

There were various factors, in the past, that have inhibited farmers from adopting research results and modern farming techniques(see Oglah , 1984 ;for a review).

Research has been carried out on a limited number of crops in the drylands of Jordan - mainly wheat, barley and most recently grain legumes. Very little research has been done on other crops or other components of the farming system in these areas.

In the following chapters , we will present research results and recommendations on different aspects of rainfed agriculture in Jordan , especially those which are related to soil-water-crop management. Also, we will try to identify research gaps and suggest research needs for each of the presented topics.

In the second chapter the general features of climate in relation to agriculture are reviewed. In the third chapter soil resources in the country are presented and a proper strategy for the best use of this resourse is outlined. The history of soil and water conservation is discussed in chapter four and appropriate practices for proper soil and water conservation are outlined. The problem of

soil fertility and fertilization in the rainfed areas is addressed in chapter 5. Research results in the areas of tillage, cultural practices (other than tillage), crop rotations and weed control are presented in chapters 6, 7, 8, and 9. Response farming is the subject of Chapter 10. Finally, we will present the governmental policies in the rainfed regions of the country and their impact on the development of that sector in the country's economy.

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AGROCLIMATOLOGY

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AGROCLIMATOLOGY

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2-1. INTRODUCTION

Farmers in the rainfed areas of Jordan have to contend with extreme temporal and spatial variability of climate and with a high level of spatial variability of soil and other physical factors. Rainfall is the most variable and the most important of these factors. In a country of such environmental diversity , it is important to assess the effect of environmental variability on agricultural production (A.O.A.D., 1977).

In dryland farming, agriculture interfaces with a dynamic complex of natural conditions , among which meteorological factors are the most prevalent and the most changeable (Abandah ,1978).The effect of these factors on agricultural processes and subjects determines , to a considerable extent, harvest size, product volume, cost and operation efficiency. Because of these reasons, the accurate

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calculation and measurement of meteorological components,as well as the use of information concerning weather phenomena and climate resources,are needed for the efficient solutions of many agricultural problems in the country.

2-2.GENERAL BIOCLIMATIC CHARACTERISTICS OF JORDAN

Jordan is located in the eastern Mediterranean region between latitudes 29°30' N and 32°31' N. The climate of Jordan is predominantly of the Mediterranean type, characterized by a cool,wet winter and a dry,hot summer with short transitional periods of spring and autumn (J.N.G.C., 1984). The following is a brief description of the climatological elements in the country.

2-2.1.Temperature

There is a large variation in temperature from one region to another in Jordan. The Jordan Valley and Aqaba regions are very similar in their temperature regime to the subtropical climate; these are hot in summer and warm in winter. The climate in the highlands of Jordan is characterized by a mild summer and a cold winter. The steppe and steppe desert regions have a continental climate with a large amplitude of temperature.

Figure 2.1 shows annual mean temperatures across the

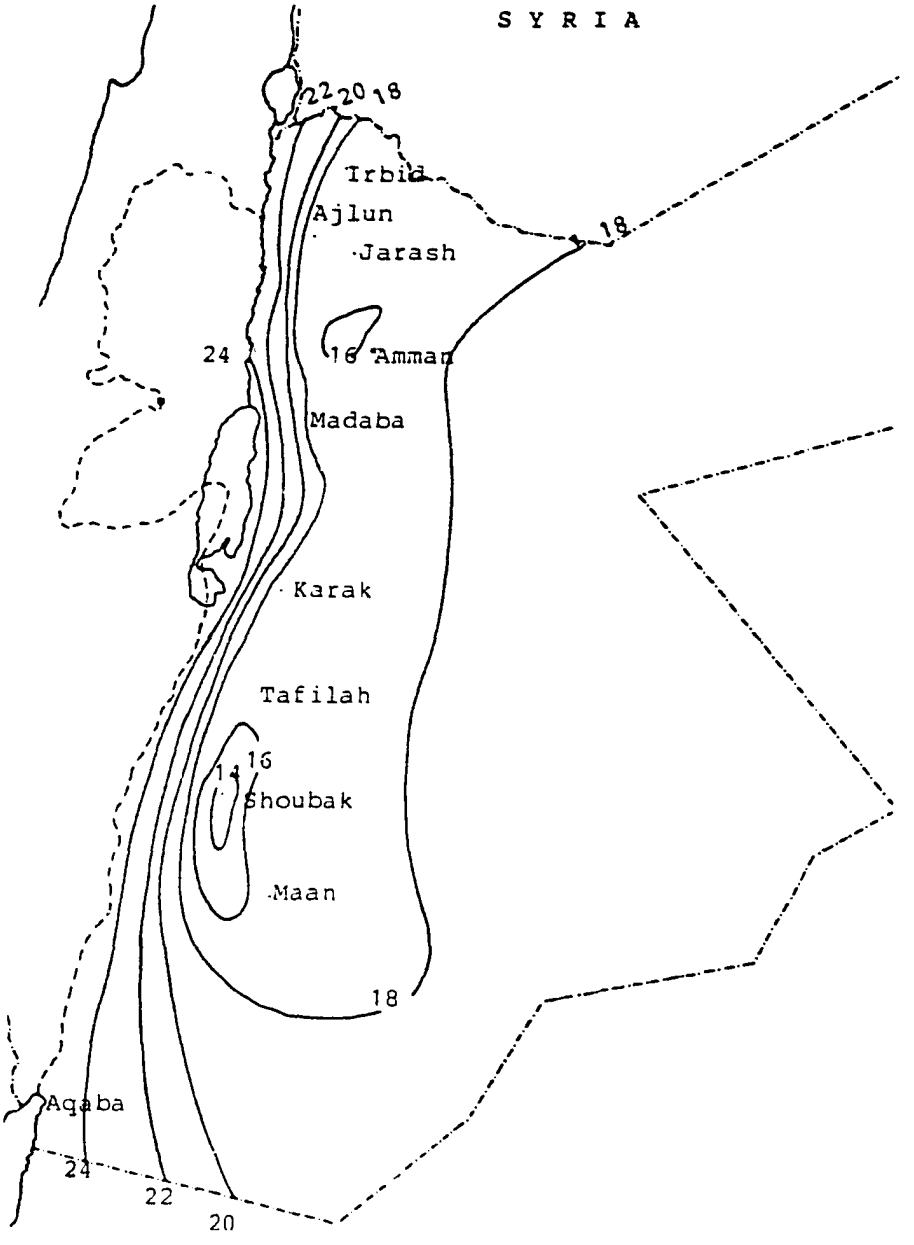

Fig.2-1. Annual mean temperature (°C) in Jordan.

country. Records from 42 stations , over a period of ten years (1966-1975),were used to prepare temperature maps for the country. Topography seems to be the main factor controlling the spatial distribution of temperature . Isotherms of annual temperature follow the contour lines and extend from north to south across the highlands,with annual mean temperatures reaching 16 and 14 C^{o} in Jubieha in the north and Shoubak in the south, respectively. Table 2.1 shows the annual average temperatures for the three main regions of the country.

2-2.2.Precepitation

Most of the rain falls between November and March. The annual rainfall averages 30-100 mm in the steppe desert and exceeds 800 mm in some areas in the highlands, with large variability between and within the regions (El-Kawasma, 1979) . Snowfall is rare and is confined, generally, to high elevations (e.g. Shoubak and Ajlun mountains).

Physiography and latitude control, to a large extent, the spatial distribution of rainfall in Jordan (Abandah , 1978). Rainfall decreases considerably from west to east and from north to south. Rainfall data were compiled from 42 stations over a period of 35 years (1942-1977) to prepare the map in Fig 2.2 .

Winter rainfall constitutes 75% of annual rainfall in the highlands, while it reaches 50% of annual rainfall in

Table 2.1: Mean , mean maximum and mean minimum temperatures (°C) for three distinct regions in Jordan .

Region	Mean	Mean Maximum	Mean Minimum
Jordan Valley	22 - 23	28 - 29	14 - 17
Highlands	13 - 17	22 - 23	10 - 12
Steppe and Steppe desert	15 - 18	23 - 27	8 - 12

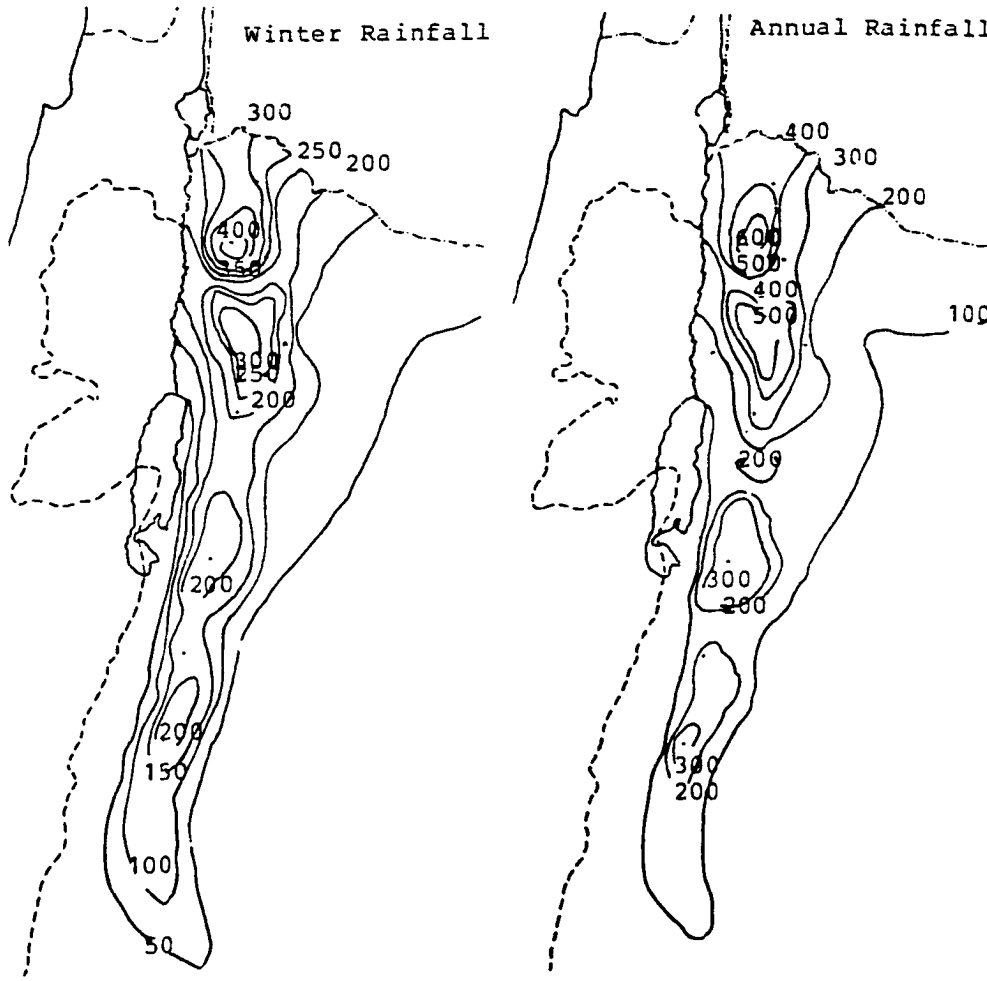

Fig. 2-2. Winter and annual rainfall (mm) over Jordan (Average 1942-1977).

the steppe and steppe desert.

2-2.3.Wind

Two main wind regimes affect Jordan. These are: The northwest flow during summer and the southwest-east flow during the rest of the year (Department of Meteorology , 1970).

The northwest summer wind blows at a speed of 8-15 knots/h ; it is northerly in the Jordan Valley, southeast-northwest in the highlands and east-north in the steppe and steppe desert region (El-Kawasma, 1983).

Southwest and east winds, during winter, vary in speed with time and location . The average speed varies from 8-15, 12-18 and 10-15 knots/h in the Jordan Valley, the highlands and the steppe regions, respectively (Department of Meteorology,1970, El-Kawasma, 1983).

2-2.4.Humidity

Relative humidity varies largely from season to season and during the day (J.N.G.C., 1984). This variation depends on the region and the nature of soil cover. Relative humidity is fairly low during summer months. It is about 50% in the highlands while it drops to about 30% in the steppe. Maximum values of more than 75% were recorded in the highlands during winter and values of 40-45% in the steppe .

Relative humidity may drop to a low level (25%) during transitional periods, especially when the country is under the influence of the desert depression.

2-2.5.Evaporation

Annual total potential evapotranspiration (PET), calculated according to Penman (1948), is above 1300 mm in most parts of the country. Differences in PET, among regions within the country, can be attributed to differences in temperature, radiation, wind speed, cloud cover and humidity (Department of Meteorology, 1970; W.A.J.,1985).

Mean monthly values of PET during winter range from 20-30, 45-60 and 35-45 mm in the highlands, the Jordan Valley, and the steppe, respectively. Maximum monthly values were recorded during July. The range was 150-180, 200-240 and 210-230 mm for the highlands, the Jordan Valley and the steppe, respectively (J.N.G.C., 1984).

2-3.SUBDIVISIONS OF THE MEDITERRANEAN BIOCLIMATE IN JORDAN

The calculation of the rainfall/temperature quotient according to Emberger (1955) made it possible to classify areas in Jordan according to their bioclimates. Fig. 2.3 shows the main subdivisions. Climatically, similar sites are close to each other in that figure. The features of each

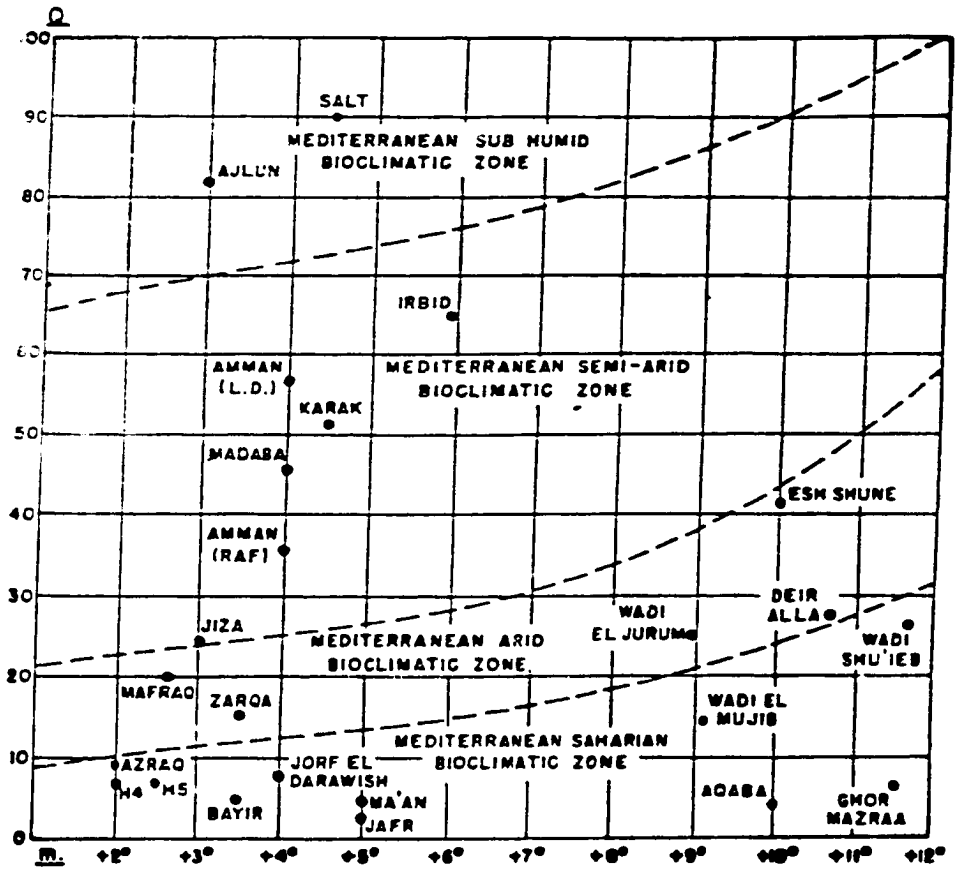

Fig.2-3. Subdivisions of the Mediterranean bioclimate in Jordan according to mean minimum temperature (m) and rainfall/temperature quotient(Q).

bioclimatic subdivision , according to Emberger(1955) and Meigs (1962), follow .

2-3.1.Subhumid Mediterranean Bioclimate

The quotient(Q)according to Emberger(1955)lies between 70 and 100. The mean minimum temperature (m) of the coldest month (January) varies between +2 and +5 °C. The mean maximum temperature of the hottest month (August) varies between 27 and 33 °C. The map in Fig. 2.4 shows that this bioclimatic subdivision exists only in a relatively small part of the country, namely, areas around Ajlun and Salt.

2-3.2.Semiarid Mediterranean Bioclimate

The quotient (Q) for this bioclimate lies approximately between 30 and 70. The Irbid campus of Yarmouk University, which is close to the subhumid zone , has a quotient of 65, while Ramtha Agricultural Research Station, 17 km east of Irbid, has a quotient of 45.

The average minimum temperature (m) during the coldest month (January) varies approximately between +3 and +7°C ; it is characteristic of a warm variety of the semiarid Mediterranean in which frost is rare or exceptional.The average maximum temperature during the hottest month(August) varies from 29 to 34°C. The region is therefore slightly warmer in summer than the subhumid zone.

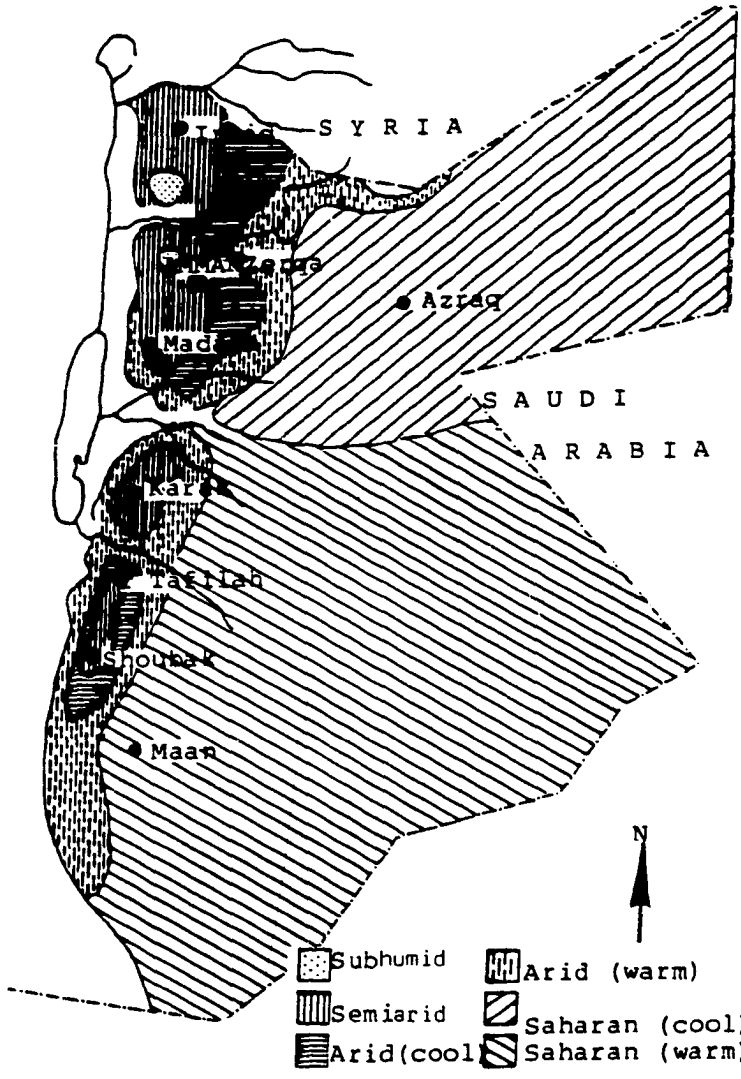

Fig.2-4. Distribution of Mediterranian bioclimate subdivisions in Jordan.

An attempt has been made to circumscribe the areas covered by the semiarid Mediterranean bioclimate; going from north to south (Fig. 2.4), three main geographic zones can be recognized:

(i) Irbid-Amman-Madaba,

(ii) Karak, and

(iii) Shoubak.

In Shoubak region , the semiarid bioclimate covers areas lying between 1200 and 1500 meters, while in Irbid - Amman - Madaba region it covers areas varying in altitude between 300 and 800 meters .

2-3.3.Arid Mediterranian Bioclimate

The quotient (Q) lies between 10 and 30, in the cool and warm varieties, and between 20 and 50 in the very warm variety of this bioclimate. The mean minimum temperature (m) of the coldest month (January) varies from +1 to +11°C.

This large range makes it possible to observe a number of varieties within this bioclimate. The minimum temperature range, in the cool variety,is +1 to +3, while in the warm variety it is from +3 to +7 °C., and in the very warm variety from +7 to +11 °C. The mean maximum temperature of the hottest month (August),within this bioclimate, varies between 34 and 40 °C.

The geographical distribution of the three varieties of

the arid Mediterranean bioclimate is indicated in Fig. 2.4. The cool variety covers the eastern slopes of the Ajlun mountain range and the Amman-Madaba plateau; it is transitional between the semiarid and arid bioclimates.

The warm variety of the arid bioclimate covers a much larger area ; it is delimited from north to south by the mountains or hills of Jordan and occupies a narrow strip on the western slopes of these mountains.

The very warm variety of this bioclimate covers the upper reaches of the Jordan Valley; Deir Alla and North Shuna are located within this division .

2-3.4.Saharan Mediterranean Bioclimate

The quotient(Q)for the Saharan bioclimate lies approximately between 2 and 15 for the cool and warm varieties, and between 2 and 30 for the very warm variety of this bioclimate. The mean minimum temperature (m) of the coldest month (January) varies from +1 to +3°C and from +8 to +12 °C. for the cool and very warm varieties, respectively . The mean maximum temperature of the hottest month(August)varies between 36 and 42°C. Summers are very warm, while the winters are mild to cool.

The geographical distribution of the three varieties of the Saharan Mediterranean Bioclimate is very interesting. A

large part of the Jordanian territory (71%) is characterized by this bioclimate. The cool variety exists particularly in the northern part of the country; Azraq, H4 and H5 are located within this variety. The warm variety covers the south eastern part of the country. Ma'an, El-Jafr and Bayir are located within its boundaries. A very warm variety exists in the lower part of the Jordan Valley, the Dead Sea area, Wadi Araba, Aqaba region and Mudawara.

2-4. RAINFALL

Agriculture in Jordan depends largely on rainfall, especially in the highlands and the steppe. Precise knowledge of the rainfall characteristics is essential for agricultural planning and decision-making under dryland conditions (Abandah, 1978).

A network of rainfall stations has been established by the Natural Resources Authority, Department of Meteorology and, recently, by the Jordan Water Authority (N.R.A., 1977; J.W.A.,1985). The electronic weather stations, installed by the Jordan Water Authority, have the capacity to record 25 weather variables and store readings on magnetic tapes for further computerized analysis.

2-4.1.General Characteristics of Rainfall

General characteristics of rainfall in Jordan have been documented during the last 40-50 years (e.g. Department of Meteorology, 1970; M.O.A., 1974; A.O.A.D., 1977; Kabakibo, 1980; El-Sayed,1980; Taha, 1981).

Heavy showers, during the last part of October, usually mark the beginning of the winter season in Jordan. Rainfall is mainly due to cyclones moving in over the country from the Mediterranean. These cyclones, which might be connected with shallow westerly waves moving rapidly in the troposphere, cause rainfall in the northern and middle parts of the country. The spatial extension, amount and intensity of rainfall depend on the tracks of these cyclones and their frequencies (Abandah, 1978; Shehadeh, 1985).

Another type of cyclones (Cyprus Cyclones) is usually connected with the upper cold trough; these usually move slowly and affect most parts of the country .

A third type affects the country during spring; this is the khamasine cyclone which causes intense rainfall in some parts of Jordan (A.O.A.D., 1977). Rain intensity, caused by the khamasine cyclones, depends on their tracks and on the air circulation in the upper atmosphere.

Although rainfall during winter is basically of cyclonic origin, cyclones are connected, sometimes, with upper cold troughs. This adds a considerable convective effect and might be intensified by orographic and surface warming. Such conditions favor rainfall of high intensities over parts of the highlands (e.g. Ajlun and Salt mountains) in winter, and over the steppe region in spring (Shehadeh, 1976).

2-4.2.Spatial Distribution of Annual Rainfall

The spatial distribution of rainfall over Jordan is closely related to topography and is affected by at least two factors:

(i) Distance from the Mediterranean, and

(ii) The shadow effect of the mountain range parallel to the east Mediterranean coast(Burden,1959; Abandah, 1978). Rainfall distribution, over the country, is highly influenced by the superimposed vertical motion of the air masses moving across the Jordan Valley, which is below sea level, to the highlands (Fig. 2.5) (Abanda, 1978). It is clear that annual rainfall drops sharply with increasing distance from the mountain range .

The mountain range receives the highest amount of rainfall (Table 2.1). Fig 2.5 shows the general variation of

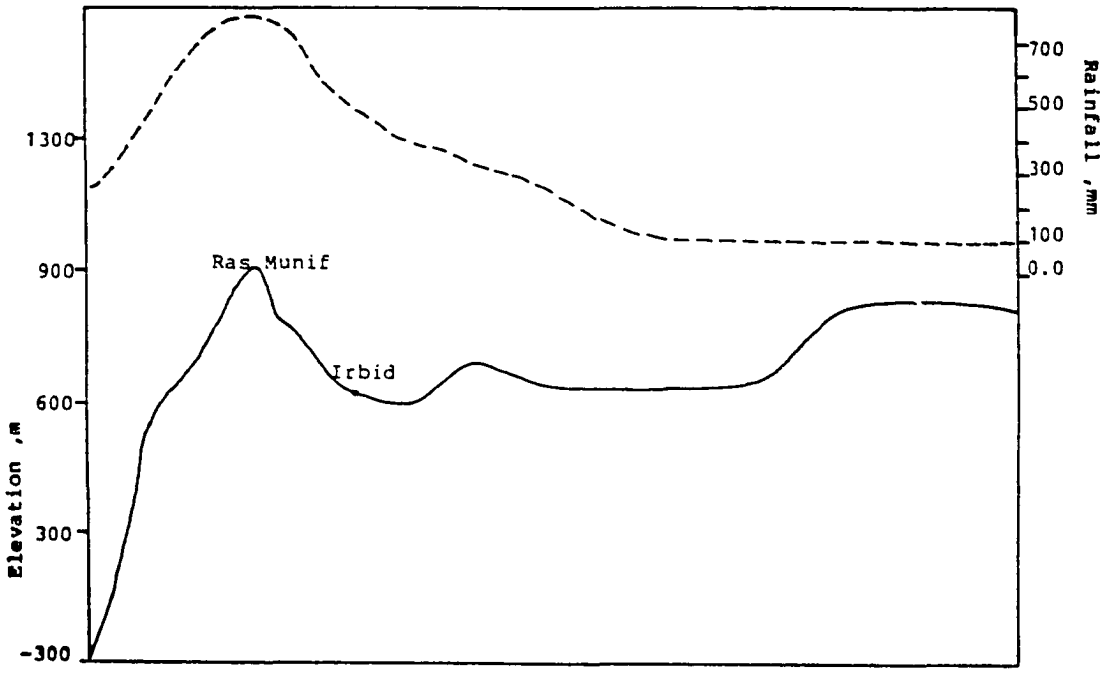

Fig.2-5. Distribution of rainfall through a cross section in Jordan near Irbid.

precipitation from west to east and the importance of altitude and local topography on rainfall (Abandah, 1978). The relationship between rainfall and altitude can be expressed by the following equation:

$$Y = 293.75 + 0.193\ X \quad , \ (r = 0.87 \ , \ P < 0.05)$$

where Y is amount of rainfall in mm, and X is the altitude in meters. This equation covers altitudes between 250 and 1100 meters above sea level.

There is an increase of approximately 19 mm in rainfall for each 100 meters increase in elevation . In the steppe region rainfall decreases gradually from west to east and southeast, to a very low level (Fig 2.5).

2-4.3.Interannual Variability in Rainfall

The yearly variation in amount of rainfall is very pronounced especially in areas of low rainfall. This interannual variability is expressed by the coefficient of variation (C.V.)(Fig. 2.6). The coefficient of variation for rainfall was calculated for a number of sites across the country over a 20 year period. The relationship between amount of rainfall and its C.V. can be expressed by the linear equation :

$$Y = 43.97 - 0.03634\ X,$$

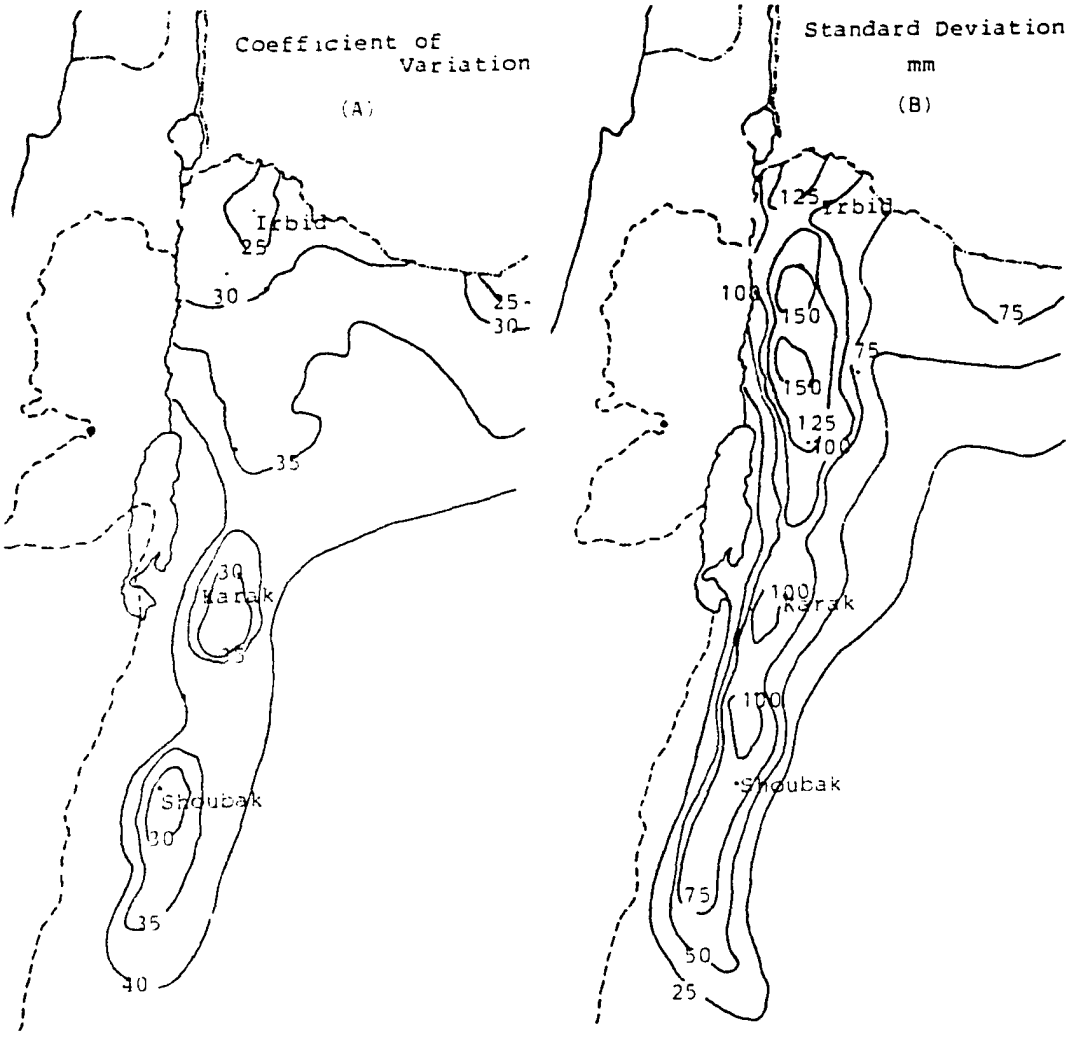

Fig.2-6. Coefficient of variation (A) and standard deviation (B) of rainfall in Jordan.

where Y is the coefficient of variation and X is amount of rainfall in mm. The two parameters are negatively and significantly correlated ($r = -0.65$, $P < 0.05$).

Generally, the higher the rainfall, the lower is its interannual variability, expressed as a coefficient of variation. However, the rainfall standard deviation is higher for high rainfall areas.

2-4.4.Characteristics of Monthly Rainfall

The rainy season in Jordan may start as early as October and ends in May . Usually, rainfall increases from October to January, then decreases to zero by the end of April or May. Monthly mean rainfall values are highly variable. The interannual variability of monthly values is greater than those of the yearly values (Shehadeh , 1976). It is clear that monthly rainfall changes dramatically from year to year. The rate of change and its magnitude depend on total annual rainfall, location and topography (Shehadeh, 1985). This variability and its magnitude create a serious problem for cereal farmers in most regions of the country.

2-4.5.Rainfall Intensity

Rainfall of intensities greater than the infiltration rate of the soil may cause soil erosion and loss in

agricultural production. Data on an hourly rainfall basis are becoming available since the electronic weather stations were installed (J.W.A.,1985). The highest daily rainfall recorded in Jordan was 158 mm at Naor , southwest of Amman, (Table 2.2).

Most stations in the highlands have records of daily rainfall of 100 mm. Smaller values were recorded in the steppe region. However, these values of daily rainfall are considered harmful when soil erosion and runoff are taken into account (see chapter 4: Soil and Water Conservation , in this monograph).

2-4.6.Rainfall Probability

The general characteristics of precipitation in Jordan are: (i) irregularity, (ii) high variability, and (iii) occasional high intensity;these are typical rainfall characteristics of semiarid regions of the world (El-Kawasma , 1979).

It is very difficult and risky to rely on mean rainfall for decision-making in dryland agriculture (Thomas, 1980). A more reliable and dependable parameter should be used under these conditions. Rainfall probability was found by many researchers to be a more reliable parameter to base agricultural decisions upon. Several statistical formulae

Table 2.2 : Absolute maximum daily rainfall compared to the mean annual rainfall, 1954 to 1978.

Region	Station	Annual Mean (mm) (1)	Absolute Max. Daily (mm) (2)	Ratio 1/2 %
	Irbid	435.5	105.0	24.1
	Shoubak	285.3	74.0	25.9
HILLY	Naor	468.6	158.0	33.7
	Kitta	498.4	135.0	27.1
REGION	Karak	339.1	115.0	33.9
	Salt	530.3	105.0	19.8
	Wadiwalla	247.3	120.0	48.5
	Mafrag	144.5	44.0	30.4
STEPPE	Petra	131.2	85.0	64.8
AND				
STEPPE	H4	78.0	43.0	55.1
DESERT	H5	67.2	31.0	46.1
REGION	Maan	40.7	44.0	110.0
	Aqaba Airport	32.6	65.0	199.0

have been used to calculate rainfall probabilities for high and low rainfall regions of the country (Thomas, 1980).

Annual precipitation probabilities, for a number of locations in the highlands and the steppe, are presented in Table 2.3. It was possible to draw statistical graphs for these locations, after some smoothing, in order to calculate rainfall probabilities with reasonable accuracy. Probability lines as a function of mean annual rainfall, for low and high rainfall areas are shown in Figure 2.7 a and b. It was found that the rate of decrease in rainfall probability, is higher for low rainfall areas than for high rainfall parts of the country.

The discontinuity, observed in rainfall probability lines for low and high rainfall areas, can be attributed to many factors such as :

(i) Higher interannual variability , and
(ii) Erratic distribution of rainfall in low rainfall areas.

2-4.7.Rainfall Forecast

Abandah (1978) emphasized the importance of forecasting seasonal rainfall during early October,with the advantage of advanced agricultural planning.

Krown (1951) found a positive and strong relationship

Table 2.3 : Probability of total annual rainfall (mm) being above a certain value for a selected number of locations in Jordan .

Location	Probability level %								
	10	20	30	40	50	60	70	80	90
Amman	384	330	300	280	265	232	214	187	160
Rabbah	450	381	332	310	285	256	230	200	170
Irbid	630	560	500	462	420	390	360	320	280
Jiza	329	251	205	170	141	111	88	70	46
Jubeiha	655	560	512	473	450	410	380	345	294
Madaba	445	385	340	320	290	265	242	212	182
Mafrag	205	180	165	150	140	128	117	105	90
Naor	710	620	555	505	455	414	375	330	280
Quren	256	228	208	191	176	162	149	134	114
Ras-Munief	681	618	570	539	505	473	442	405	365
Shoubak	475	410	350	310	280	250	215	190	150
Tafila	568	467	400	351	309	270	234	192	148
Taibeh	643	583	541	510	478	449	420	389	342
Wadi-Duhleil	213	187	172	159	146	137	126	113	97
Wadi-Walla	365	320	288	263	239	219	199	178	150

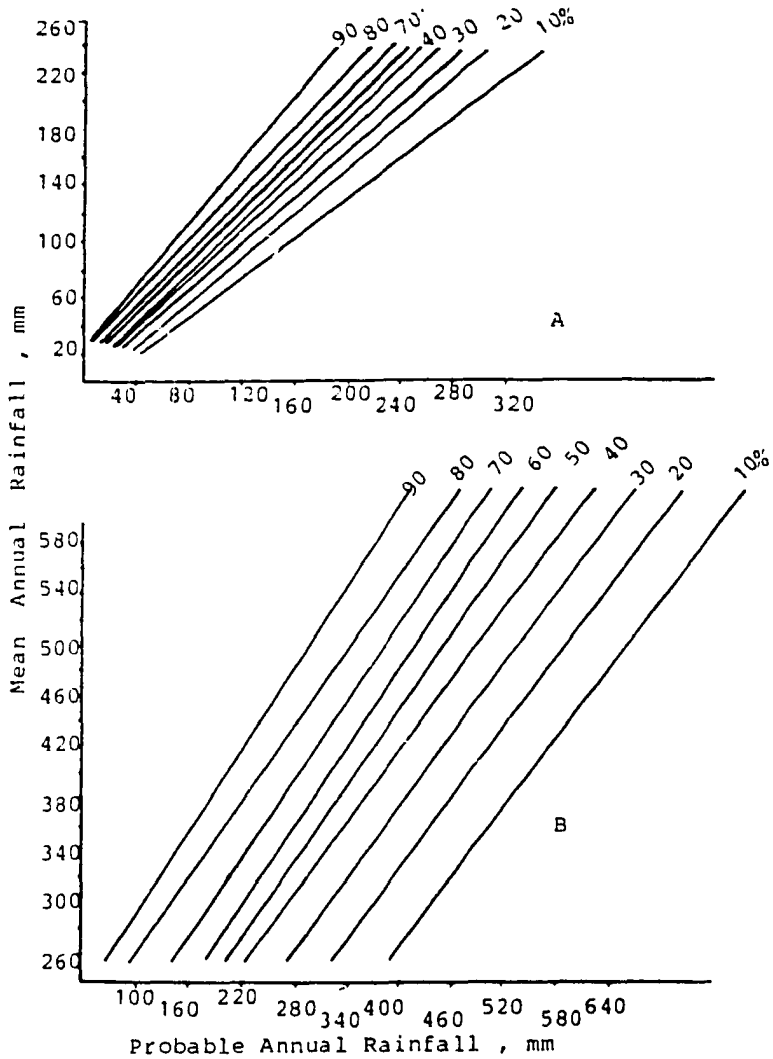

Fig. 2-7. Probability curves for rainfall in low (A) and high (B) rainfall regions of Jordan.

between October rainfall and the seasonal rainfall over Israel. Later, Krown(1966) found a positive and strong relationship between the 500 mb trough for October and the seasonal rainfall. The last study was based on rainfall averages for eight stations representing various agroclimatological zones. Krown used rainfall records from 1924 to 1950 and concluded that:

(i) Moderate rainfall (6-52 mm) during October, over a period of 12 years,was followed in all 12 years by below-normal rainfall.

(ii) Low rainfall (0.0-5.9 mm) during October was followed by above-normal rainfall in 9 out of 13 years, and

(iii) Heavy rainfall (> 100 mm) was followed by above-normal rainfall in two years.

Moreover, Krown used these simple findings to forecast the rainfall for the period 1951 to 1964 and he obtained correct forecasts for 11 out of 14 years in that period.

In a similar study, Abandah (1978) used a modified standard for rainfall during October as follows:

(i) Low rainfall in October (< 3) followed by above-normal seasonal rainfall,

(ii) Moderate rainfall (3-20 mm) in October followed by below-normal seasonal rainfall, and

(iii) Heavy rainfall (> 21 mm) in October followed by above-normal seasonal rainfall.

In this study, Abandah used rainfall data from eight stations across the country for 25 years (1950-1975) and found that the probability of success in forecasting seasonal rainfall using October's rainfall was about 55%. He concluded that the amount of precipitation during October of each year is not a reliable indicator of the seasonal rainfall.

Abandah (1978) proposed, instead, the use of the position of the major troughs, the wave length and the intensity of the 500 mb trough in the Mediterranean during the month of October. Using these factors, Abandah developed an empirical formula to forecast the seasonal rainfall over Jordan by the end of October each year. The developed formula gives the expected deviation of the seasonal rainfall from the normal rainfall, in percent. The formula is:

$$Y\ (\%) = 3\ (\lambda - 60) + 3\ (\Delta Z - 8) + (16.5 - Lm),$$

where Y (%) is the expected deviation of rainfall from the normal ; λ is the wavelength in degrees of longitude along 35° N between the Mediterranean and the Atlantic trough axis

(mean = 60 long); Δ Z is the wave intensity in decameters (mean = 8 decameters); and Lm is the longitude of the Mediteranean trough axis along latitude 35 N (mean = 16.5 E).

The developed formula gave accurate forecasts for amounts of precipitation during the three months following October. However, it was found (Abandah, personal communication,1986) that waves longer than 60 Long (3000 miles) along 35 N gave above-normal rainfall over Jordan regardless of the position of the trough; and waves shorter than 60 Long gave below-normal rainfall.

Abdel-Aty (1976) used rainfall records, for 34 years,to estimate the parameters necessary for rainfall simulation. He used the probability distribution of the length of spells developed by Gabriel and Newman (1967). The results of simulation for wet spells, dry days and, consequently,rain-cycles were tested against actual data using a chi-square test.

The formula, developed by Gabriel and Neuman and tested by Abdel-Aty , gives the rain-cycle length of maximum probability Zmax as :

$$Zmax = 1 + \log (\log q0 / \log q1) / \log (P1 / P0),$$

where P0 = is the probability of a wet day if the previous day is dry; P1 is the probability of a wet day if the previ-

ous day is wet; $q0 = 1 - P0$ and $q1 = 1 - P1$.

Observed and expected frequencies of rain-cycles according to cycle length in days,using this formula, are presented in Table 2.4 for Amman Airport. Obviously ,there is a good agreement between the two.

This approach is useful for agricultural purposes where it is necessary to specify suitable crops for certain areas,taking into consideration the most frequent rain-cycle for that area (Abdel-Aty, 1976; Baier, 1965).

2-5.POTENTIAL EVAPOTRANSPIRATION

Numerous methods have been devised to calculate potential evapotranspiration (PET),i.e.,of a short crop completely covering the soil surface and never suffering from lack of soil moisture. The most popular methods are those of Thornthwaite (1948) and Penman (1948) . These methods are based on the dependency of free water evaporation (or the transpiration of a freely evaporating crop surface) on a number of meteorological parameters, mainly: net radiation flux, wind-speed and relative humidity (Van Bavel and Hillel, 1976).

Techniques have been devised to measure evaporation directly; the most commonly used is the U.S Weather Bureau Class A Pan. This procedure is simple enough that a farmer

Table 2.4 : Observed and expected frequencies of rain-cycle according to cycle length in days(for rainy seasons of 34 years at Amman airport).

Cycle Length (days)	Observed (freq .)	Expected (freq .)	Cycle Length (days)	Observed (freq .)	Expected (freq .)
2	47	46	13	15	22
3	80	65	14	16	19
4	82	70	15	15	16
5	73	67	16	15	14
6	58	61	17	6	11
7	51	54	18	8	10
8	43	48	19	11	8
9	38	41	20	5	7
10	34	35	21-25	15	22
11	30	30	26+	15	18
12	26	26			
			Total	683	690

can set up the instrument on his land and use it to determine the water requirements of his crops.

2-5.1.Characteristics of PET in Jordan

Total annual PET decreases as elevation increases , with the mountains having the lowest values and the steppe desert and the Jordan Valley having the highest values(El- Kawasma, 1983). The PET increases at a rate of about 6 mm/km distance from the mountains. Potential evapotranspiration (PET)values are affected by elevation and distance from the River Jordan. It was observed(J.N.G.C.,1985)that PET values follow a uniform pattern, with maximum monthly values during July and minimum values during January and December.Also it was found (El-Kawasma,1983) that the rate of change in PET rises sharply during spring (April-May) while it falls sharply during fall (October-November). This sharp change might be due to the rapid change from a rainy to a dry season or vice versa.

Generally,PET is less variable,temporally and spatially, than rainfall, especially in the highlands and the steppe (El-Sayed,1980). However, in the mountains, this is not true because elevation affects PET values markedly.

2-6.ACTUAL EVAPOTRANSPIRATION (AET)

The Class A Pan evaporation is very close to being the potential evapotranspiration (PET), which is about that of a crop growing constantly at field capacity (Thomas, 1980). However, crops grow most of the time at soil moistures that are much below field capacity; consequently, their actual evapotranspiration (AET) is not the same as a Class A Pan. Experimentally, it was found that such plants transpire at a rate that is proportional to the evaporation of a Class A Pan under the same conditions. The ratio of proportionality depends on the crop, its phenological age and leaf area index (LAI) (Frere and Popov, 1979; Masa'd, 1985).

2-6.1.Characteristics of AET in Jordan

Mean values for AET, calculated according to Penman(1948) were less than the annual rainfall except in low rainfall areas. When rainfall efficiency was calculated as the ratio between AET and annual rainfall, it ranged from a minimum of 68% for the high rainfall areas,to a maximum of 100% for low rainfall areas. However, rainfall efficiency on an annual basis is misleading because it depends on rainfall amount and distribution and on PET (El-Kawasma, 1983).

Monthly values of AET are more reliable to use for the calculation of rainfall efficiency. Monthly rainfall

efficiency (i.e. the percentage of rainfall utilized during the same month) varies with PET level throughout the country (El-Kawasma,1983). Table 2.5 shows rainfall efficiencies for a selected number of stations during a six-month period. It was noticed that rainfall efficiency increases as the amount of rainfall decreases. In areas with medium to high rainfall (350-500mm), excess water is stored in the soil when rainfall exceeds PET and the latter is reasonably small. This explains rainfall efficiencies exceeding 100% during March and April for some stations (Table 2.5).

2-7.AGROCLIMATOLOGY AND IMPROVED CROP CALENDERS

Very limited research has been done in Jordan on the relationship of agroclimatology and crop calendars.

The R-index, the ratio between actual evapotranspiration and potential evapotranspiration, was calculated (El-Kawasme, 1983) for some locations in the country. This index reflects the water supply and demand for crops in the area under study (Masa'ad, 1985). It might be used, at a regional or a country level, to determine crop alternatives (i.e. crop choice). The R-index can also be used to estimate crop production under certain rainfall and soil moisture conditions. Table 2.6 shows seasonal(Nov-May) R-index as affected by soil moisture capacity and atmospheric demand.

Table 2.5 : Rainfall efficiency(%) (AET/rainfall) for selected stations for the rainy months*.

Stations	PET (PENMAN)					
	N	D	J	F	M	A
Amman	90.3	50.3	44.0	87.2	111.7	188.4
Ras-Munief	63.4	22.7	22.2	36.8	90.7	175.0
Jubeiha	71.0	20.3	20.2	40.5	72.7	204.5
Irbid	76.2	31.7	28.2	51.0	93.6	244.7
Baqura	85.3	32.2	36.9	73.3	128.4	250.5
Tafila	85.1	33.4	37.2	60.0	102.5	163.5
Rabbah	91.6	46.1	39.4	64.8	94.7	182.9
Shoubak	96.9	28.0	28.9	59.4	107.1	206.3
Wadi-Yabis	92.9	37.7	42.5	87.5	134.8	220.4
Deir-Alla	87.1	59.2	55.5	84.6	122.7	199.5
Mafrag	81.1	67.5	70.0	101.0	140.8	164.3
Jiza	93.2	71.6	68.4	101.7	132.7	138.7

* : For low rainfall months and low rainfall stations values of rainfall efficiency become meaningless.

Table 2.6 : Mean seasonal (Nov.-May) value of R-index under different soil moisture capacities and at estimated capacity ,1964/78.

Location	Soil Moisture Capacity (mm)									Es.Capacity	
	50	75	100	125	150	175	200	225	250	e.c.	CV.%
Amman	.55	.60	.62	.64	----------			.63	.62	.64	20
Baqura	.57	.62	.66	.68	.70	----------			.69	.70	15
Rabbah	.58	.64	.67	.70	----------					.70	20
Irbid	.65	.70	.73	.76	.77	.78	.79	.80	.80	.80	15
Jiza	.51	.54	.53	.52	.50	.49	.48	.48	.48	.53	24
Jubeiha	.66	.71	.75	.78	.80	.82	.83	.84	.84	.83	9
Maan	.13	----------								.13	45
Madaba	.60	.64	.67	.69	.70	.70	.69	.69	.69	.69	22
Mafrag	.44	.45	.46	.45	.44	.43	.42	.41	.40	.45	34
Naor	.67	.72	.75	.78	.79	.81	.82	.83	.83	.83	14
Quren	.54	.58	.58	.58	.57	.56	.55	.55	.54	.58	20
Rasmunief	.72	.77	.80	.83	.85	.86	.87	.87	.88	.87	8
Shoubak	.62	.67	.70	.71	.72	.71	.71	.70	.70	.72	19
Tafila	.59	.64	.66	.67	----------				.66	.67	24
Taibeh	.64	.69	.73	.76	.78	.79	.80	.81	.82	.80	10
Wadiduleil	.44	.45	.45	.44	.43	.42	.42	.41	.40	.45	29
Wadiyabis	.52	.56	.58	.60	.60	.60	.59	.58	.57	.60	23

------- : All data are equal to the preceding value.

Seasonal R-index values (Nov-May) reflect the ratio of estimated to potential crop yield for some locations at different soil moisture capacities.

The R-index was used to estimate wheat yield relative to its potential. Table 2.7 shows the sites of high crop yield and those where crop yield can be improved.

Another area of interest is the effective growing period, i.e., the period (in days) when there is enough soil moisture and energy for crop growth and development. Effective growing period has been calculated according to two different models (Kassam, 1978; McCown, 1973).

The first model (Kassam,1978) uses rainfall and PET. The total growing period is the time for which rainfall >= 0.5 PET. The growing season ends when rainfall (mm) becomes less than PET/2. Soil moisture and temperature are taken into consideration in this model.

Available data were used to calculate growing periods for selected areas in Jordan. Three types of growing periods were observed. First, there is a normal growing period during which rain exceeds PET. During this period, rainfall meets all the PET requirements of the crop at 100% ground cover, and replenishes, to some extent, the soil moisture. Under such conditions, the growing season starts when rainfall/PET >= 0.5 . It ends when rainfall / PET < 0.5 . A

Table 2.7 : Estimated crop yield (Y) relative to potential yield: (Yb =Y/Yb) for a selected number of locations in Jordan .

Location	Y/Yb %
Amman	59
Baqura	79
Deir Alla	56
Errabbah	72
Irbid	86
Jiza	41
Jubeiha	91
Mafrag	33
Ras Munief	96
Shoubak	69
Tafila	62

10-15 day period is added to the length of the growing season when rainfall is above 300 mm. Irbid in the north and Rabbah in the south are good examples of this type .

An intermediate growing period is realized when the average monthly rainfall never exceeds PET, but exceeds 0.5 PET for a limited period of time. The duration of the growing period, in this case, is shorter than in the first type.

A third type of growing period is encountered when the average monthly rainfall is always less than PET/2.

The second model uses the R-index (i.e., the AET/PET ratio) and soil moisture capacity. However,more research is needed in this area to obtain more reliable results which can be used for establishing crop calendars.

2-8.RESEARCH NEEDS

The adaptation of farming to local conditions of soil and climate requires climatological observation over an extended period of time.

Up to the present time, the utilization of agroclimatological data has followed a classical pattern. Mean values were calculated for individual months, seasons and years. This rigid pattern of time, however, does not correspond entirely with the actual plant life cycle.

Mean values, for certain environmental parameters, lose their significance as their variances increase. The WMO took the first step by calculating and publishing probabilities of certain environmental parameters such as precipitation (Lomas, 1976).In agricultural meteorology, however, precipitation alone is not sufficient to characterize a certain area. Other parameters such as temperature, PET, AET, sunshine duration etc., are of equal importance. Frequency distributions and probabilities of these parameters are more meaningful than average values. Consequently, all available meteorological information has to be reprocessed and analyzed. Availability of high-speed computers will facilitate the process. It is necessary to establish a main data and, if possible, regional data banks, so that the whole country has access to all available meteorological information.

This will require a great effort to check the reliability of the records and to organize them in data bank forms.

In consulting the literature, it is astonishing to see that a large number of observations/records have been done over the last 50 years in Jordan. However, the number of studies which have been undertaken in the field of agricultural meteorology is very limited .

Soil and climate parameters play a major role in the life

cycle and rate of plant development. Basic research is needed on plant phenology as affected by weather variables. Research is needed on the effect of weather conditions on farming operations (e.g. plowing, sowing, fertilization, etc.). More research is needed to prepare production probability charts of the major crops in the country as a result of the highly variable climate.

Research is needed to develop improved crop calendars in relation to agroclimatology. Also, it is important to use climatic parameters in studying and predicting the population dynamics of diseases and insects for better crop protection and production.

Meteorological data should be used to construct or modify existing simulation models for plant growth, development and production. These models should be as simple as possible , using parameters which are measured in all meteorological stations across the country. It is hoped that, in the near future, the application of modern agricultural meteorological methods , modeling being one of them, will help in raising crop production in this and other developing countries.

2-9.SUMMARY

The climate of Jordan is predominantly Mediterranean

characterized by mild, rainy winters and hot, dry summers. However, it displays a few variants caused by the effect of latitude, altitude and the shadow effect of the mountain range. These factors bring about marked differences in temperature, amount and distribution of precipitation during the rainy season. Climatologically, the country is divided into three distinct regions. These are the Jordan Valley, the highlands and the steppe and steppe desert .

The rainy season extends from October to March or April. Annual rainfall is very much related to topography, with the mountain region receiving the highest, and the steppe desert the lowest rainfall. Over 50% of the area of Jordan receives less than 100 mm of annual rainfall, while annual rainfall in the major dryland agricultural areas ranges from 250-600 mm. Rainfall is erratic, irregular and highly variable, with occasional high intensities ,especially in the highlands.

A limited number of studies have been undertaken to predict rainfall amount and duration, and a number of empirical formulae have been developed. However, agroclimatological data have been used, in the past, in a classical manner and rarely have been used for agricultural planning or for constructing improved crop calendars. It is hoped, in the near future, that available data will be fully computerized and used to build simulation models for the purpose

of improving agricultural research and production in the country.

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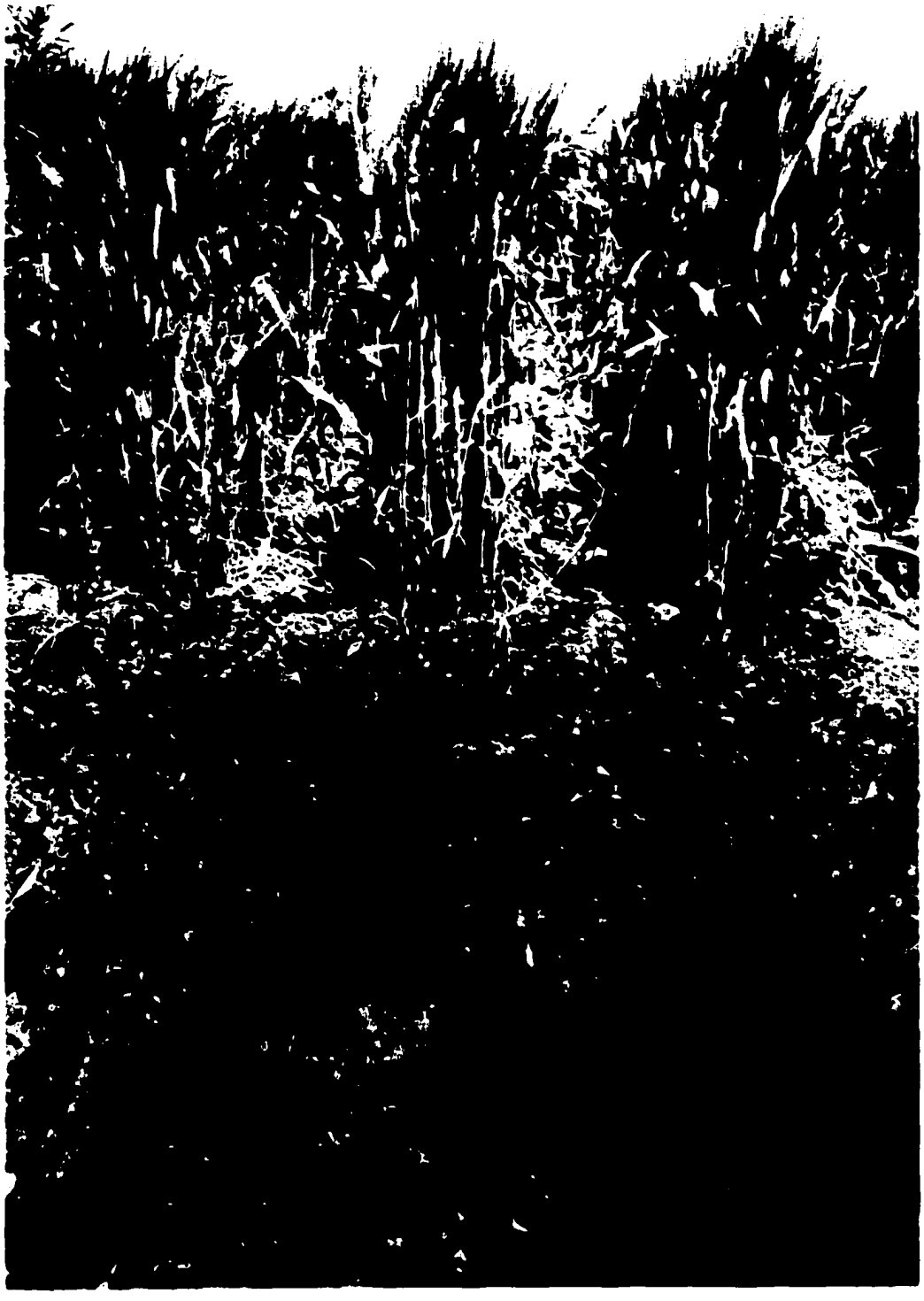

SOIL RESOURCES

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SOIL RESOURCES

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3-1.INTRODUCTION

Jordan is a small country in southwest Asia with a large proportion of its rural population relying on agriculture to meet their basic food needs.

Land use in the rainfed agricultural sector of Jordan is inefficient , partly because of a lack of information on capabilities of soils for crop production. Although soil survey studies were conducted in the past 30 years in several parts of the country, no attempt has been made to document available soil survey information for land assessment purposes (Qudah , 1983). Also, there appear to be large areas of underutilized soils in the rainfed parts of the country. Most of these soils are undergoing rapid depletion of fertility under the prevailing land use systems. Thus, agricultural specialists in Jordan should view the conservation of the country's agricultural lands as their highest priority and determine the best use of these

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limited resources to maximize food production.

Opportunities for improved use of Jordanian soils for crop production do exist and are highlighted in a number of reports (e.g. Mitchell and Haward , 1978) and feasibility studies (e.g. NRA , 1967 , 1969 ; MOA , 1974).

In this chapter the soil resources of Jordan are discussed and the major soil taxonomic units in the country are presented.

3-2.PHYSIOGRAPHY

3-2.1.Geology And Geomorphology

Seven main geomorphological units can be distinguished in Jordan (Fig.3.1) . Their extension and specific relief patterns are closely related to their structural and stratigraphic composition. However, the epeirogenic movements during Middle Cambrian, Triassic and Cretaceous to the Oligocene resulted in marine transgression and regression. As a result , different strata of sandstone , limestone, marl and dolomite were deposited. Rifting, northward movement, tilting to the east and eruption of the basaltic mountain of Jebal Druze in the Lower Miocene and Pleistocene, resulted in the present physiography shown in Fig.3.2. During these successive processes, the Jordan Valley developed its course and the rejuvenated drainages,

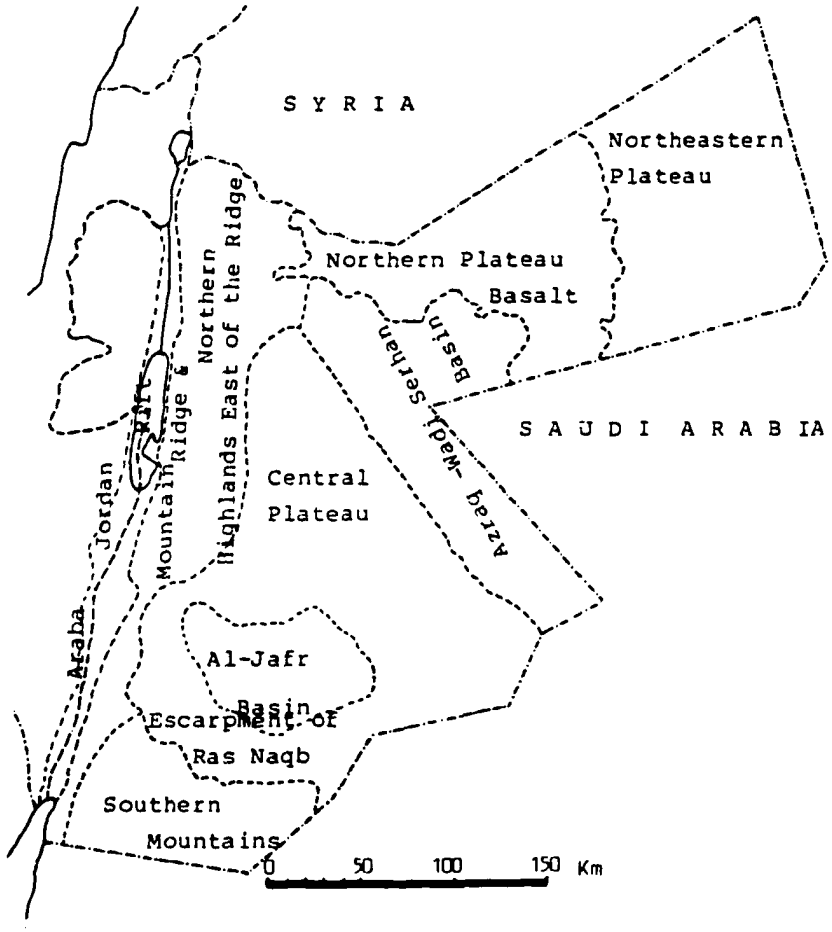

Fig. 3-1. Main geomorphological units in Jordan.

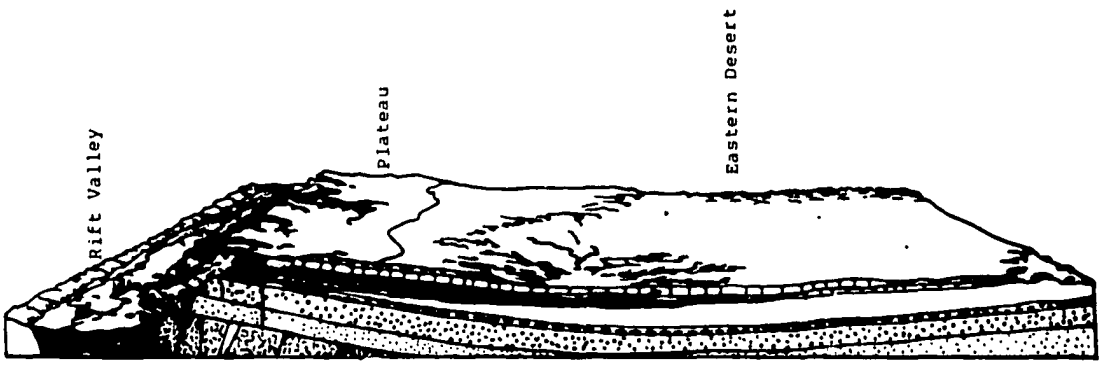

Fig. 3-2. A cross section of Jordan showing the rift valley , the plateau and the eastern desert.

like Yarmuk, Zarqa, Mujab and Alhassa, cut back farther to the east in the plateau, capturing more land and revealing older rocks.The erosion products of these rejuvenated drainages were deposited in the Jordan rift valley floor. In addition to these main lithological groupings, other units comprised of Pleistocene to recent age, are found. These include an association of shale conglomerates and sediments of alluvial and colluvial origin (Burdon , 1959).

3-2.2.Climate

The whole of Jordan lies within the Mediterranean bioclimatic region,characterized by a concentration of rainfall during the cool winter season while the summer is dry and hot. The total precipitation varies greatly from year to year as well as in its distribution during the season . The rainy months extend from October to May, with rain being heaviest between November and March.

Relative humidity may reach its highest level (~ 75%) during the winter months (December - February), then it gradually decreases during spring until it reaches its lowest limits during early summer (42 to 50%) . Very low relative humidities occur during "Khamasin" periods when hot, dust-laden winds from the east and south prevail during spring and early summer . Both soil temperature and moisture regimes were characterized for a number of locations

throughout the country. They are presented in Table 3.1 and show the distribution of each regime as determined by soil temperature and moisture (El-Kawasma , 1983).

3-2.3.Vegetation And Land Use

Jordan has a long land use history in agriculture and farming. Irrigation in Jordan has probably been practiced as early as Roman times or even before. For centuries, there has been sufficient vegetative cover to meet the domestic needs for wood and to provide grazing for a large number of animals. Among the crops, which were extensively grown during ancient times and still occupy a considerable proportion of the drylands , were cereals, vines and olives (Mitchell,1982).

Changes in land use and cropping patterns have occurred in most areas in Jordan for many reasons including economics, discovery of water resources for irrigation , insect problems, and plant disease.

3-3.SOILS

3-3.1.Previous Studies and Results

Soil mapping and classification started in Jordan in the 1950s . Moorman (1959) mapped the soils of Jordan at a scale of 1:1,000,000, using the U.S Soil Classification

Table 3.1 : Classification of some Jordanian Soils According to Their Temperature and Moisture Regimes (ACSAD , 1984).

Location	Station	Moisture Regime	Temperature Regime
	Amman	Xeric	Thermic
	Rabbah	" "	" "
Rainfed	Irbid	" "	" "
Areas	Jubeiha	" "	" "
&	Madaba	" "	" "
Mountains	Naor	" "	" "
	Ras-Munief	" "	" "
	Shoubak	" "	" "
	Tafila	" "	" "
	Wadi-Wala	" "	" "
	Baqura	Ustic	Hyperthermic
Jordan	Deir-Alla	" "	" "
Valley	Wadi-Yabis	" "	" "
&	Taibah	" "	" "
Southern	Aqaba/Airport	Aridic	" "
Parts	Aqaba/Port	" "	" "
	Ghor-Safi	" "	" "
	Azraq	Aridic	Thermic
	H4	" "	" "
	H5	" "	" "
Desert	Jafr	" "	" "
Areas	Jiza	" "	" "
&	Ma'an	" "	" "
Eastern	Mafraq	" "	" "
Parts	Quren	" "	" "
	Rum	" "	" "
	Wadi-Duhleil	" "	" "
	Zerqa	" "	" "

System of 1938. He recognized twelve great soil groups ,the most common of which were grey desert soils, alluvial soils developed under desert climate, yellow soils developed under steppe conditions, and yellow and red Mediterranean soils developed where annual rainfall exceeds 250 mm.In addition, minor soils were scattered among the three major great soil groups in varying amounts and associations as shown in Fig 3.3 . Total areas of these lands are delineated according to their long-term annual rainfall and agroecological zones. In Moorman's study, the combination of rainfall and soil characteristics were used as criteria for general land use and capability classifications . He proposed such general land use capabilities as: irrigated farming , dryland farming , rangeland farming and forestry.

During the 1960s, West (1970) mapped the soils of Baqa'a Valley at a scale of (1:10,000) using the U.S. Soil Taxonomy (7th Approximation). The area covered by this study was about 6700 ha. The dominant taxonomic units encountered were Xerochrepts and Chromoxererts. Usually, these were located on gentle slopes and flat topography. Xerorthents were also identified in that area , however , their distribution was limited and they only occurred on the eroded slopes.

This work was extended, during the 1970s, to Irbid and Karak regions. A detailed survey was carried out for 2500

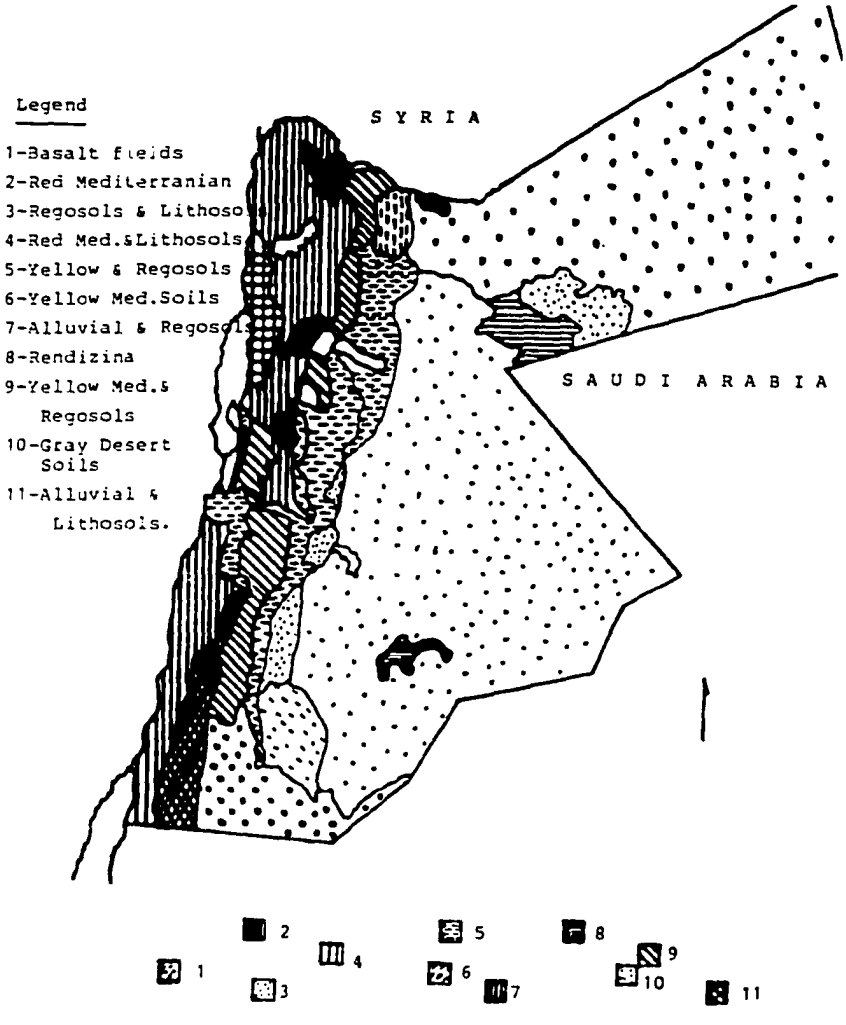

Fig. 3-3. General soil map of Jordan.

ha, and a semidetailed survey for 70,000 ha in the Irbid region. At the same time, an area of about 8000 ha was surveyed, in detail, in the Karak region.

A local mapping legend was developed and used to distinguish the different soils in both regions (see Appendix I). Land suitability classification maps were produced at a scale of 1:25,000 , for the Irbid region, and at a scale of 1:5000 for the Karak region. Factors such as rainfall, soil depth, slope, texture and structure were taken into consideration for the soil survey , classification and mapping.

Similar soil studies were conducted in different parts of the country. An estimated area of 80,000 ha was mapped, at a scale of 1:50,000, in Balqa region. The locally developed mapping legend was used in this study. Unfortunately, little information is available about this study.

The lower Zarqa valley catchment area was a subject of another study by GTZ (1982) . A new land classification system was devised for this area and maps were developed at a scale of 1:25,000. Eight land classes were defined throughout the area, based on soil depth, stoniness, slope and rainfall.

Bonifica (1973) surveyed over 30,000 ha and mapped,in detail , about 2000 ha in the Disi area in southern Jordan.

This work was the basis for the land reclamation and irrigation project which was started in 1974 in that part of the country. Similar studies were carried out by the Department of Soil Survey for the same purpose,in the southern and eastern parts of Jordan (Qudah , 1983).

A major project for developing the rangelands and improving livestock production in the steppe region of Jordan was carried out jointly by the Arab Center for Studies in the Arid Lands and Dry Regions (A.C.S.A.D) and the Ministry of Agriculture (MOA). This project utilized the USDA Soil Taxanomy System of 1975 (ACSAD , 1984). Maps were developed at a scale of 1:1,000,000 for the Hamad basin (see Fig 3.4).

3-3.2.Evaluation of Previous Work

In the above mentioned studies, the systematic soil survey has been generally avoided. A notable exception is the soil survey and land classification of the Jordan Valley, Baqa'a Valley and Hamad catchment. Single land characteristics (e.g. slope) were also directly used in this study as a basis for establishing the land capability classes.

Slope, for example, is not only important in determining the erosion hazard, but it also affects workability and irrigability of the land. Its complex

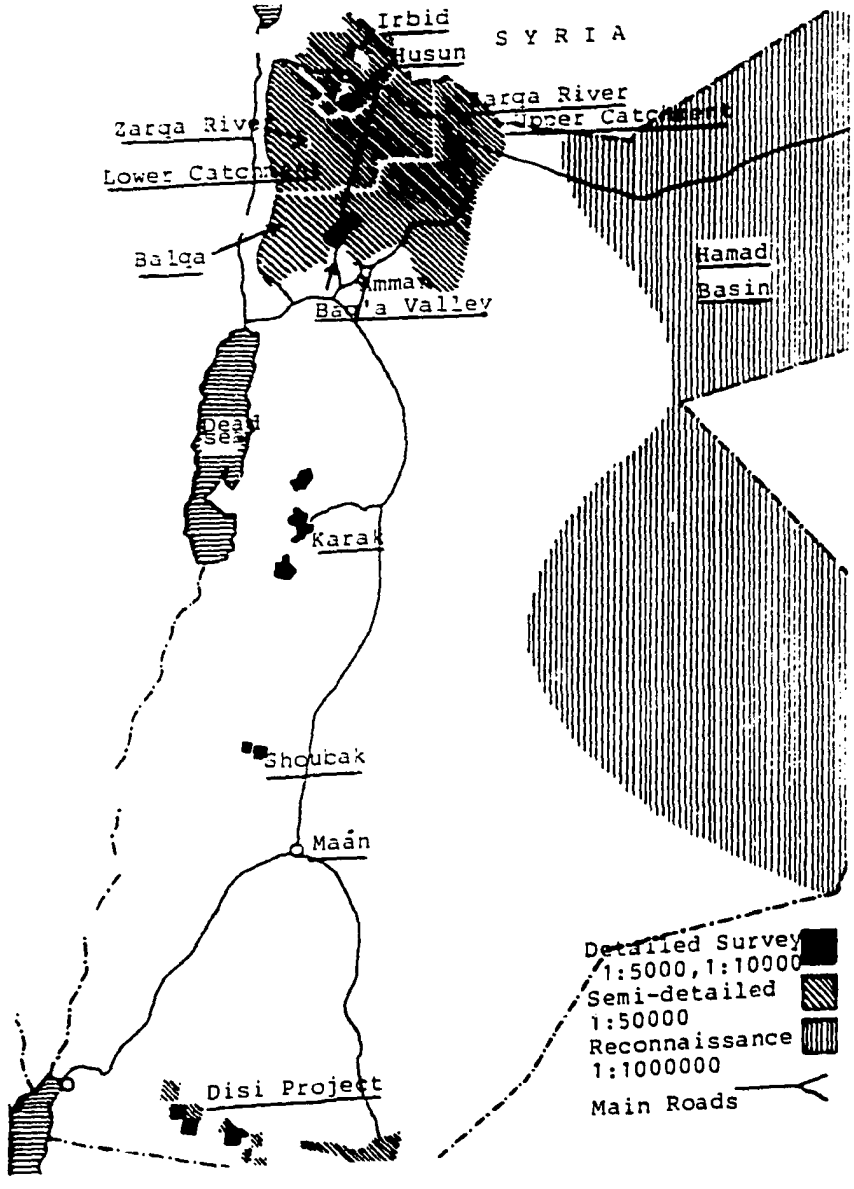

Fig. 3-4. Location of existing soil survey and classification studies in Jordan.

interactions with other land characteristics such as slope length, soil permeability, soil structure and rainfall characteristics, influence the actual capability of the land in question.

It is for this reason , that the previously mentioned classification systems failed to predict the actual capabilities of the target land areas. These studies were not comprehensive. They were done at different times by different agencies which employed diverse standards, methods, map scales and land class specifications. General standards were lacking among the different studies and , therefore, it is very difficult to correlate their results . In addition, extrapolation from both local and foreign projects is not possible unless the basic soil classification information is also available.

In the absence of a systematic soil survey system and land classification maps at three different levels of detail for the whole country, land use in Jordan is unbalanced and suffers from conflicting interactions among the various major land uses. For example,the urban areas are gradually increasing at the expense of the potential agricultural lands , thus reducing areas destined for crop production . The currently marginal lands (<200 mm isohyte) have been brought under cultivation at the expense of natural rangelands. This has resulted in the desertification

and erosion of valuable agricultural lands (Qudah ,1983).

3-3.3.Soil Forming Factors

The most active soil forming factors acting on Jordanian soils are climate, parent materials, and relief. These factors along with the biotic factors will be discussed in the following sections.

3-3.3.1.Climate

According to Embergar (1955) the whole of Jordan lies within the Mediterranean bioclimatic region. In a recent study by El-Kawasma (1983), soil temperature and moisture regimes were evaluated for several meteorological stations covering most of Jordan. This study shows that xeric soil moisture and thermic temperature regimes prevail in the rainfed and mountainuous regions of the country. Ustic soil moisture and hyperthermic soil temperature regimes prevail in the Jordan Valley and the southern part of the country. The soil moisture and temperature regimes of the eastern part of Jordan are aridic and thermic, respectively. The direct effect of the climate on soils can be observed by going from the high rainfall areas in the North towards the more arid zone in the South and Southeast . Due to low rainfall and high evaporation in southern Jordan, the percolation effect and , hence the translocation of soil

constituents are limited. Therefore, soils in these areas remain immature and have been subjected to fewer soil formation processes than soils in the higher rainfall areas . These soils are characterized by grey color, coarse texture, weak structure, and they are high in calcium carbonate and magnesium sulfate . The more immature brown and grey soils in the higher rainfall areas occupy the slopes and mountain tops where erosion is active, while more developed, red brown soils occur in the cooler areas of the country.

3-3.3.2.The Parent Material

The following associations of lithological units are found in Jordan : cherty limestone, limestone associated with basalt, marly limestone, dolomitic limestone, sandstone and granite. These rocks have different mineralogical composition , coherence, and permeability. It has been observed that soils developed on soft marly limestone are calcareous and have a high percentage of coarse rock fragments throughout their profiles. In these soils, the surface erosion is very intensive . Consequently they are regularly rejuvenated and remain immature with a brown and grey color matrix. Basalt and hard limestone in the high rainfall zones produce deep profile, heavy textured soils with moderate to strong structure and a red brown color. In the southern plateau where sandstone and granite

dominate, soil development is limited and the profile mainly contains stable elements such as quartz. In the eastern part of the country, chemical weathering is limited due to low rainfall ; subsurface horizons such as calcic, gypsic, and salic are very common to these soils (Qudah , 1983; Rihani, 1983).

3-3.3.3.Reliefs

Relief has played an important role through its influence on erosion activity and on the soil moisture regime. In Jordan, the topography ranges from nearly level to mountainous and slopes range from 1 to greater than 60%. Soils in steeply dissected landscapes , developed on soft marly limestone and where annual precipitation is concentrated in short but heavy showers, have continuous soil erosion and permanent rejuvenation of the soil profile. These soils remain shallow,skeletal and show all the characteristics of Entisols . On more protected surfaces , soil profiles are deeper, have good structure and better water infiltration rates ; slightly developed soils such as Inceptisols or Alfisols have been recognized , especially around Irbid, Madaba, Karak, and Shoubak (ACSAD , 1984).

3-3.3.4.The Biotic Factor

In an area that has been densely populated for several centuries, man has had a tremendous influence . In

ancient times, man was the cause of almost complete destruction of the original vegetative cover. Willimott (1965) made some observations about the effect of tree canopies' shade on some soil properties. In his study he found that pH and calcium carbonate decrease towards the trunk of the tree, and humus and C.E.C. increase . This would indicate a decreased soil fertility as a result of tree uprooting and land use for agricultural production purposes.

Vegetative cover has a great influence on soil formation and characteristics . The organic horizon would not exist without a dense plant cover such as the one found in Ajlun mountains . On the other hand, a light plant cover in the plains or desert, results in low organic matter content. Generally speaking , soil type in Jordan is a function of precipitation , parent material , relief and vegetative cover.

3-3.4.Major Soils of Jordan

Since soil surveys have been mainly limited to localized projects in separate parts of the country, comparatively little is known about the soils of Jordan at a national level. The only exception is the outdated Moorman (1959) study . So far there has been no attempt to assemble or reevaluate all previous activities in order to establish

a general soil map in current terms. However, according to our present knowledge and based on all previously published soil studies and available data, the following soil taxonomic units, according to USDA Soil Taxonomy, have been identified in Jordan (Qudah,1983;Rihani,1983;ACSAD,1984).

3-3.4.1.Soils Developed Under Xeric Moisture Regime

3-3.4.1.1.Xerochrepts

These soils have an epipedon and calcic subsurface horizon under a xeric soil moisture regime which prevails in the rainfed and mountainous areas. They are developed on both upper and lower slopes. The Xerochrepts of Jordan are well-represented by subgroups such as Vertic Xerochrepts, on the lower gentle slopes, and Lithic and Calcixerollic Xerochrepts on the upper, slightly convex slopes. These are generally productive soils. The main limiting factors for their utilization in agricultural production are their depth to bedrock and the content of rock and gravel in the profile and on the surface.

3-3.4.1.2.Chromoxererts

These are the Vertisols developed under a xeric soil moisture regime. They are deep, clayey soils, developed on hard limestone and basalt. They are distributed on level to

nearly level areas in the Irbid basin in the North, and Madaba and Karak in the South. The Chromoxererts are well-represented by subgroups such as Typic and Entic Chromoxererts. These soils are inherently fertile, have a high water-holding capacity and are well-suited for all cereal crops . When fruit trees are planted in these soils, their root systems might be damaged because of the moderately wide cracks which develop during the dry season. Other soils such as Xeralfs, Xerolls and Xerorthents have a limited occurrence and distribution .These can be found in the mountains of Ajlun, Balqa'a and Shoubak. Descriptions of typical profiles are presented in Appendix II.

3-3.4.2.Soils Developed Under a Torric (Aridic) Moisture Regime

3-3.4.2.1.Aridisols

These taxonomic units cover about 60% of the total area of Jordan. In addition to their aridic soil moisture regime, these soils are characterized by having an ochric epipedon and one or more pedogenic subsurface horizons. The dominant suborder is Orthids. The most common subsurface horizons in the Aridisols of Jordan are the calcic and gypsic horizons. Aridisols with a cemented calcic horizon are also found in Jordan , especially in the northern plateau.

3-3.4.2.1.1.Calciorthids

These are Aridisols with an ochric epipedon and a calcic horizon, they contain high amounts of lime in the subsoil and the parent material. Sometimes the calcic horizon becomes indurated ,decreasing the rootability of the soil. These soils are distributed in the steppe region where rainfall is very low. Land use is restricted to grazing during the spring season. Water harvesting can be very profitable on such soils.

3-3.4.2.1.2.Gypsiorthids

These are distinguished by the presence of gypsum in high amounts, deep in the profile. Some Gypsiorthids have gypsum in all horizons. They are common in eastern and southeastern parts of Jordan (Sirhan basin and Mudawarah). Rainfall is very limited in these areas , not exceeding 50 mm annually, and the only possible land utilization is grazing. However, the presence of gypsum or salts could severely decrease grass growth and production. The plant species are also specific to these conditions. Descriptions of typical profiles are presented in Appendix II.

3-3.4.2.1.3.Camborthids

Camborthids are aridisols that have an ochric epipedon and a cambic subsurface horizon. Most Camborthids are deep

with flat slopes; they are associated with Entisols and Calciorthids. The color of the cambic horizon is darker than the topsoil.

These soils have much less calcium carbonate content than the Calciorthids. The extent of these soils in Jordan is very limited compared to other Aridisols.

3-3.4.2.1.4.Salorthids

These are the very salty soils occurring in wet places in the desert ,where capillary rise and evaporation of water concentrate the salts into a salic horizon. The Salorthids are usually deep and wet , but the dissolved salts make the soil physiologically dry because of the osmotic pressure. The Salorthids are good soils for crop production if the salts are leached beyond the root zone and irrigation water is available . Salorthids occur in Jordan around Azraq Oasis, the Qa-Disi mudflats and in some places in Wadi Araba. In these areas , Salorthids are associated with Torrifluvents and Torripsamments.

3-3.4.2.2.Entisols

These are very young soils. Some of them have an ochric epipedon at the surface, especially when they are protected from erosion. They are good soils for agriculture unless a lithic or paralithic contact is present. In Jordan , they

are mostly stoney or sandy and are associated with Aridisols.The main great groups observed are the following:

3-3.4.2.2.1.Torrifluvents

These are the Fluvents of arid climates that are not flooded frequently or for long periods. They have a torric moisture regime and most of them are saline or alkaline. They are distributed in mudflats such as Qa-Disi in the South, and Qa-Khana near Azraq in the North.

3-3.4.2.2.2.Torripsamments

These are Entisols formed on sandy parent materials that could be poorly graded sands , shifting or stabilized sand dunes, and under torric soil moisture regimes.

They have low or very low water-holding capacity and high infiltration rates . They have single-grain texture, mainly formed by quartz with or without coating. This coating is mainly iron oxides that give the red color to the material inherited from the argillacious sandstone near to these soils. Some are slightly calcareous or saline due to the presence of shale fragments.

These soils are generally deep unless a lithic or paralithic contact is present. They are sometimes gravelly and associated with gypsum. They occur mainly in Disi-Mudawara and Wadi Araba regions. They are good soils for

agricultural production if irrigation water and fertilizers are available.Descriptions of typical profiles are presented in Appendix II.

3-3.4.2.2.3.Torriorthents

These are the Orthents of arid climates that are dry or salty. They are gravelly or of sandy loam texture and are associated with Torripsamments. They occur in the eastern desert and the southern sandstone plateau.

3-4.RESEARCH NEEDS

Soil survey and land classification work in the dryland regions of the country lagged for a considerable period of time behind soil surveys for irrigation purposes. However, in the current five-year plan (1986-1990) soil surveys in the dryland regions were considered major objectives (Ministry of Planning, 1986) .

Agricultural planners felt that the following two objectives are very important for the development of dryland agriculture in the country . The first is to assess capabilities for crop production of agricultural soils in Jordan using an appropriate land use capability system based on modern soil taxonomy . The second is to determine agronomic practices and management inputs required to bring each soil type to its maximum yield potential.

Productive soils in the rainfed parts of the country are a limited resource. In order to utilize this resource profitably , it is necessary to conserve and manage it properly. Soil conservation and management should be based on a sound land use system and suitable cropping patterns. Consequently , research is needed to develop suitable op-ping patterns and management practices for the different soil classes present in Jordan.

A small part of the country (~ 25 %) was mapped , while the major part ,especially in the semiarid region , has not yet been mapped . The lack of soil maps has been keenly felt by the staff of the Soils Department , Ministry of Agriculture. As a result , a soil-mapping project was formulated and approved by officials in the Ministry of Agriculture . This project emphasized the following objectives to be achieved during the current five-year plan:

1- The collection , summarization and mapping of all available environmental(e.g., weather , topography , geology etc.) and resource (e.g., rangelands, ground water, present land use, size and shape of land holdings etc.) information. This information can be collected by conventional and remote sensing techniques , then plotted on a base map for the whole country.

2- A semidetailed map at a scale of 1:50,000 must be

produced during the second phase of the project. Potential agricultural lands will be identified and located on this map .

3- A detailed soil survey at a scale of 1:10,000 will be conducted for promising lands throughout the country and recommendations for land use will be developed.

It is expected that the activities of this project will build a national soil survey and land classification team .

Finally, it is recommended that technical information about soils and land capability classes be conveyed to farmers . It is suggested that well -qualified extension agents with access to such technical information be stationed in each regional office of the Ministry of Agriculture.

3-5.SUMMARY

A limited area (25 %) of Jordan's agricultural land was mapped during the last 30 years. Several national and international agencies were involved in this activity , which has not been completed.

Climate , parent material and biotic factors are the major soil forming factors under Jordanian conditions. The soils of Jordan developed under two major regimes : the

xeric and the torric (aridic) moisture regimes. Xerochrepts and Chromoxererts developed under the first , while Aridisols and Entisols developed under the second regime.

The field work which was carried out during the last 30 years indicated the presence of the following taxonomic units: Xerochrepts , Chromoxerts , Calciorthids , Gypsiorthids , Camborthids , Salorthids , Torrifluvents , Torripsaments and Torriorthents.

A sound land use system and suitable cropping patterns should be developed for the different soils throughout the country . This work, however, should be based on modern soil taxonomy principles.

A major project was planned and will be carried out during the current five-year plan (1986-1990) in order to :

a) identify potential agricultural lands in the country,and

b) carry out a detailed soil survey and develop recommendations for land use of these soils .

It is hoped that the activities of this project will build a soil taxonomy team , and develop recommendations to bring each soil type to its maximum yield potential .

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3-7.APPENDIXES

3-7.1.Appendix I

DESCRIPTION OF SOIL SERIES

Series 11 : Red clayey soils which form moderately wide cracks in the dry season , and which are developed on hard limestone associated with small amounts of chert.

Series 12 : Brown clayey soils which form moderately wide cracks in the dry season , and which are developed on limestone associated with small amounts of chert.

Series 13 : Red gravelly clay soils which form moderately wide cracks in the dry season, and which are developed from hard limestone associated with small amounts of chert.

Series 15 : Red clayey soils which form moderately wide cracks in the dry season,and which are developed from hard limestone associated with basalt.

Series 31 : Red clayey soils with good structure and developed on hard limestone associated with small amounts of chert.

Series 32 : Brown clayey soils with moderately good structure and developed on limestone associated with small amounts of chert.

Series 33 : Brown silty soils with a moderate tendency to form surface crust and developed on limestone associated with variable amounts of chert.

Series 34 : Yellowish brown silty soils with moderate tendency to surface crust and developed on limestone associated with a friable amount of chert.

Series 37 : Red or brown gravelly clay soils with good structure and developed on hard limestone associated with small amounts of chert.

Series 41 : Brown clayey soils with strong structure and tendency to form crust,and derived from soft limestone and sandstone.

Series 42 : Very dark brown sandy loam over dark brown clay loam with moderate structure and tendency to form surface crust and developed on limestone , marl and sandstone.

Series 44 : Brown sandy soils not calcareous , with weak or massive structure, developed on sandstone.

3-7.2.Appendix II

Series : Jordan 6
Pedon No.: S82FN-500-006
Taxonomy : Very fine, montmorillonitic,thermic, Typic Chromoxerert
Location : Ramtha Station near Dera Junction on Irbid to Mafrag highway.
Vegetation : Fallow-(volunteer wheat) . Local staff says get good crops about 2 years in 10. Local soil scientists consider this soil to be at the dry end of xeric moisture regime.
Soil Moisture : Moist throughout.

Description

AP 0-12cm : Strong brown (7.5YR 4/6) clay; strong fine to medium subangular blocky structure; firm ,very sticky and very plastic; common very fine roots; a few very fine tubular and many fine interstitial pores ; strongly effervescent; abrupt wavy boundary. About 3% chert fragments throughout.

A1 12-32cm : Strong brown (7.5YR 4/6) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic ; common very fine roots; a few very fine tubular and many fine interstitial pores; strongly effervescent;clear wavy boundary. About 3% chert fragments throughout.

ABK 32-58cm: Brown to dark brown (7.5YR 4/4) clay; strong medium to coarse angular blocky structure;firm, very sticky and very plastic; common effervescent; clear wavy boundary. Common weakly expressed slickensides.Cracks up to 2 cm wide.Common fine soft lime masses and weathered limestone fragments.

BW1 58-89cm: Brown to dark (7.5YR 4/4) clay ; weak coarse prismatic parting to strong medium to coarse angular blocky structure; firm, very sticky and very plastic; a few very fine and a few course roots; a few very fine tubular pores;

strongly effervescent;gradual wavy boundary.Many strongly expressed slickensides and wedges. Cracks up to 2 cm wide.

BW2 89-116cm: Brown to dark brown (7.5YR 4/4) clay; weak coarse prismatic parting to strong medium to coarse angular blocky structure; firm, very sticky and very plastic; a few very fine and a few coarse roots; a few very fine tubular pores; strongly effervescent ; gradual wavy boundary. Many strongly expressed slickensides and wedges. Cracks up to 2cm wide.

C 116-150cm: Brown to dark brown (7.5YR 4/4) clay; medium; firm, very sticky and very plastic; a few coarse roots; a few very fine tubular pores; strongly effervescent.

Series : Jordan 7
Pedon No.: S82FN-500-007
Taxonomy : Fine, montmorillonitic, thermic, Entic Chromo-xerert
Location : About 10km Northeast of Irbid; Maru Experiment Station.
Vegetation : Fallow wheat stubble; chisel plowed for planting sesame . Local soil scientist called this area the "Basalt area" distinguished by basalt cobbles or stones (float) mostly on surface.
Field Moisture : Moist to about 49 cm, nearly dry below.

Description

AP 0-10cm :Dark brown(7.5YR 3/4) clay, dark brown(7.5YR 3/4 ,dry); strong fine subangular blocky structure; firm, very sticky and very plastic; common very fine roots; a few very fine tubular pores;coarse fragments;10 pct larger than 2mm mixed lithology ; strongly effervescent; abrupt wavy boundary.

A1 10-27cm:Dark brown (7.5YR 3/4) clay , dark brown (7.5YR 3/4,dry);strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine roots; a few very fine tubular pores and many fine interstitial pores; coarse fragments,10 pct larger than 2mm mixed lithology ;weakly effervescent; clear wavy boundary.Common pressure faces.

AB 27-49cm:Dark brown(7.5YR 3/4)clay, dark brown (7.5YR 3/4 , dry); strong medium to coarse angular blocky structure; firm, very sticky and very plastic; a few very fine roots; a few very fine tubular pores; coarse fragments, 10 pct larger than 2mm mixed lithology; weakly effervescent; clear wavy boundary.Many moderately expressed slickensides.

BW1 49-78cm:Dark brown(7.5YR 3/4) clay, dark brown(7.5YR 3/4 ,dry); strong medium to coarse prismatic parting to strong medium angular blocky very fine tubular pores; coarse fragments, 10pct larger than 2mm mixed lithology; weakly effervescent; clear wavy boundary.Many prominent slickensides. Cracks 5 to 10cm wide extend to surface when dry.

BW2 78-105cm:Dark brown(7.5YR 3/4)clay,dark brown (7.5YR 3/4 ,dry); strong medium angular blocky structure; firm, very sticky and very plastic; a few very

fine roots; a few very fine tubular pores; coarse fragments, 5 pct larger than 2mm mixed lithology; weakly effervescent; abrupt wavy boundary.Many prominent slickensides and wedges. Weathered limestone fragments. Cracks 5 to 10cm wide extend to surface when dry.

R 105-130cm: Dark brown (7.5YR 3/4) texture not recorded;very strong extremely fine.

Series : Jordan 10
Pedon No. : S82FN-500-010
Taxonomy : Typic Natrargids.
Location : Across highway from Hotel Hunter.
Vegetation : Mostly a rhizomatous grass; some bunch grass.
Field Moisture : Moist throughout (little is known about the moisture regime-soil may be wetted with run-on from summer showers).

Discription

O 9 - 0cm : Root mat with many rhizomes.

A 0 -21cm : Grayish brown (10YR 5/2) clay loam; moderate fine subangular blocky structure; friable, sticky and plastic; many fine roots; common fine tubular and many interistial pores; weakly effervescent; abrupt smooth boundary.

BW 21-36cm : Light brownish gray (10YR 6/2) clay; weak medium prismatic structure; firm, very sticky and very plastic; common fine roots; common fine tubular pores; strongly effervescent; clear wavy boundary.

BK1 36-73cm : Light gray (5Y 7/2) clay; moderate medium prismatic structure; firm, very sticky and very plastic; common fine roots; common fine tubular pores; strongly effervescent; clear wavy boundary.

BK2 73-97cm : Light brownish gray (2.5Y 6/2) clay; weak medium prismatic structure; firm, very sticky and very plastic; common fine roots; common fine tubular pores; strongly effervescent; clear wavy boundary.

BK3 97-123cm: Light brownish gray (2.5Y 6/2) silty clay; moderate fine angular blocky structure; firm, very sticky and very plastic; common medium roots; few fine tubular pores;strongly effervescent; abrupt wavy boundary.

2BK4 123-150cm:Light yellowish brown (10YR 6/4) silty clay; common to many coarse prominant brownish yellow (10YR 6/6) mottles; moderate fine angular blocky structure; firm, very sticky and very plastic; some stress oriented coates ;a few medium roots; a few fine tubular pores ; weakly effervescent.Many pressure faces and few weakly expressed slickensides.

Series : Jordan 13
Pedon No. : S82FN-500-013
Taxonomy : Clayey-skeletal, montmorillonitic, thermic, Typic Argixerolls
Location : Road cut 4km from Salt on road to Amman.
Vegetation : Field inside fence planted to wheat. Rock fragments are chert. Approximately 2 meters to soft limestone or marl. Shamont says area where profile is located has been plowed in the past but not for last 10 years. This soil is in the highest elevation and greatest ppt in Jordan. Could not detect any clay films but there should be an increase in fine clay.
Field Moisture : Moist throughout.

Description

A 0 - 26cm : Dark brown (7.5YR 3/2) very gravelly clay loam, dark brown(7.5YR 3/2, dry); moderate fine to medium subangular blocky structure; slightly hard; friable, sticky and plastic; many fine roots; many interstitial pores; coarse fragments, 20 ptc larger than 2mm mixed lithology; weakly effervescent; clear smooth boundary.

Bt1 26 - 39cm : Brown to dark brown (7.5YR 4/4) extremely gravelly clay; moderate fine angular blocky structure; firm, very sticky and very plastic; common fine roots; common fine tubular pores; coarse fragments, 42 pct larger than 2mm mixed lithology; weakly effervescent; clear wavy boundary.

Bt2 39 - 81cm : Reddish-yellow(7.5YR 6/8)extremely gravelly clay; structureless; firm, very sticky and very plastic; a few medium roots; few fine tubular pores; coarse fragments, 24 pct larger than 2mm mixed lithology; weakly effervescent; gradual wavy boundary.

Bt3 81 -106cm : Brown (7.5YR 5/4) extremely gravelly clay ; massive structure;firm, very sticky and very plastic;a few medium roots; few fine tubular pores; coarse fragments, 12 pct larger than 2mm mixed lithology; weakly effervescent; clear wavy boundary.

Btk 106-150cm : Strong brown (7.5YR 5/6) extremely gravelly clay;structureless;firm,very sticky and very plastic;a few medium roots; few fine tubular pores; coarse fragments, 22 pct larger than 2mm mixed lithology; weakly effervescent. Many pressure faces. Rock fragments are mostly pebbles, about 10% cobbles ,a few stones in 106 to 150.

Series : Jordan 4
Pedon No. : S82FN-500-004
Taxonomy : Ustochrepts
Location : Deir Alla Experiment Station
Vegetation : Irrigated tomatoes . Irrigation water is quite silty and probably has considerable lime and possibly some gypsum.The texture of the Ap horizon is probably influenced by the silty irrigation water . Soil may be Vertisol but could not detect any cracks to surface.
Soil Moisture : Irrigated soil.

Description

Ap 0 - 23cm : Brown to dark brown (10YR 4/3) silty clay loam, pale brown (10YR 6/3 ,dry); moderate fine to medium subangular blocky structure; firm,very sticky and very plastic; many very fine roots; many very fine interstitial and tubular pores; coarse fragments,1 pct larger than 2mm mixed lithology; strongly effervescent; abrupt wavy boundary.

Bw 23 - 40cm : Brown(10YR 5/3)silty clay loam; a few medium prominent white (10YR 8/2) mottles; very few moderate medium to coarse subangular blocky structure; very hard; firm, very sticky and very plastic;common very fine to fine roots; common very fine tubular pores; strongly effervescent; clear wavy boundary. Few chert fragments 1%.

Bk1 40 - 59cm : Brown (10YR 5/3) clay; moderate medium to coarse angular blocky structure; firm, very sticky and very plastic; common very fine roots; common very fine tubular pores; irregular calcium carbonate concentration; strongly effervescent; clear wavy boundary. Very few chert pebbles < 1%. Few pressure faces.

Bk2 59 - 79cm : Yellowish-brown(10YR 5/3)clay; strong medium to coarse angular blocky structure;firm,very sticky and very plastic;a few fine and medium roots;common very fine tubular pores; irregular calcium carbonate concentration ; strongly effervescent; clear wavy boundary. Very few chert pebbles 1%.

Bk3 79 -102cm : Yellowish-brown(10YR 5/4)clay; strong medium to coarse angular blocky structure;firm,very sticky and very plastic; a few fine, medium and coarse roots; common very fine tubular pores; irregular calcium carbonate concentration; strongly effervescent; clear wavy boundary; very few chert pebbles < 1% . Common moderately expressed slickensides.

BC 102-133cm : Yellowish-brown (10YR 5/4) silty clay loam; common to many medium prominent dark grayish brown(10YR 4/2)very dark grayish brown (10YR 3/2)Yellowish-brown(10YR 5/6)and white (10YR 8/2) mottles; weak medium subangular blocky structure;firm,a few medium and coarse roots ;few very fine tubular pores;strongly effervescent; clear wavy boundary.

C 133-150cm : Yellowish-brown (10YR 5/4) silty clay loam; common to many medium prominent yellow (10YR 7/8), gray (10YR 6/1) and white (10YR 8/2) mottles; structureless; firm, a few medium roots; few very fine tubular pores; strongly effervescent.

Series : Jordan 8
Pedon No. : S82FN-500-008
Taxonomy : Typic Gypsiorthids
Location : Schuamari Wildlife Reserve on highway from Azraq to Saudi Arabia.
Vegetation : 4-wing saltbush.
Soil Moisture : Dry throughout.

Description

A 0 - 2cm : Brownish-yellow(10YR 6/6) gravelly silt loam, very pale brown (10YR 7/4,dry); moderate fine to medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; a few fine roots; many very fine to fine vesicular pores; strongly effervescent; abrupt wavy boundary.

Bw1 2 -27cm : Yellowish-brown(10YR 5/6)fine sandy loam,very pale brown(10YR 7/4,dry); structureless;soft, very friable, nonsticky and nonplastic; a few fine roots; many fine interstitial pores; weakly effervescent;clear irregular boundary.

Bw2 27-62cm : Brownish-yellow(10YR 6/8)fine sandy loam;very pale brown(10YR 7/4); structureless;soft,very friable, nonsticky and nonplastic;a few fine roots; many fine interstitial pores;noneffervescent; abrupt wavy boundary.

Bym 62-84cm : Very pale brown(10YR 7/3)texture not recorded ,white(10YR 8/2,dry);structureless; extremely hard; extremely firm, a few fine roots; noneffervescent; abrupt wavy boundary.

Ck1 84-100cm: Yellow(10YR 7/6) fine sandy loam, white (10YR S/2,dry);structureless;very friable,nonsticky and nonplastic; a few fine roots; many fine interstitial pores; violently effervescent; clear wavy boundary.

Ckz 100-144cm: Light yellowish brown (10YR 6/4) fine sandy loam, white(10YR 8/2,dry); a few medium prominent very dark brown (10YR 2/2) mottles; structureless ; friable , nonsticky and nonplastic ;a few fine roots; many fine interstitial pores;violently effervescent;abrupt wavy boundary;30% calcium carbonate concentrations.

Cz 144-170cm: Light olive gray(5Y 6/2)fine sandy loam,light gray(5Y 7/2,dry);a few medium prominent black (5Y 2.5/1) mottles ; structureless ; friable nonsticky and nonplastic; a few fine roots; many fine interstital pores;coarse fragments, 10 pct larger than 2mm chert pebbles; weakly effervescent.

Series : Jordan 5
Pedon No. : S82FN-500-005
Taxonomy : Entic Chromoxerert
Location : Approximately 28 km SW of Amman 1.5 km west of highway from Naour to Madaba.
Vegetation : Fallow wheat stubble.
Field Moisture : Moist throughout.

Description

Ap 0 - 12cm : Brown to dark brown (7.5YR 4/4) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine to fine roots;many fine interstital pores; strongly effervescent; abrupt smooth boundary.About 3% internal pebbles throughout pedon.

A1 12 - 37cm : Brown to dark brown (7.5YR 4/4) clay; strong fine to medium subangular blocky structure; firm, very sticky and very plastic; common very fine and a few fine roots;few fine tubular and many fine interstital pores;strongly effervescent; clear wavy boundary. About 3% fine pebbles throughout pedon.

AB 37 - 60cm : Brown to dark brown (7.5YR 4/4) clay; strong medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots; few fine tubular and many fine interstital pores;strongly effervescent;clear wavy boundary; common weakly expressed slickensides. About 3% fine pebbles throughout pedon.

Bw 60 - 93cm : Brown to dark brown (7.5YR 4/4) clay; strong medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots;a few fine tubular pores; gradual wavy boundary. Many moderately expressed slickenside.About 3% fine pebbles throughout pedon.

Bk1 93 -125cm : Brown to dark brown (7.5YR 4/4) clay; strong medium angular blocky structure; firm, very sticky and very plastic; a few very fine roots; a few fine tubular pores; strongly effervescent; gradual wavy boundary. Many strongly expressed slickensides. Common fine and medium lime masses.About 3% fine pebbles throughout pedon.

Bk2 125-150cm: Brown to dark brown (7.5YR 4/4) clay; strong medium angular blocky structure; firm; very sticky and very plastic; a few very fine roots;a few fine tubular pores;strongly effervescent; many strongly expressed slickensides; common fine and medium lime masses. About 3% fine pebbles throughout pedon.

Pedon No. : NES-10
Taxonomy : Fine, mixed, hyperthermic,Typic Torrifluvent .
Location : Center of a small basin in the SE corner of the area

Description

C1 0 - 20cm : Dark brown(7.5YR 4/4)clayey;platy;very hard, firm, very sticky and very plastic; few very fine pores; moderate reaction with HCl;clear smooth boundary.

C2 20 - 70cm : Dark brown(10YR 4/3)clayey; platy, hard,strongly firm, very sticky and very plastic; few fine pores; moderate reaction with HCl; clear smooth boundary.

C3 70 -110cm : Dark brown(7.5YR 4/4)clay loam to clay;platy ; hard, strongly firm, very sticky and very plastic, many very fine pores;moderate reaction with HCl ; no roots.

Pedon No. : NES-17
Taxonomy : Fine, mixed, hyperthermic, Typic Camborthid .
Location : Center of the small basin in the western side of the area.
Vegetation : No vegetation.

Description

A 0 - 20cm : Dark brown(7.5YR 4/4)moist, clay loam; weak platy and subangular blocky , soft,friable, sticky and plastic, many fine pores, strong reaction with HCl, clear smooth boundary.

B 20 -100cm : Reddish-brown(5YR 4/4)moist, clayey;angular blocky, very hard, friable, very sticky and very plastic, many fine and medium pores, patchy pressure faces and slickensides,strong reaction with HCl.

Pedon No. : NES-3
Taxonomy : Loamy-skeletal,hyperthermic, Typic Torriorthents
Location : About 300 m south of the road to El-Mudawwarah.

Description

A 0 - 12cm : Reddish-brown(5YR 4/4)moist,sandy clay loam; weak platy, hard, strong sticky and strong plastic, many fine and medium pores, strong reaction with HCl, no roots, clear smooth boundary

Cz 12-110cm : Dark brown (7.5YR 4/4) moist, gravelly sandy loam;massive, extremely hard , nonsticky and strong plastic, many pores, no roots, weak reaction with HCl,common free salts or gypsum crystals.

Pedon No. : NES-7 or WH-3
Taxonomy : Oxidic, hyperthermic, Typic Torripsaments
Location : A large unit about 4km SW road to El-Mudawwara.
Vegetation : Pasture.

Description

A	0 - 5cm :	Light brown(7.5YR 6/4)dry, sandy loam,platy, hard, strong sticky and strong plastic, few pores, weak reaction with HCl, clear smooth boundary.
C1	5 - 74cm :	Reddish-yellow(7.5YR 6/6) dry, sand massive, platy, hard, friable , nonsticky and non-plastic, no reaction with HCL, few pores, clear smooth boundary.
C2	74 - 92cm :	Reddish-yellow(7.5YR 6/6) sand,single grains ,loose, nonsticky and nonplastic , no reaction with HCL, clear smooth boundary.
C4	92 -120cm :	As above but texture is fine sand.

Pedon No. : J-5
Taxonomy : Fine, mixed, thermic,Typic Calciorthids.
Location : Area II (Bir Ibin Jazi).

Description

Ap 0 - 15cm : Strong brown(7.5YR 5/6)clay loam; weak medium subangular blocky, friable, sticky and plastic, many fine pores, average density, strong reaction with HCl, few fine roots, clear smooth boundary.

Bk 15 - 95cm : Strong brown(7.5YR 5/6)clayey, strong medium angular blocky, hard, friable,very sticky and very plastic, common fine and medium pores. common fine calcium carbonate concentration, average density, strong reaction with HCl,common fine roots,clear wavy boundary.

Ck 95 -120cm : Brown(7.5YR 5/4) moist, clay loam, moderate subangular blocky ,friable, sticky and plastic,few fine and medium pores,many calcium carbonate concentrations, average density, strong reaction with HCl, few very fine roots.

Pedon No. : Sh-16
Taxonomy : Fine, mixed, mesic, Typic Haploxeralfs.
Location : Area I.

Description

Ap 0 - 15cm : Brown(7.5YR 5/4)moist, clay loam, weak fine and medium subangular blocky, very friable, sticky and plastic, common fine pores, average density, moderate reaction with HCl, few fine roots.

Btk 15-115cm : Strong brown(7.5YR 5/6)moist, clayey,moderate fine and medium subangular and angular blocky, common fine and medium pores , common calcium carbonates micelium, average density, moderate reaction with HCl, few fine roots.

SOIL AND WATER CONSERVATION

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SOIL AND WATER CONSERVATION

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4-1. INTRODUCTION

The highlands of Jordan consist of a north-south succession of high , wide blocks of mountains and rolling plateaus of various widths, which fall steeply toward the Jordan Valley depression in the west and descend gently toward the east, gradually merging into the desert (Moorman, 1959).

The extent of dryland area in Jordan is shown in Fig. 4.1. The total area of these lands according to their long-term annual rainfall, agroecological zones and slopes appears in Table 4.1 .

The Mediterranean climate ,under which dryland farming in Jordan is practiced, is characterized by a cool, wet winter and a hot,dry summer with short transitional periods of spring and autumn.

The rainy season extends from November to March,with

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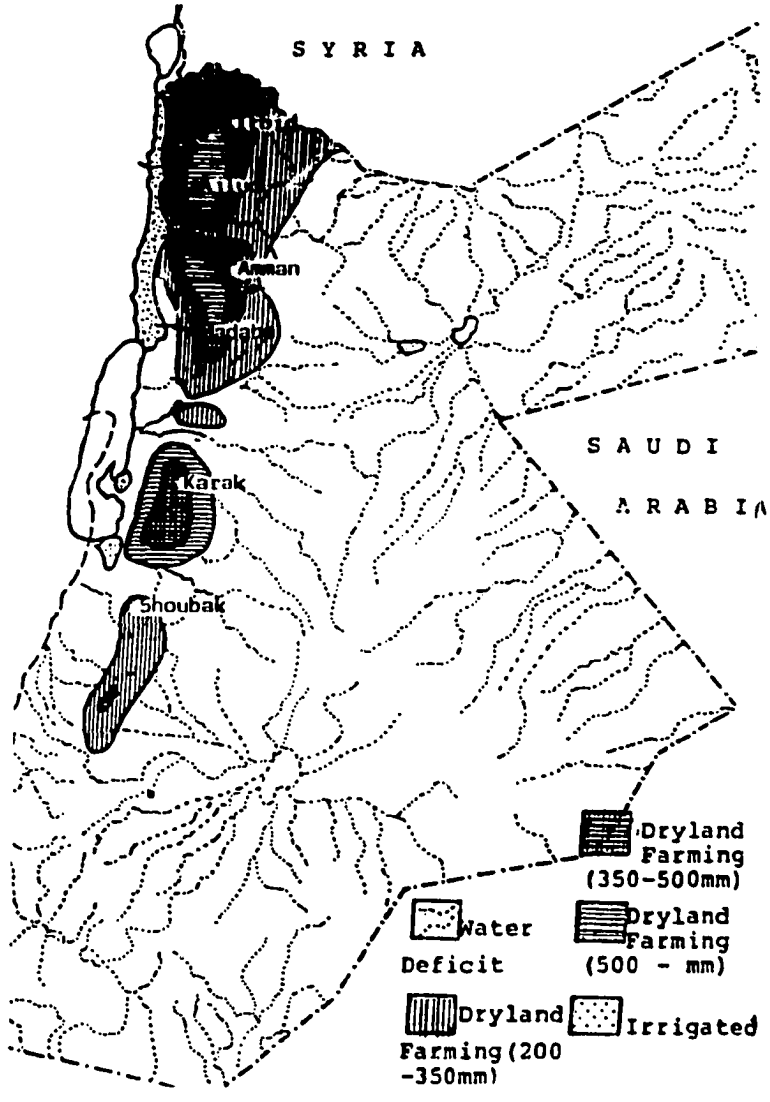

Fig. 4-1. Agroclimatological zones in Jordan according to mean annual rainfall.

Table 4.1 : Land areas of Jordan (in km^2) partitioned according to annual rainfall and slope (MOA , 1974).

Zone	Rainfall mm	Slope %			
		0-8	9-25	25-50	Total
Arid	< 200	78222	4140	2206	84568
Marginal	200-350	2362	2233	988	5633
Semiarid	350-500	262	648	447	1357
Semihumid	500-800	6	619	363	988
Total		80852	7690	4004	92546

annual rainfall as low as 30 mm in the steppe and as high as 800 mm in the mountains of Ajlun , Jarash, and Salt.

The average annual amount of rain that falls over Jordan is 9,000 million cubic meters . A large part of it (80%) is lost in streams and to evaporation ,however, the loss depends on the intensity and distribution of rainfall (Shamout , 1966) . Runoff was estimated at 1-20 % of total rainfall , depending on several factors such as slope , rainfall intensity and soil cover (MacDonald , 1965).

Rainfall intensity is one of the factors responsible for soil erosion;intensities as high as 158 mm/24 hr have been recorded. However, most rainfall stations in the highlands have records of daily rainfall of 100 mm (Table 4.2) . These factors and others to be discussed in this chapter contribute to serious soil erosion hazards.

Soil erosion , as a natural process , is continuous and is easily accelerated by man. In many Third World countries, the increased demand for food due to population increases is causing a marked acceleration of man-made erosion. Soil erosion reduces crop production by decreasing water infiltration , nutrient supply , and soil water-holding capacity (Larson et al. ,1983).

Natural erosion in a certain area is controlled by its geology , topography , vegetation , and climate . These

Table 4.2 : Comparison of maximum monthly and maximum daily values of rainfall with annual rainfall.

REGION	STATION	Annual Mean mm(1)	Monthly Maximum mm(2)	Daily Maximum mm(3)	Percentage (2)/(1)	(3)/(1)
Hilly	Irbid	453	270	105	62	24
	Naor	530	276	158	52	30
	Shoubak	285	352	74	123	26
	Karak	339	286	115	84	34
Steppe	Mafraq	144	99	44	68	30
	Petra	131	178	85	136	65

factors , in addition to rainfall intensity are causing soil erosion and the gradual loss of fertile lands in different parts of Jordan .

Accelerated erosion is usually the result of improper management of productive soils or exploitation of marginal lands, both of which are taking place in Jordanian dryland agriculture (Rafiq , 1978).

Jordan's first interest in soil erosion and soil and water conservation started during the early 1960s (Shamout 1966). The earliest reported case study (MacDonald, 1965) showed that more than 1100 ha were lost out of 5400 ha of arable land in the southern Ghor region during the period 1958-1965. Other studies (see below) showed that soil erosion is taking place at varying levels throughout the country.

The conservation of soil and water resources in Jordan is a necessity because :

(i) These resources are very limited, and

(ii) The population pressure on the land is increasing dramatically; the population of Jordan is expected to reach 4 million by 1990. People then must exploit the limited arable area in the country (5% of the country's 97,000 km^2) if no further land is lost due to erosion,desertification and urbanization.

4-2.HISTORICAL BACKGROUND

Jordanian officials were aware, as early as the late 1950s, of the soil erosion problems in the country. Considerable soil and water conservation work has been planned and carried out through various projects of the Ministry of Agriculture , the Natural Resources Authority and the Agricultural Credit Corporation (see : Battikhi and Arabiat , 1983 for a review).

A detailed report (Shamout,1966) was prepared by a technical committee from the above mentioned governmental agencies, in cooperation with officials from FAO and USAID . The proposed policy for soil and water conservation outlined in that report included the following major points:

1- A comprehensive study should be undertaken to survey the soils of the country and classify them according to their suitability for agriculture, forestry, or range.

2- A special policy should be prescribed for each soil class in order to guarantee maximum productivity and minimum soil loss.

3- Achieve maximum rainfall efficiency and flood control through :

(i) Building necessary soil erosion control measures ,

(ii) Terracing to control soil erosion and make use of runoff water in agriculture ,

(iii) Demonstrating soil conservation practices to the farmers in areas endangered by soil erosion ; and

(iv) Agricultural zoning.

A number of soil and water conservation projects have been carried out in different parts of the country since the mid-1960s .

The Dryland Farming Project was initiated in 1964, with the objective of constructing stone and soil contour terraces to minimize soil erosion in Governmental Dryland Research Stations.

The work in this project was experimental, however, it provided necessary information on the basics of soil conservation for farmers in neighbouring areas.

Another project was initiated in 1969 with the objective of implementing a soil conservation and agricultural development program. Soil conservation and erosion control measures were built on farmers' fields in Irbid and Karak districts. Over 8000 ha were surveyed and stone terraces were constructed on 3000 ha and these were planted with fruit trees (Viertmann ,1973; Kaliski , 1976).

The World Food Program, in cooperation with the Ministry of Agriculture started a soil conservation program with the objective of minimizing soil erosion and planting olive trees.

The program provided consultancy, olive tree seedlings, and paid food subsidies to farmers building soil conservation measures on their lands. The program covered an area of 40,000 ha and an estimated 3,500,000 olive trees were planted during the last 20 years (Abu Mushrif , personal communication,1986).

Other projects ,such as the Integrated Agricultural Development Project in Irbid district, the Soil Survey and Land Classification Project, and the Afforestation Project, were efficient tools in conserving endangered soils and raising their productivity.

Most recently, a soil conservation project was initiated in the Zarqa River basin area . The main objectives of this project were to curb the accelerated erosion and to stabilize the income of the rural population , if not to improve it , to safeguard the production potential of agricultural lands in the basin and reduce the siltation of the King Talal Dam (G.T.Z.,1982).

4-3.AN APPRAISAL OF LAND RESOURCES IN JORDAN

4-3.1.Major Land Resources Areas

Several authors (e.g. Kasapligil; 1956 ; Draz, 1979) have discussed the land resources of Jordan and their distribution according to average rainfall. The five-year plan of 1976-1980 partitioned the total area of Jordan (i.e. 9,255,100 ha) into four regions according to average rainfall (Table 4.3). A little over 8% of this area can be considered as potentially arable land, while the majority of it is classified as arid desert, receiving less than 200 mm of rainfall annually.

4-3.2.Land Capability Classification

The most important resource for agriculture in Jordan is the availability of good agricultural land. A knowledge of its extent and distribution is essential for sound agricultural planning (M.O.A.,1974).

Efficient cropping practices and effective erosion control measures are fundamental bases for safe land use (Alexander, 1977). Land classification is the first step in determining the most suitable usage for an area of land and the erosion control measures needed for its conservation.

Table 4.3 : Profiles of agroecological zones in Jordan, (MOA, 1974).

Agroecological Zones	Long-Term Average Annual ppt.*(mm)	Total Area (hectare)	% of Total Population
Arid Zone	0 - 200	8,456,900	31
Marginal Zone	200 - 350	563,400	41
Semiarid Zone	350 - 500	135,900	19
Semihumid Zone	500 - 800	98,900	9

* : Annual Precipitation.

The USDA Land Capability Classification System (USDA , 1961) rates the restrictions on the use of soils for most crops and pasture plants . This system assumes that modern farming methods are being used , and classifies lands into eight capability classes and four capability subclasses. The basic principles of the USDA system were used in carrying out land capability classification in Jordan .

4-3.3.Previous Capability and Classification Studies

A number of land capability studies have been carried out in Jordan since 1958. Moorman (1959) was the first to survey and classify most lands in Jordan. His study was the most extensive one to date , with maps produced at a scale of 1:1,000,000 .

Moorman's potential land use capability map was based primarily on a combination of rainfall and soil characteristics. He proposed such general land use capabilities as irrigated farming, dryland farming, rangelands for grazing and forestry. Generally, Moorman's work was a broadly based attempt and did not try to examine certain agronomic and economic aspects of land classification.

The Ministry of Agriculture (MOA, 1974) classified the

country on the basis of a combination of three slope classes and four rainfall zones (Table 4.3). This classification was an attempt to establish guidelines for agricultural zoning . However, in the five-year plan for 1976-1980 only agroclimatological characteristics were considered in the proposed agricultural zoning for the country.

The system followed by the Ministry of Agriculture recognized the following land classes:

1- Natural rangelands receiving less than 200 mm of annual rainfall,

2- Marginal lands receiving 200-350 mm of annual rainfall, and

3- Agricultural lands receiving more than 350 mm of annual rainfall.

The different soil classes present in a certain region were not included in the classification . As a result , these subdivisions were not sufficiently sensitive to differentiate among the cultivation of various field crops and tree crops .

The Food and Agriculture Organization (FAO, 1975) used a different classification approach in which land was grouped into a series of land systems and smaller land units. The land systems were organized on the basis of

climate, physiography and geology. This classification system was assisted by the interpretation of the photogeomorphic patterns of LANDSAT imagery. Each land system was described by means of a block diagram and then subdivided into a number of land units. These land units were regarded as basic units for land use planning. According to this approach,the lands of Jordan were classified into lands suitable for grazing, others of low-or high agricultural potential under rainfed conditions and lands suitable for extensive agriculture under irrigation .

LANDSAT imagery was used by Mitchell and Haward (1980) for land classification and later by Mohammad (1984) as a part of the application of LANDSAT imagery for aiding soil degradation mapping of Jordan.

In 1973, a regional project was conducted in which 60,000 ha in the Irbid district was classified for land use (Kaliski, 1976).

Maps were produced, at a scale of 1:25,000 ; rainfall, soil depth, soil texture and soil structure were incorporated into this classification scheme . Moreover, recommendations were made for the planting of annual or tree crops in each land class . Similar projects were carried out in Karak and Balqa districts , but little information is available about either of these projects(Viertmann ,1973).

The World Bank (1981) financed a field study in which a new land classification system was devised based on soil, slope and annual rainfall. Five basic slope categories and six rainfall zones were combined to form eight major land capability classes (Table 4.4). No soil data were incorporated into the classification although soil conservation recommendations based on the system were made.

A regional land classification system was proposed by the German Agency for Technical Cooperation (GTZ, 1982) for the Zarqa River Basin Project. This system was composed of eight land classes based on soil depth , stoniness and slope .

The system contained recommendations for soil conservation measures to be used on lands susceptible to erosion . A pilot land use project based on this system in which soil conservation measures were constructed on farmers fields , currently covers an area of 1000 ha .

4-3.4.Proposed Land Classification System by the Jordan-Australia Dryland Farming Project

After reviewing the agricultural sector and previous land capability classification systems, Watkins et al.(1983) proposed a modified scheme which takes into consideration some criteria used by previous systems (see above) and

Table 4.4 : Land classification basis for land capability planning in Jordan (World Bank , 1981).

Land Class	Slope	Conservation Measures
I	<1%	None
II	1-9%	(Contour Cultivation and Widely Spaced Earth Banks)
III	10-14%	(Closely Spaced Earth Contour Banks,Gully Control, Contour Cultivation)
IV	Flat with Surface Rock > 50%	--
V	15-25%	(Gradoni or Stone Terraces)
VI	>25%	
VII	Low Rainfall or Steep Slope Range Land	
VIII	Roadsides and Village Areas	

incorporates others. The primary objectives in developing this system were:

(i) To incorporate the major factors affecting crop productivity, and

(ii) To ensure that the new system is capable of encompassing all previous studies with minimum modifications.

The proposed land capability classification system contains eight land classes based on rainfall and soil characteristics (Table 4.5).

4-4.LAND CLASSIFICATION FOR SOIL CONSERVATION PURPOSES

Kaliski (1976) modified a land classification system for soil conservation, developed earlier by the Soil Conservation Service of N.S.W., Australia, for local Jordanian conditions. The new system utilizes topographical maps (scale 1:50,000) and takes into consideration soil parameters , climate, topography and present and potential land use. In it , Jordanian lands are classified into three categories. These groups along with their respective classes are :

i- Lands Best Suited for Annual Cropping.

Class I :This land is level with deep soil profiles and

Table 4.5: A prposed land capability classification , based on rainfall and soil characteristics (Watkins et al. 1983) .

Class	Slope	Profile Depth cm	Surface Rock (%)	Texture	Area(ha)/Rainfall Zone(mm) >500	300-500	200-300	<200
I	0-2	>100	None	Clay to Sandy Loam	570	5420	8960	
II	2-7	50-100	None	" "	7050	22190	118580	7775300[a]
III	8-14	50-100	None	" "	9790	18550	21150	
IV	15-25	50-100	None	" "	2310	1840	1060	375400[b]
V	0-24	50-100	10-25	Coarser than Sandy Loam	53020	60050	280600	
VI	25-50	50-100	10-25	" "	4270	13890	89960	
VII	Variable	<20	>50	" "	20350	36640	8220	
VIII	>50	Variable	Variable	" "	1540	11420	1340	305500[c]

a : Classes I & II Combined.
b : Classes III & IV Combined.
c : Classes V & VIII Combined.

heavy soil textures. No special soil conservation practices are necessary .

Class II: Simple soil conservation practices are necessary for lands in this class. Contour cultivation is recommended on gently (7 %) sloping land , and widely spaced earth banks on long low slopes. These soil conservation practices should be carried out in conjunction with improved agronomic practices.

Class III: Intensive soil conservation practices are necessary on lands belonging to this class. Practices such as closely spaced earth banks, gully control structures, and water disposal areas are essential, in addition to practices recommended for Class II above.

2- Lands Best Suited to Perennial Crops.

Class IV: No special soil conservation practices are necessary on level or low sloping lands with surface rock, however , contour ripping and contour planting should be used where possible .

Class V : Intensive soil conservation practices are necessary on lands with steep (>15 %) slopes in this class. In addition , contour planting and cultivation should be adhered to.

3- Lands Best Suited for Forestry.

Class VI: These lands are too steep (> 35 % slope) or otherwise unsuitable for regular cultivation. Intensive soil conservation practices , such as gradoni terraces, are required . These structures are usually installed prior to tree planting on terraces.

4-5. EXTENT OF SOIL EROSION

There is limited quantitative data available to indicate the exact extent of the soil erosion problem in Jordan. A regional study (Rafiq, 1978) concluded that soil degradation by water erosion is a serious problem in most Middle Eastern countries ; Jordan is no exception.

The soil erosion map in Fig 4.2 shows that most of Jordan's soils are subject to erosion by water and wind (FAO/UNDP,1979). Some areas in the highlands are highly erodable as a result of high rainfall and steep slopes.

A report by McDonald Engineering Company (1965) submitted to the Natural Resources Authority (NRA), estimated that 1,328,000 tons of soil were lost by water erosion from the Jordanian East Bank catchments in 1963-1964. This amount of soil is equivalent to an average loss of 14 cm of soil over that shallow catchment area during 100 years.

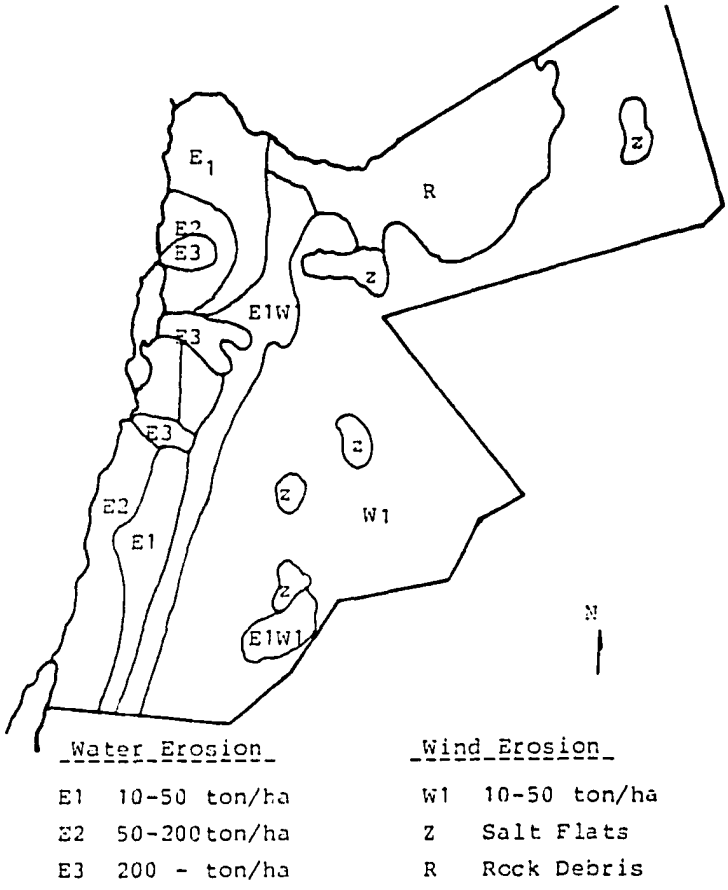

Fig. 4-2. Soil erosion map of Jordan.

The feasibility study for the King Talal Dam calculated a suspended sediment load of 1.89 % of the water mass of the Zarqa river at a point just upstream from the dam site (Abidi,1974).

This is an indication of the severity of erosion in that watershed and reflects the life expectancy of the dam. The first in-depth survey on erosion in the Zarqa river catchment took place in 1978 (GTZ, 1978). The study showed that areas receiving more than 250 mm of annual rainfall are subjected to erosion in varying degrees; over 90% of the region is subjected to sheet erosion and gully erosion occurs on 20% of the watershed. However, gully erosion, in the western part of the watershed is characterized by downcutting of the drainage line to a depth of 1-1.5 meters and significant amounts of soil are carried into the reservoir.

Other sources (e.g Kasapligil,1956 ; Talli,1969 ; DeVitt,1983; Shamout,1966 and Draz, 1979) have also cited examples of the severity and extent of soil erosion due to rainfall intensity, overgrazing, uprooting of forest trees, and urbanization.

The use of agricultural machinery, mainly the introduction of the tractor, contributed to more desertification in the steppe and accelerated erosion rates

in the main agricultural areas (Lanzendorfer, 1985). With the introduction of the tractor, cultivation of vast areas with barley, and occasionally with wheat, became possible at a minimal cost. The resultant plowing destroyed the natural vegetation and rendered much land vulnerable to erosion. The World Bank (1981) estimated that over 120,000 ha of previously good pasture has been destroyed by plowing. In addition, the pressure on the remaining grazing areas has increased .

Plowing against the contour lines promotes runoff and soil erosion in main dryland agricultural regions (Otto, 1980). Moreover, the incorrect use of plows which turn the soil over , i.e., the moldboard, and the disk harrow , aggravates the erosion problem (FAO,1980,1981; Battikhi and Arabiat,1983). The side effects of such practicse are:

(i) The residual moisture in the lower soil layers is brought to the surface and is lost through evaporation ,

(ii) Soil structure is destroyed , especially in soils with low organic matter content ,and

(iii) The soil is loosened to such an extent that it is heavily exposed to water and wind erosion.

4-5.1.A Case Study

Battikhi and Arabiat (1983) collected 331 soil samples

from the highlands of Jordan, in an attempt to assess the extent of soil erosion in the country. The soil samples came from areas differing in rainfall, soil type and slope. The authors rated the samples by the FAO system for soil degradation assessment .

A summary of the results is presented in Table 4.6 . In general, most of the highlands are within the E0 category , with erosion hazard increasing as rainfall and slope increase.

Battikhi and Arabiat (1983) found that the soils in Karak and Ma'an districts are subjected to wind erosion more than soils in Irbid and Balqa districts . An FAO study (FAO, 1975) , however ,indicated that the steppe is the only region subjected to wind erosion (Fig 4.2).

4-6.SOIL AND MOISTURE CONSERVATION PRACTICES IN JORDAN

In an effort to encourage farmers to adopt a more productive and stable land use system, the Ministry of Agriculture and other governmental agencies, in cooperation with international donors, initiated several programs for soil and moisture conservation . The objectives were :

(i) To control soil erosion;

(ii) To ensure better utilization of the limited water

Table 4.6 : Number of soil samples according to the level of erosion (E),as affected by topography(T),and rainfall(R) for the case study(Battikhi and Arabiat,1983).

Slope	Erosion extent	Maan R1	Maan R2	Maan R3	Karak R1	Karak R2	Karak R3	Balqa R1	Balqa R2	Balqa R3	Irbid R1	Irbid R2	Irbid R3	Total
T1	E0	10			37	41		11	26		7	90	5	227
	E1								1			12		13
	E2	1				1								2
T2	E0				4	8						1	6	19
	E1					2						8		10
	E2											2		
T3	E0				4	2			2			1		9
	E1				6	7			4			6	2	25
	E2				1				4			5	2	12
T4	E0													
	E1											2	2	4
	E2								1				1	2
T5	E0											1		1
	E1											1		1
	E2					1						1	2	4

T= Slope% : T1= 0-8%,T2=8-20%,T3=20-30%,T4=8-30%,T5=>30%
R=Rainfall, mm;R1=200-300,R2=300-600,R3=>600 .
E=Erosivity,t/ .: E0=0-10,E1=10-50,E2=50-200 .

resources;

(iii) To stabilize agricultural output at higher levels; and

(iv) To bring about a shift in production from cereals to olive and other fruit trees in hilly areas with shallow soils.

It was realized, in the early 1960s that soil erosion can not be controlled by a single practice but by a system composed of a number of conservation practices. These practices should be looked at as components of an agricultural development package which could lead to erosion control and higher agricultural productivity (Wiltshire,1968; Alexander, 1977;1979).

Moreover, erosion control measures which could be used in Jordan must be appropriate to the scale of operation and level of sophistication of the farming system in the country.

Therefore, it was necessary to modify some of the technologies introduced from countries where the science of soil co vation is advanced (Alexander,1977),or even develop new methods to suit local Jordanian conditions (Abu Mushrif , Personal communication,1986).

The following practices were used by several of the soil conservation projects carried out in the country.

4-6.1.Correct Tillage Equipment

Lanzendorfer (1985) observed that disk and moldboard plows are not appropriate for Jordanian dryland conditions. As a result,the Jordanian Cooperative Organization (JCO) has introduced and encouraged farmers to use conservation tillage implements to conserve moisture and minimize soil erosion (Otto,1980).

Quantitative data on the effects of using such implements are very limited . In similar situations, however , conservation tillage has been shown to greatly reduce soil erosion with little effect on runoff (Laflin et al.,1985).

4-6.2.Contour Cultivation

In contour cultivation , runoff is reduced by trapping water in the furrows , thus increasing infiltration into the soil (Kaliski,1976) . Well-defined contour furrows cut to a depth not exceeding 10 cm by heavy rigid tyne and chisel plows are recommended , even after seeding .

This practice comprised a major component of soil conservation within the Irbid area project , particularly throughout the low sloping lands receiving 350 mm of annual rainfall .

Moisture conservation was considered as a major

objective in these areas . In order to channel the limited amount of available moisture to the bottom of the contour furrows , and ensure its best use by the cereal crops ,Kaliski (1976) has suggested that seed should be drilled with a scarifier-type drill which bands seed and fertilizer at the bottom of the furrow and drains moisture to that point.

4-6.3.Ripping

This practice was mainly used in areas to be planted with olive or other fruit trees (Alexander,1979). Ripping for soil conservation purposes can be best carried out using the stand-in ripper along contour lines to a depth of 40 cm, especially in Class V lands with moderate to high rainfall and where active erosion is occurring .

The experience gained in the Irbid project suggested the use of all three tynes during ripping. However, where rock is soft , the whole area to be planted with fruit trees should be contour ripped . In areas of hard rock and large surface rock , it was suggested to operate only with one tyne and produce widely spaced and deep contour furrows (Kaliski,1976).

4-6.4.Terracing

Different types of terraces were constructed according to soil type and conditions. These were designed for control

of runoff in high rainfall areas and for conservation of water in low rainfall areas (Wiltshire,1968). The following is a short description of different types of terraces which were constructed in dryland farming areas of Jordan.

4-6.4.1.Earth Banks

Two types of earthen banks are constructed as soil and water conservation measures:

(i) Diversion banks: These were designed to intercept run-off,either from broad areas or depressions, and carry it to areas where it can be safely drained . In Karak area , diversion banks were principally used to protect cropped land from foreign water (Viertmann , 1973).

(ii) Contour or absorption banks: These are constructed along level lines and were designed to intercept and retain surface runoff before it attains a high velocity . They form temporary retention reservoirs so that accumulated run off can infiltrate into the soil profile.It was noticed that these structures helped in increasing soil moisture available for the crops .

4-6.4.2.Gradoni Terraces

A gradoni terrace is an excavated ditch constructed

along the contour. Trees are planted directly into the terrace.These structures intercept water which runs from the interterrace areas, and hold it in the terrace while it infiltrates into the soil (Alexander and Abu Mushrif,1979).

Gradoni terraces have been used extensively by the Forestry Department for the establishment of pine trees on class VI lands in high rainfall areas of Jordan (Talli,1969).

In Irbid region , Kaliski (1976) suggested that areas of up to 25% slope and cultivated with cereals should be converted to contour-planted olives, vines and other fruit trees . This technique was considered as the most successful soil conservation practice for this land class.

It was expected that these structures could increase available moisture in the root zone of fruit trees planted on the terraces. Another expected benefit is to reduce soil eroded from the area by surface runoff. It was recommended that these gradoni terraces be used only where soil is deep with a slope of 5-15 %.

4-6.4.3.Bench Terraces

These structures should not be used except in situations where other soil and moisture conservation practices are not

applicable (Alexander,1979). This is due to the relatively high construction cost of bench terraces. Contour stone walls were preferable where sufficient stones were available to build them. Bench terraces were built on slopes of 15-35 % where stones were not sufficiently available (Abu Mushrif and Alexander,1978).

4-6.4.4.Contour Stone Terraces

This soil conservation measure proved to be the most useful method of controlling soil erosion on the steep and stony lands in Jordan (Abu Mushrif and Alexander,1978). Contour stone terraces have the following advantages:

(i) Intercepting and reducing the velocity of surface runoff, thus reducing the erosive power of water and allowing suspended soil sediments to be dropped.

(ii) Encourage farmers to cultivate on the contour, ensuring maximum conservation of soil and soil moisture.

(iii) Clearing surface stones from agricultural lands.

Stone terrace construction was not recommended if suitable surface stone was not available adjacent to the terrace site. Other soil conservation measures, such as earthen banks or gradoni terraces, were recommended where no surface stones are available.

4-6.4.5.Stone and Reinforced Concrete Structures

These structures were designed to deliver flows from natural surfaces to the floor of a gully without causing erosion. Some types were used to slow down runoff from banks and dissipate its energy. Building materials used were :

(i) Dry structure:Stones of different sizes and shapes are stacked as densely as possible without a mortar bond.

(ii) Concrete-capped layer of stones at the top of a dry structure as in (i).

(iii) All stones in the structure were bonded together with mortar or concrete.

The above mentioned structures can be built entirely of reinforced concrete (Alexander,1979).

4-7.RESEARCH NEEDS

It is evident that dryland agricultural resources in Jordan are very limited . It is only through the effective conservation of these resources that we can hope to maintain crop productivity in the country.

The installation of soil conservation works , as an

infrastructure for improved agronomic practices , should be emphasized . This sequence is necessary in order to achieve the best land use and maximum long - term productivity .

A small part of the rainfed area has been surveyed and mapped,however, for effective planning of appropriate cropping systems and soil conservation practices, the entire rainfed agricultural area should be surveyed at a scale of 1:50,000, utilizing the Soil Taxonomy System. This survey has to be performed before the implementation of any development projects. Moreover, land classification maps based on soil maps ,should be prepared for the entire rainfed area and utilized in conjunction with the crop zoning recommendations.

Quantitative data on soil and water losses are lacking. A data base is urgently needed in this regard. Specific interactions of topography, climate, soil type, cropping system, and crop residue management ,as related to soil erosion, need to be identified to enable effective planning of appropriate soil conservation practices .

Soil erosion can be reduced through improved cultural practices. The management of crop residues from wheat may be a good method of erosion control. However, weed control problems and the lack of adequate mechanical equipment for

residue management have to be overcome. It is essential, in this case , to study the effects of any new practices on soil physical and chemical properties.

Although several soil conservation practices have been used in dryland farming areas of Jordan, quantitative data are lacking on their effects and their efficiency in reducing soil erosion. There is an urgent need to quantitatively identify the most appropriate practices or modify existing ones for more efficient soil and water conservation. For this purpose, research should be initiated to adapt the Universal Soil Loss Equation (USLE) to Jordanian conditions. The use of this equation and certain simulation models ,such as the Erosion Productivity Impact Calculator (EPIC)model, can facilitate erosion control planning.

Finally, a strong extension program to educate and encourage farmers to use and maintain effective conservation measures in their crop production systems is highly needed. Moreover , a soil conservation service, with the power to prevent acts leading to soil erosion should be established in the country.

4-8.SUMMARY

Soil and water resources are very limited in this country. A population of more than 3 million relies on 5%

of the country's 97,000 km for its food if no more land is lost to erosion , desertification , and urbanization .

Natural and man-made erosion has caused the loss of fertile lands and reducing productivity in different parts of the country. Several governmental agencies, in cooperation with international donors ,carried out a number of land capability studies , soil surveys and soil conservation projects.

As a result of these studies , the major land resource areas were defined and a limited area was mapped.

Quantitative data ,on the extent of soil erosion in the country , is lacking. However, the few available experimental results and general observations indicate that soil erosion is a major problem in dryland agriculture .

Thus ,farmers have been encouraged , through food subsidies and technical consultancy , to build soil conservation measures on lands susceptible to erosion .

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SOIL FERTILITY AND FERTILIZER USE

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SOIL FERTILITY AND FERTILIZER USE

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5-1. INTRODUCTION

Lack of soil moisture was identified as the major factor limiting crop growth and production under rainfed conditions in Jordan. While soil fertility and the need for fertilizers have been secondary to inadequate soil moisture, nutrient deficiencies may often be limiting as well.

Summer fallow has been practiced for a long time in the rainfed parts of Jordan. Farmers believe that the practice conserves soil moisture , kills weeds and improves soil fertility (Tamimi,1981) . According to Olson (1980) , fallow is responsible for an extra year's mineralization of nutrients from native soil organic matter and mineral sources.

The native nutrient levels of Jordanian soils are relatively low (Qudah & Jaradat,1988). Soils in the arid and semi-arid regions do not contain much organic matter and it is

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likely that nitrogen is the major plant nutrient which limits maximum crop yields. On the other hand, where soils are calcareous, insufficient levels of phosphorus and its low availability to plants can significantly limit crop yields (Table 5.1).

During the 1960s and 1970s, researchers realized that there may be considerable room for increasing crop production in the rainfed areas of Jordan through proper fertilizer application. Since that time , numerous experiments have been conducted in the major rainfed areas of the country which have involved a number of national and international research agencies.

5-2.PRODUCTION AND FERTILIZER USE IN JORDAN

Presently, fertilizer production in Jordan is mainly for export . The fertilizer complex, established by the Jordan Fertilizer Industry Company and owned by the Jordan Phosphate Mines Company (JPMC), consists of two units for sulfuric acid, each with a production capacity of 1800 metric tons per day ; one unit for phosphoric acid with a production capacity of 1250 metric tons per day ; and two units for fertilizer granulation with a total production capacity of 2200 metric tons per day.

The complex utilizes a minimum of 1.3 million tons of

Table 5.1 : Chemical analysis for representative soils in different agroecological zones in Jordan.

Location	Rainfall (mm)	pH	Available N %	Available P ppm	Available K ppm	$CaCO_3$ %	Organic Matter %
Irbid	450	7.8	0.060	2.2	165	15.0	---
Maru	370	7.9	0.050	9.5	490	17.0	---
Ramtha	180	8.0	0.056	4.0	480	16.0	---
Naimeh	250	8.1	0.100	6.0	560	13.9	0.6
Manja	200	8.5	0.200	17.4	---	19.1	---
Madaba	350	8.1	0.060	6.0	580	19.8	---
Rabbah	300	7.7	0.100	9.5	416	21.0	1.2

--- : No Available Data.

rock phosphate per year from the phosphate mines in central and southern Jordan. Other raw materials (i.e., sulfur and ammonia) are imported from international sources (JPMC , 1986) .

The fertilizer complex produces diammonium phosphate (DAP) fertilizer , with a minimum of 18% and 46% of N and P_2O_5 , respectively (JPMC ,Personnal Communication, 1987).

Table 5.2 shows that the amount of DAP sold in Jordan is very small and almost 90% of this is sold in the Jordan Valley and to the Irrigated Wheat Production Project (JPMC , Personal communication,1987). Furthermore , DAP does not provide the appropriate mix of N and P required by cereals and legumes under rainfed conditions. Consequently , most , if not all, of the N and P fertilizers used in rainfed farming regions of Jordan are imported from the international market. Fertilizer consumption per hectare of arable land in Jordan is the lowest among countries in the Near East region, only 6 and 11 kg/ha of N and P , respectively (Aresvik ,1976).

Obviously , fertilizers are not used at optimal rates in the rainfed farming areas of the country (Arabiat et al.,1983; Oglah ,1984) . The estimated requirements of N and P fertilizers in the wheat producing areas are 17,000 and 11,000 tons ,respectively, based on recommended rates for

Table 5.2 : Local fertilizer production and consumption for the period 1982 - 1986.

Fertilizer	Year				
	1982	1983	1984	1985	1986
	Tons				
DAP(Production)	17,000	337,000	569,000	495,000	551,000
DAP (Local Consumption)	----	2,391	1,286	2,541	3,590
Muriate of* Potash	--	285,000	485,000	908,000	1,103,000

DAP : Diammonium phosphate.
* : For export only , it is not used in Jordan as a fertilizer.

both nutrients (Oglah,1984). However, the recommended rates of both N and P fertilizers ,as presented in Table 5.3, are very conservative , especially for the higher rainfall areas (i.e., > 300 mm of annual rainfall).

An earlier estimate of N and P fertilizer requirements in the wheat producing areas was based on tests conducted by the Jordan Wheat Research and Production Project (Haldorson, 1975). Moreover, this estimate was based on a recommended rate of 100 kg/ha of ammonium sulfate and 50 kg/ha of triple superphosphate . A total of about 20,000 tons of ammonium sulfate and 10,000 tons of triple superphosphate would be required if the entire area of 200,000 ha of wheat were fertilized .

The Jordan Cooperative Cereal Improvement Project (JCCIP,1984) expects a gradual increase in the use of fertilizers by farmers in the highlands of Jordan. Assuming that 20% of these dryland farmers will adopt the use of fertilizers annually , the projected N and P requirements at the end of the current Five-Year Development Plan would be 51,000 and 25,000 tons , respectively (Ministry of Planning, 1986).

5-3. FERTILITY MANAGEMENT PRACTICES

Past and current research indicates that nitrogen and

Table 5.3 : Recommended fertilizer rates for wheat in different agroecological zones (NCARTT,1982).

Rainfall (mm)	Recommended Rate	
	Ammonium Sulfate (kg/ha)	Triple Superphosphate (kg/ha)
< 250	--	50 - 100
250 - 300	100	50
300 - 400	100	50
> 400	300	100

phosphorus are the most critical limiting nutrients in rainfed agriculture in Jordan (Moore, 1974; Hopkinson,1975; Duwayri,1980). Sulfur is not likely to be a limiting nutrient until N and P levels are optimal and crop yields have been substantially increased (Hattar ,1986) . The potassium content, in most soils under rainfed conditions seems adequate. However, both the content and availability of sulfur and potassium should be monitored in soils devoted to rainfed agriculture because as crop production increases, greater stress will be placed on the supply and release of these two nutrients from indigenous sources .

5-3.1.Recommended Nitrogen Rates

Increased use of N fertilizer has been a major factor in increasing wheat yield under experimental conditions in Jordan (JCCIP,1984) . The extension of this approach to farmers' fields in the semiarid regions of the country appears to be feasible. In actual practice, however, a very limited number of farmers (about 5%) do apply N fertilizer to their wheat crops. However, the application of N fertilizer in these areas is risky due to low and erratic rainfall (Stewart, 1988). In addition to that , farmers are usually prepared to accept lower , but consistent, yields in preference to occasionally higher, but more variable, yields.

Wheat in semiarid areas requires approximately 30 kg of available soil N for each 1000 kg of grain produced up to a point where the yield curve starts to level off (Olson, 1984). Nitrogen is the most limiting fertilizer nutrient to optimum crop production under rainfed and irrigated conditions (Olson,1980). However, it is the most difficult of all elements to control in the soil-plant system. It is subject to losses by volatilization as ammonia , or denitrification from reduction of nitrates, microbiological immobilization, and leaching beyond the root zone as nitrate. Nitrogen loss usually depends on soil conditions which are influenced by management practices employed by the farmer .

5-3.1.1.Small Grains

More wheat is grown in the rainfed areas of Jordan than in other region of the country (GOJ,1985). Approximately 140,000 ha of wheat are grown every year, with a coefficient of variation for the area planted of about 13.1% (Department of Statistics, 1983). However , the variability in wheat production and yield/unit area are much higher, i.e., 62% and 69% ,respectively (Department of Statistics,1983)

Nitrogen requirements of wheat in semiarid (>350 mm of annual rainfall) and arid (<350 mm) regions of Jordan were estimated to be 30-60 kg N/ha , depending on annual

rainfall and distribution. Yields tend to level off at about 2500 kg/ha (see section: 5-4 in this chapter).

Nitrogen fertilizer experiments conducted by researchers at the Ministry of Agriculture (MOA) during the 1950s and 1960s and by Hopkinson (1973,1975) indicated that, under low and variable rainfall conditions ,responses to fertilizers are rather small and nitrogen can have a negative effect on wheat yields . A general recommendation based on these experiments and in years of above average rainfall was to apply 20 kg N/ha at sowing , with another 20 kg N/ha at tillering as a top dressing.

The approach which has been suggested by the Jordan Wheat Research and Production Project (Moore,1975) was to divide the dryland wheat growing area of Jordan into three rainfall zones, i.e., low, medium and high rainfall, and to run a series of trials over several years in order to determine the optimum nitrogen rate for each zone. The plan which was outlined in Moore's report was not implemented in its entirety. However, preliminary information indicates that satisfactory wheat yields were obtained with 30 kg N/ha in the medium rainfall areas of the country.

The above approach was adopted by the Jordan Cooperative Cereal Improvement Project (JCCIP ,1984) . Experimental results of N fertilization trials over four

growing seasons (1978/79 - 1981/82) showed that a nitrogen rate of 60 kg N/ha is optimal if rainfall exceeds 400 mm . However , it was recommended that 30 kg N/ha be applied at sowing and an additional 30 kg N/ha added as a top dressing at tillering, provided that rainfall is higher than average.

In areas of lower rainfall (i.e.250-350 mm) JCCIP (1984) recommended 30 kg N/ha at sowing with an additional 30 kg N/ha at tillering,but only if timely rainfall occurrs.

Barley is traditionally grown on marginal lands and in the low rainfall zone (200-300 mm). Farmers usually do not fertilize barley because of limited response due to low rainfall. Nevertheless, there has been little work done on establishing the nutrient requirements of barley under low rainfall in Jordan.

Experimental results of N fertilization trials over four growing seasons (JCCIP,1984) indicated that it is not necessary to apply N to barley at sowing but,if the rainfall is above average, 30 kg N/ha may be applied as a top dressing at tillering.

5-3.1.2. Grain Legumes

Two grain legume crops are of economic importance in Jordan. These are lentil and chickpea . Both crops are

usually grown in rotation with wheat in areas of more than 350 mm of annual rainfall (see: chapters 6 and 8 for more details) .

On the average, lentil is grown on one tenth of the area devoted to wheat, approximately 14,850 ha, while chickpea is grown on a much smaller area ,not exceeding 4000 ha (Department of Statistics, 1983).

Traditionally, these two legume crops are not fertilized and farmers do not feel that N fertilizers would improve their low yields. But farmers have noticed that wheat yields,grown after an unfertilized lentil or chickpea crop, are lower than wheat yields grown after fallow (Haddad and Arabiat,1985).

Nitrogen requirements of lentil and chickpea in arid and semiarid regions of Jordan were estimated at 20 kg N/ha, especially when both crops are planted early in the winter season (Haddad,1986 a,b). This practice would leave a reasonably acceptable level of residual nitrogen for the subsequent wheat or barley crop in the rotation.

5-3.2. Recommended Phosphorus Rates

Soils in the arid and semiarid regions of Jordan are normally alkaline and sometimes contain free lime in rooting the zone(Qudah & Jaradat,1988).Generally,calcareous soils in

these regions are inherently too low in available phosphorus to sustain optimum growth and production of crops. Phosphorus has proved to be an essential element in rainfed agriculture in such soils (Matar,1981).

Phosphorus is relatively immobile in the soil, and when calcareous soils are fertilized with increasing amounts of P, the element tends to become fixed at a rate dependent on soil type and chemical properties (Matar,1976).

5-3.2.1. Small Grains

Limited soil tests and P response data in Jordan during the early 1970s suggested that P deficiency was widespread in the rainfed wheat growing regions, particularly in red soils of the higher rainfall (> 450 mm) zone (Moore , 1975).

A series of experiments were conducted to help define appropriate P application rates for different rainfall zones. Unfortunately, the results of these experiments have not been published (Moore,1975).

Hopkinson (1973,1975), could not establish a consistent response to P in different parts of the Karak district, but observed a positive interaction between N and P on wheat yield. He also found that a combined application of 20 kg N/ha and 20 kg P_2O_5 /ha doubled wheat yields, although no

yield data were presented in these reports.

In a series of experiments carried out by NCARTT , researchers tried to establish site-specific P fertilizer rates for wheat and barley (NCRATT, 1975-1982). The results of these experiments were inconclusive (Table 5.4) and varied somewhat from one year to another. In general, rates of 40-80 kg P_2O_5/ha gave the highest grain yield when added to the soil before sowing and when the recommended N rate for a particular area was applied.

JCCIP researchers (1984) tested two P fertilizer rates(30 and 60 kg P_2O_5/ha) in combination with varying levels of N for wheat and barley. They concluded that 30 kg P_2O_5/ha a was general recommendation that was acceptable throughout different agroecological zones. These researchers felt that a new set of experiments should be designed to test varying rates of P in combination with different N levels in order to determine more specific P rates for different soils and rainfall zones. Moreover, it was suggested that individual recommendations should eventually be linked to soil tests.

5-3.2.2. Grain Legumes

Both lentil and chickpea responded very well to P rates of 40 and 80 kg P_2O_5/ha, but in some cases could

Table 5.4 : Recommended P fertilizer rates for different locations in the arid and semiarid areas of Jordan (data compiled from NCARTT Annual Reports).

Location	Year	Rainfall (mm)	Crop	Recommended P Rate P_2O_5 (kg/ha)
Naimeh	1974-1975	250	Wheat	90
Manja	1974-1975	200	Wheat	*
Rabbah	1975-1976	230	Wheat	*
Rabbah	1976-1977	245	Wheat	80
Irbid	1979-1980	450	Wheat	80
Madaba	1980-1981	470	Wheat	40
Maru	1980-1981	370	Wheat	80
Ramtha	1980-1981	180	Barley	80

* : No recommended rate was given due to low rainfall.

depend on the availability of soil P. Moreover, both crops responded better to P fertilizer during years of below average rainfall (Haddad , 1986a,b).

Abu-Alen (1986),investigated the effect of lentils on the yield of wheat and barley in semiarid (Mushagar) and arid (Ramtha) regions. He concluded that 40 and 80 kg P_2O_5 /ha were the optimal rates for lentils in arid and semiarid regions, respectively.

5-3.3 Sulfur and Micronutrients

Calcareous soils occur extensively in the arid and semiarid parts of Jordan (Qudah & Jaradat,1986). Their $CaCO_3$ content which may be as high as 65% could markedly decrease the availability of P and micronutrients to crops (Hattar,1986). Problems of micronutrient availability in these soils are aggravated by low soil organic matter content (El-Bagouri, 1980).

Sulfur ,as elemental S or as H_2SO_4 , can readily decrease soil pH (especially in soils having a low buffering capacity,e.g. soils with a low organic matter content) and, thus, can affect the level of active $CaCO_3$. Hatter (1986) found that these reactions caused a marked increase in available P and extractable micronutrients such as Fe,Mn, Zn, and Cu (Table 5.5).

Table 5.5 : Effect of application rates of elemental S on the DTPA* extractable Fe , Mn , Zn , and Cu in a calcareous soil following incubation of 4 weeks.

Elemental S	Fe	Mn	Zn	Cu
kg/ha	ppm			
0	8.0	18.5	1.2	0.9
500	12.3	27.8	1.6	2.0
1000	10.1	24.4	1.2	1.1
5000	10.1	32.8	1.7	1.8

* : Diethylenetriaminepentaacetic Acid.

Results of a five-year research program (Hatter, 1986) indicated that yield of a wheat crop under medium rainfall conditions (long-term average 370 mm), was increased by 18% when 2000 kg elemental S/ha were applied. However, this response level was not enhanced by the addition of 50 kg P_2O_5/ha,in which case wheat yield was reduced by 6% . The highest wheat yields were obtained when 5000 kg S and 50 kg P_2O_5/ha were added (Table 5.6). These results are difficult to explain , but suggest a complex interrelationship involving pH, P availability , and micronutrient imbalances. Future research is needed to resolve these interactions.

5-3.4.Time of Fertilizer Application

The proper timing of fertilizer application is an important means of improving its use efficiency . In the case of N fertilizer , losses from leaching , volatilization of ammonia (NH_3) , or denitrification can be minimized by applying and incorporating N as close to the time of plant uptake as possible. Usually , split applications of fertilizer N are recommended with one-half applied at planting of wheat , and the remainder sidedressed just prior to the rapid growth which coincides with tillering (Olson, 1980).

Information on time of fertilizer application under rainfed conditions in Jordan is very limited. However, some

Table 5.6 : The effect of elemental sulfur and phosphate fertilizer on wheat yield grown in northern Jordan (N rate for all treatments was 80 kg/ha).

P_2O_5	Elemental S	Yield
	kg/ha	
0	0	1558
0	2000	1804
0	5000	1670
0	10000	1357
50	0	1646
50	2000	1695
50	5000	1934
50	10000	1869

results (NCARTT,1984) have shown that there was little difference in wheat yields whether all of the N was applied at planting or by split application. These findings agree with earlier results obtained under similar environmental and edaphic conditions in southern Syria (Matar, 1981).

Phosphorus is relatively immobile in the soil and is, therefore, generally applied prior to planting of wheat , since the growing plant needs P early in its development.

5-3.5.Fertilizer Placement

The method of fertilizer N application can have a significant effect on N use efficiency by plants, especially when there is potential for loss through volatilization, leaching, denitrification and immobilization (Russell,1980). Ammonium sulfate ,the commonly used N source for cereal production in Jordan, is often drilled with the seed , or broadcast and incorporated. Where split application is practiced, one half of the N is usually broadcast at tillering. There is little information in Jordan on the effect of method of application and placement of fertilizer N on N use efficiency and crop yield. In low rainfall areas where the shallow soil layers become dry during the later stages of crop growth and development , deep placement of N fertilizer may be an advantage. For example Cochran et al.(1978) suggested that deep-placed N is more available to the roots

extracting water from below the dry layers , and that water use efficiency may be improved.

Phosphorus fertilizer is usually broadcast and incorporated prior to sowing of wheat. However, Moore (1975) suggested that P should be banded near the seed at planting since broadcasting may not give the desired response even in dry areas. No data were presented to support this suggestion. Other research showed that banding 4 to 5 cm to the side of the seed row is the most effective placement method in deriving the maximum "starter" benefit and highest yields (ICARDA, 1985b). Matar (1981), working under similar environmental and edaphic conditions in southern Syria , showed that deeper P application by plowing after broadcasting was more advantageous during periods of dry weather.

5-4.YIELD RESPONSE TO FERTILIZERS

Effective crop response to applied fertilizers is heavily dependent on the genetic potential of high-yielding cultivars.

Landraces and local cultivars of field crops grown in Jordan are among the least responsive to fertilizers . Hence a low fertilizer response is expected from them when compared with newly bred , high-yielding cultivars.

Under the Fertilizer Program of the Food and Fertilizer Technology Centre, FAO carried out fertilizer experiments in 40 developing countries (Olson, 1980). Crop response to fertilizers was lowest in the Middle East and North Africa. The ratio of the yield value obtained per cost of fertilizer applied in this region was calculated as 1.0-1.8 . In Turkey, this ratio ranged as high as 3.6.

Research conducted in the ICARDA Region (ICARDA, 1984) has shown that fertilizer response is likely to be affected by cropping history, and that response to residual fertilizer in subsequent years must be considered in any experimental or economic evaluation.

ICARDA scientists (ICARDA, 1985) were able to establish a clear relationship between the amount of mineral N at sowing and the level of a crop response to applied N . An attempt was made to establish such a relationship under rainfed conditions in Jordan (Table 5.7). Wheat grain yield was positively and significantly correlated with N% and annual rainfall, but not with P content of soil at sowing (Table 5.7). Wheat was found to respond to both N and P , however , its response to P was more pronounced at higher N rates (Abu- Aien , 1986; Gharaibeh ,1987 Unpublished Data) (Fig. 5.1) . Lentil, however, responded well to P , especially at lower N rates. Its response to N was mostly negative (Fig. 5.1) . These results are in

Table 5.7 : Wheat yield (kg/ha) as affected by N (%) , P (ppm) and annual rainfall (mm).

Yield (kg/ha)	N %	P (ppm)	Rainfall (mm)
925	0.06	2.2	450
1200	0.10	6.0	250
590	0.07	5.0	245
395	0.10	9.5	230
305	0.05	9.5	370
854	0.10	14.4	200
2330	0.06	6.0	470

Partial Correlation Coefficients : (r)
r (yield & N% = 0.58).
r (yield & p = 0.44).
r (yield & rainfall = 0.70).

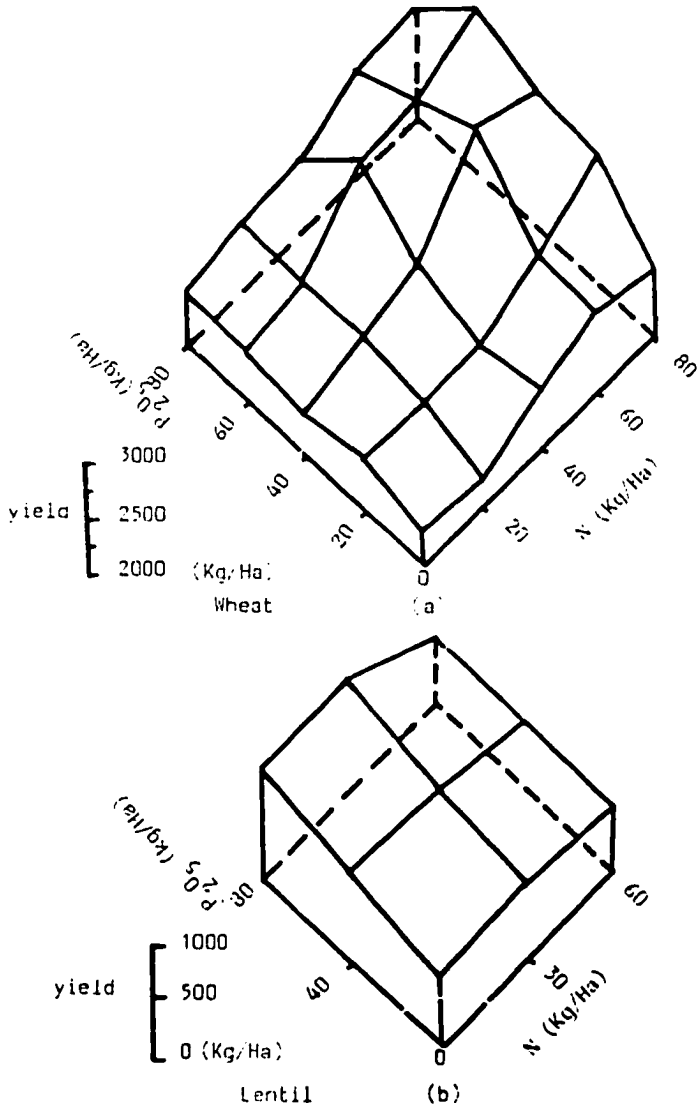


Fig. 5-1. Response of wheat (a) and lentil(b) yield to different N and P fertilizer rates in semiarid regions of Jordan.

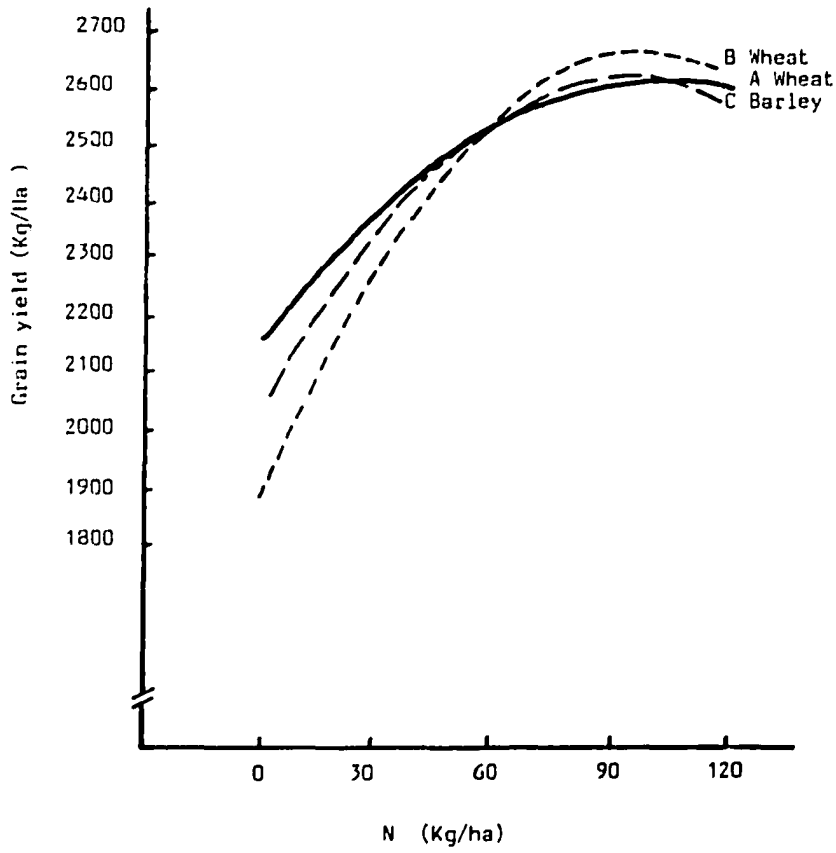
agreement with earlier findings by ICARDA researchers (ICARDA , 1984).

The highest yields of barley were obtained with 30 kg N/ha when grown after a lentil crop, that had been fertilized with 60 kg N and 80 kg P_2O_5/ha (Abu-Alen,1986). Wheat exhibited the same trend .

Grain yield response to nitrogen in a typical growing season (1980-1981),in low, medium and high rainfall zones of Jordan (JCCIP,1984), is presented in Fig. 5.2 along with regression equations expressing grain yield as a function of N rate. Generally, the yield curves reached a plateau at 60 kg N/ha and the response to higher fertilizer rates was insignificant.

In a series of P fertilizer experiments , researchers at the National Centre for Agricultural Research and Technology Transfer (NCARTT, 1975-1984) concluded that a positive response of wheat to P fertilizer is very pronounced when soil-extractable P levels exceed 31 ppm. ICARDA's experience in this regard showed that wheat grain yield responded to P rates of 30 and 60 kg P_2O_5/ha when soil-extractable P levels were less than 5.8 ppm (ICARDA, 1985).

Wheat grown in the semiarid parts of Jordan responded to varying sources of N and P in the same manner



$$Y_A = 2151 + 9.2628N - 0.04619N^2$$
$$Y_B = 1874 + 16.562N - 0.08524N^2$$
$$Y_C = 2031 + 12.6948 - 0.06865N^2$$

Fig. 5-2. Grain yield response of wheat and barley to varying N fertilizer rates in high (a) , medium (b) and low (c) rainfall zones in Jordan.

(Table 5.8). Although diammonium phosphate resulted in the highest grain yield , no significant differences were detected as a result of the source of N and P (NCARTT, 1983).

Crop response to applied N and P is also affected by fertilizer placement and time of application. Researchers at NCARTT (NCARTT, 1983;1984) recommended that N and P be drilled at sowing to obtain the best response.After inspecting data published by NCARTT , however, no significant differences were found which could be attributed to the method of fertilizer placement or time of application.

5-5.FERTILIZER USE EFFICIENCY

Varietal differences in grain yield response of cereals to applied fertilizers, particularly nitrogen, have been demonstrated over a wide range of environmental conditions, and under different management practices (ICARDA, 1984). If these varietal differences in response to fertilizers are to be exploited by plant breeders , appropriate methods for their measurements are required (Spriertz and van Keulin, 1980).

There is an urgent need, especially in developing countries , to determine the N use efficiency of landraces

Table 5.8: Wheat yield (kg/ha) as affected by source of N and P.

Source	Wheat Yield (kg/ha)
Ammonium Sulfate & Triple Superphosphate	1554
Urea & Triple Superphosphate	1700
Ammonium Nitrate & Triple Superphosphate	1535
Diammonium Phosphate	1703
N - P - K (15 - 15 - 15)	1351

LSD (0.05) = 561

and newly bred cultivars and identify lines that are highly responsive to both low and high rates of N fertilizers.

Fertilizer use efficiency can be considered a result of nutrient uptake, utilization, and agronomic efficiencies combined. Uptake efficiency is defined for N as: (N uptake at X kg N/ha - N uptake at 0.0 kg N/ha)/ X kg N applied/ha. Utilization efficiency is defined as :(Grain yield at X kg N/ha - grain yield at 0.0 kg N/ha)/(N uptake at X kg N/ha - N uptake at 0.0 kg N/ha). Finally, agronomic efficiency is defined as :(Grain yield at X kg N/ha - grain yield at 0.0 kg N/ha)/ X kg N applied/ha (Campbell and Paul,1978).

No attempts have been made to determine these efficiencies for major crops in Jordan. However, uptake and agronomic efficiencies have been calculated from data published by others (El-Khattari,1985 ;Abu-Aein,1986; Gharaibeh,unpublished data,1987).

In a greenhouse experiment (El-Khattari,1985),the semi-dwarf wheat variety ACSAD 71 was found to exhibit a slightly higher uptake efficiency than the conventional tall variety Hourani. However, it was found that uptake efficiencies for both cultivars decreased as the rate of N fertilizer increased(Table 5.9).

Agronomic efficiencies for major field crops in Jordan

Table 5.9 : Total N uptake and uptake efficiency as affected by rate of N fertilizer and wheat genotype.

N Rate (kg/ha)	N Uptake mg N/pot		Uptake Efficiency g N/ g N	
	Genotypes			
	Hourani	ACSAD 71	Hourani	ACSAD 71
0	62.9	76.7	----	---
40	123.5	230.2	0.150	0.38
80	186.7	217.0	0.154	0.17
160	240.5	269.4	0.110	0.12

are presented in Figure 5.3 . It was noted that in a lentil-barley or lentil-wheat rotation , lentil exhibited a small , but sometimes negative , N agronomic efficiency. Wheat and barley, however, showed high agronomic efficiencies , especially when compared with their agronomic efficiencies in a recrop situation.

Phosphorus agronomic efficiency was much higher under semiarid (Mushagar) than under arid conditions (Ramtha). The inclusion of a legume in the crop rotation resulted in a higher agronomic efficiency,especially in a semiarid region.

In general,lower rates of N and P,30 and 40 kg/ha, respectively, resulted in higher agronomic efficiencies . The amount of available soil moisture is probably the most critical factor that limits agronomic efficiency at higher fertilizer rates.

5-6.SOIL FERTILITY AND CROP ROTATIONS

Fertilizer requirements of crops in various rotations in the rainfed area of Jordan are not well-established. Legumes in the crop rotation supply some N to subsequent crops and thereby reduce N fertilizer requirements. The inclusion of a legume crop , although highly recommended, is not widely practiced in rainfed agriculture in Jordan (see

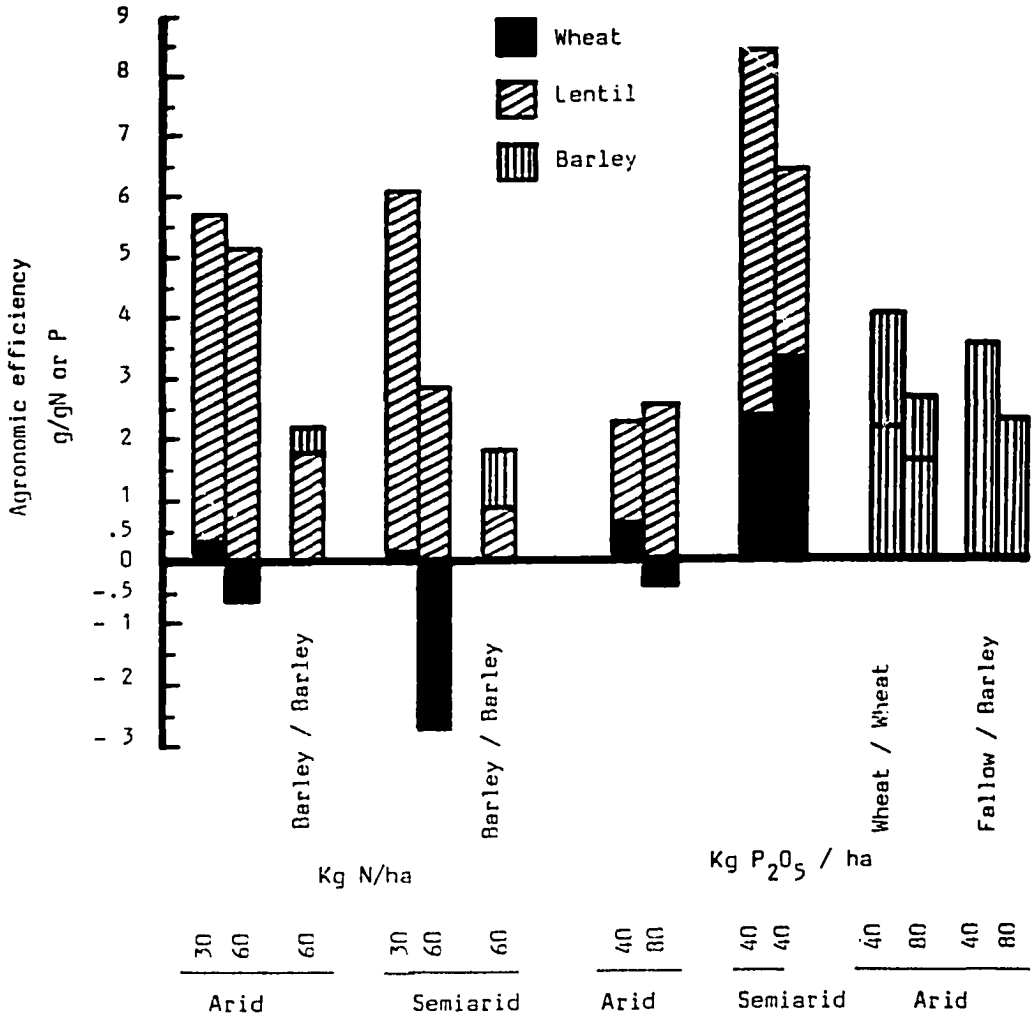


Fig.5-3. Nitrogen and phosphorus agronomic efficiencies of wheat, barley and lentil in arid and semiarid regions of Jordan.

chapter 8 : Crop Rotations). Management practices that enhance efficient N fertilizer use for various crop rotations are urgently needed in Jordan. Some of these management practices are summarized below:

1- The amount of applied N fertilizers in a crop rotation should approximate the amount required for optimum yields;

2- N fertilizer should be applied at those times which maximize its use by the current crop in the crop rotation ;

3- A cropping sequence should allow for minimum losses of fertilizers by erosion and leaching; and

4- Crops that fix nitrogen , such as grain and forage legumes, should be included in the crop rotation.

Only limited research has been conducted on crop rotations in relation to fertilizer requirements. In a two-year crop rotation of lentil-barley in an arid zone , Abu-Aien (1986) found that the optimum fertilizer rates for lentil and barley were 30 and 80 kg of N and P_2O_5/ha , respectively. Gharaibeh (Unpublished data,1987) demonstrated that P fertilizer rates of 40 and 80 kg P_2O_5/ha can maintain reasonably acceptable yields of wheat and barley , even in a recrop situation (Table 5.10).

Table 5.10 : Wheat and barley yields as affected by crop rotation and P fertilizer rates.

P Rate	Wheat-Wheat	Wheat-Fallow	Barley-Barley	Barley-Fallow
		kg/ha		
0	313	358	537.5	737.3
40	398	446	689.5	876.5
80	432	558	751.5	922.0

5-6.1. Biological Nitrogen Fixation

Legume crops (e.g. lentil and chickpea) contribute to the N economy of the soil through the process of biological nitrogen fixation , whereby the association between the Rhizobium bacteria and the legume crop results in the reduction of atmospheric N_2 to NH_3 (Vincent , 1974). Unfortunately , there is very little information in Jordan on various aspects of biological nitrogen fixation and its contribution to the N economy of the soil.

The amount of N (kg/ha/year) fixed by different legume species varies from one environment to another, depending on a number of factors. A general estimate of the amount of N fixed by a number of legume species grown under rainfed conditions is presented in Table 5.11.

Studies conducted at the University of Jordan found that the Rhizobium bacteria which can symbiotically fix atmospheric N with lentil and chickpea are abundant in Jordanian soils (Haddad, 1986a,b). Moreover, these experimental results indicated that inoculation of lentil and chickpea seed with the appropriate Rhizobium bacteria did not result in yield increases for either crop over the uninoculated treatment. However, Haddad concluded that seed inoculation is necessary only when the legume crops are planted in soil for the first time or in newly reclaimed

Table 5.11 : Amount of N (kg / ha / year) fixed by different legume crops under rainfed conditions.

Species	N (kg / ha / year)
Vetch	85
Faba Bean	210
Cowpea	198
Chickpea	103
Lentils	101

land.

5-7.FERTILITY IMPACT ON GRAIN QUALITY

In the Near East region , wheat constitutes a major source for calories and protein. It is utilized as bread , bulgur and farekah (a local product of wheat harvested at the hard dough stage then roasted) . The improvement of the nutritional quality of this staple food has received very little attention from agronomists and plant breeders in Jordan.

In general, it has been observed that the first increments of applied N give the largest yield increase per unit of N, but with only limited increase in protein. As the yield increase per unit of applied N decreases , the increase in protein per unit of applied N increases. These trends vary with different wheat cultivars (Johnson et al.,1973).

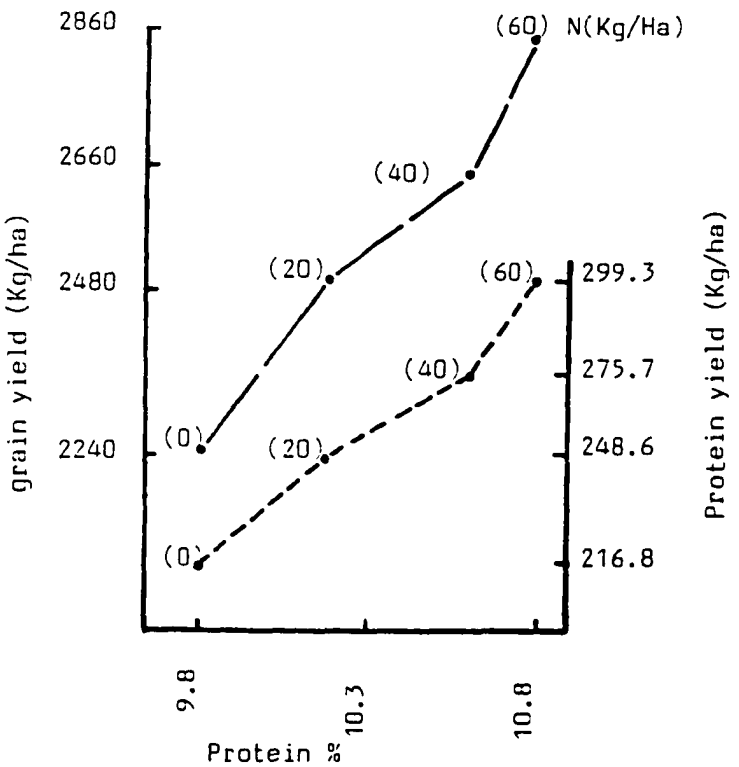
In a field experiment carried out at two locations in Jordan , Duwayri (1978) studied the effect of N fertilizer on grain yield, protein yield and percent protein of different wheat cultivars . He found that the local durum wheat cultivars, compared with Mexican semidwarf cultivars, gave the lowest grain yields but the highest protein content . Duwayri also reported an increase in protein content from 9.96 % to 10.92 % when the N fertilizer rate was

increased from 0 to 60 kg N/ha. However, after further statistical analysis, it was found that the rate of protein increase and total protein content decreased as the amount of fertilizer N was increased (Fig. 5.4). The greatest increase in protein content (0.42%) resulted from application of 40 kg N/ha, while the greatest increase in grain protein yield (31.8 kg/ha) was obtained at the 20 kg N/ha .

El-Khattari (1985) reported the effects of different N rates on grain yield and protein content of local durum (F8) and semidwarf (Stork 'S') wheat cultivars . The experiment was conducted under greenhouse conditions and included 4 N rates. Statistical analysis revealed that grain yield and protein content were significantly correlated for both cultivars ($r=0.92$, $P<0.001$) for N rates as high as 120 kg N/ha. Phosphorus nutrition, except where P is extremely deficient, has no significant effect on the grain quality.

5-8.ECONOMICS OF FERTILIZER USE

Farmers in the rainfed regions of Jordan and other countries in the region are averse to risk and usually respond to weather and climatic uncertainties with low input technologies. The most important economic factor that influences a farmer's decision of whether to apply N



5-4. Relationship between grain yield, protein yield and protein % as affected by rate of fertilizer N.

fertilizer is the relative cost of the fertilizer compared with the price he receives for his crops (Somel,1986).

A report on the economics of fertilizer use under rainfed conditions in Jordan (UOJ,1976) indicated that an application of 125 kg superphosphate, and an equal amount of ammonium sulfate per hectare at sowing resulted in increased wheat yields which more than covered the cost of fertilizer applied. In the same report ,it was concluded that the minimum yield of wheat necessary to cover production costs , using no fertilizers , was 700 kg/ha. However, wheat yield was doubled when the recommended amount of fertilizer was applied. These results were in agreement with those of Schmisseur (1975) using partial budgets he derived from the trials conducted during the period 1968-1973 .

In their economic analysis of the "best-bet" for wheat production in Jordan , Arabiat et al.(1983) calculated the minimum yield increase requirements (MYIR) to cover the cost of N and P fertilizers . These researchers concluded that each additional kg of P_2O_5 must produce a MYIR of 18 kg of wheat per hectare ,whereas the MYIR for N was 28 kg of wheat per hectare. In this analysis , N and P fertilizers were considered high risk inputs . In a dry year , N will be ineffective. While P may be ineffective in a dry year , it can have a considerable residual value in the following year.

Economic analyses of on-farm trials , under relatively similar socioeconomic conditions, indicated that marginal profit rates of over 100% can be achieved with fertilizer use (ICARDA , 1985).

Various strategies may be adopted to minimize the risk associated with the use of fertilizers under rainfed conditions (ICARDA,1984) . The use of split N application is one of these strategies ; it has proved very profitable , especially in years of low or late rainfall . Some of the N may be applied at sowing , while the remainder is applied in spring at tillering when seasonal conditions and crop growth prospects can be better assessed. This practice should maximize N use efficiency by the crop and in cases of severe drought and crop losses, the farmer is able to save one-half of his nitrogen. For more information on this subject ,see section 6 in chapter 10: Response Farming by J. I. Stewart.

5-9.RESEARCH NEEDS

Classical experiments with fertilizers in the rainfed agricultural sector have produced some basic , but insufficient , information on fertilizer management in Jordan. Many deficiencies in the area of soil fertility and fertilization still exist. Therefore , intensified field research involving sources , rates, timing and method of application with different crops , management systems and

nutrients are vitally needed.

Previous research in soil fertility has emphasized N and P with little , or no emphasis on secondary and micronutrients. These elements might be limiting crop yield because of low soil organic matter and the use of pure fertilizer materials.

Most farmers in the rainfed parts of Jordan who use fertilizers use less than optimum rates of N because of the uncertainties associated with rainfall and other factors. Field research must provide the information needed to predict optimum fertilizer rates. Associated laboratory studies are also needed to determine the transformations and movements undergone by N. Fertilizer rates could be projected from past management, moisture availability, and the amount of residual fertilizer remaining in the root profile after prior fertilizer applications.

Yield response to applied fertilizers is low. This might be due to either inhibition of nutrient uptake or inefficient use of nutrients in producing economic yield. A set of sophisticated experiments is needed to develop general principles concerning the responses of crops to N and P fertilizers.

The use of soil analyses to predict crop response to fertilizers is not practiced. This procedure is based on a correlation between some fraction of a nutrient extracted

from a representative soil sample and a measured response from fertilizer application.

Soil fertility investigations ,in the future, must be conducted utilizing all the crop cultural practices that can maximize crop yields. With the adoption of conservation tillage , crop residues incorporated into the surface soil can immobilize N , can reduce nitrification rates and might be phytotoxic to seedlings. The amount , placement, and timing of fertilizer application with the new system must be determined. Soil testing on a regular basis is essential , especially as new cropping systems (e.g. wheat-medic) and tillage practices are employed.

Where the use of N fertilizer is impractical because of low rainfall , climatic variability or high cost, more attention needs to be given to alternative strategies for increasing the amount of N in the soil-plant system. This is possible through the inclusion of pasture and/or grain legume crops in the crop rotation. It is very important , in this regard, to consider surveying the naturally existing Rhizobia and improving their efficiency. An alternative approach is to increase N fixation through the use of effectual Rhizobium inoculation techniques and genotype selection.

Long - term crop rotations are needed to assess

fertilizer fluxes and transformations. These crop rotations must be carefully planned according to land capability classes and agroecological zones.

Although numerous chemical carriers of N and P are manufactured by the fertilizer industry, their relative efficiencies have not been determined for rainfed conditions in Jordan. It is necessary to select inexpensive but efficient carriers which are easy to apply by farmers.

Sites for fertilizer experiments should be prepared by uniform cropping and detailed baseline data; e.g., total N, organic matter , and other physical and chemical characteristics, should be collected when experiments begin. Also, experimental sites should be large enough to allow superimposition of a wide spectrum of treatments on farming systems and soil management within realistic existing and alternative crop rotations.

A long-term strategy in the area of fertility research should be the selection and/or breeding of crop varieties efficient in fertilizer uptake and use.

5-10.SUMMARY

Low crop yields under rainfed conditions in Jordan can be attributed in part to low soil fertility. It is possible to increase crop yields through proper fertilizer

application in field experiments and demonstrations, however, most farmers are either not using fertilizers or using minimal amounts due to low and erratic rainfall and to economic factors. Recommended rates, timing and methods of fertilizer application have been developed through experimentation. These practices need to be improved by taking into consideration crop cultural practices that can maximize crop yields. Also, the effects of long-term crop rotations and the inclusion of a legume phase should be considered during the development of fertilizer recommendations.

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TILLAGE PRACTICES

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6-1. INTRODUCTION

The development of tillage practices for dryland crop production has been , and will continue to be , a dynamic process. This is a consequence of farmers responding to changes in market, rotation and crop requirements, the risk of soil erosion, the cost of production and the availability of specialized tillage equipment and herbicides(Fawcett, 1980).

The traditional and exploitative cropping system, which has been practiced in Jordan and other Middle Eastern countries, depleted soil resources and resulted in lower crop yields (Rafiq, 1979).

Traditional crop rotations, which are practiced in Jordan , were based on the fallow system and conventional tillage practices. This system performed reasonably well in the past, however, with the increased population pressure and

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mechanization of the dryland farming,new and highly improved tillage practices are needed to stabilize both soil resources and crop production.

6-2.GENERAL FEATURES OF TILLAGE IN JORDAN

The general features of tillage in rainfed areas of Jordan are changing, especially after the establishment of three agricultural machinery stations by the Jordanian Cooperative Organization (JCO). The first station was established near Ramtha Agricultural Research Station in Northern Jordan. The second is located near Mushagar Agricultural Research Station, in Madaba district in Central Jordan, and the third is located near Rabbah Agricultural Research Station in Southern Jordan. All three machinery stations were supplied with the necessary equipment, especially for conservation tillage, by the German Agency for Technical Cooperation(GTZ) (Otto,1980).

Until recently (Tamimi,1981),tillage in rainfed areas of Jordan was characterized by:

(i) Large number of tillage operations. In areas where wheat-fallow rotation is used,farmers felt that the more tillage operations and the deeper the plowing, the more yield they get. Four to six tillage operations during a fallow period of 16-18 months

were common in these areas.

(ii) The use of unsuitable tillage implements such as heavy disks and moldboard plows.

(iii) Plowing up and down the slopes . This practice aggravates the problem of soil erosion and will be discussed elsewhere in this Monograph.

(iv) During the fallow year, some farmers tend to delay spring plowing for weed control. Weeds are left for grazing by animals until early summer. However, early plowing is a common practice for the control of summer weeds and to minimize loss of moisture through cracks which develop in heavy soils during summer months.

Research on tillage has been very limited. This might be due to its complexity and the numerous variables involved. Lack of specialists and team work among researchers is another major constraint.

6-3.TIMING AND NUMBER OF TILLAGE OPERATIONS

As stated before(Tamimi,1981),farmers in Jordan and nearby countries believed that intensive tillage would result in higher wheat yields. Such intensive tillage was practiced in the Northwest of the U.S. (Papendick, 1984), and in Australia (Fawcett,1980). However, there is strong research evidence which indicates that intensive and deep plowing

should not be practiced in dryland areas (Papendick, 1984).

In most dryland regions of the world,tillage operations were reduced gradually; conservation tillage,minimum tillage and no-tillage systems were adopted, on a large scale, in countries like the U.S. and Australia . It was clear by the late 1930's in the U.S. that any benefits in fallow moisture conservation attributed to a surface dust mulch, or to the use of deep plowing, were not justified for cereal production. The formation of a dust mulch substantially increased the risk of erosion , and deep plowing was expensive and caused losses in grain yield in dry seasons (Papendick et al.,1980). Tillage systems were therefore modified to reduce the risk of erosion.

Winters (1976) identified two objectives for wheat research in Jordan, in relation to tillage: the first , to determine the most practical combination of tillage procedures which will most efficiently conserve moisture for maximum wheat production under summer fallow conditions ; the second, to ascertain which cultural practices, or combination of cultural practices,can be used for effective weed control in wheat producing areas of Jordan .

6-3.1.Primary Tillage

Primary tillage in rainfed areas of Jordan , and other Mediterranean countries, is performed from June till

November. Timing of tillage is very important in dryland farming. Farmers,in rainfed areas of Jordan and neighbouring countries,practice fall tillage to break open the soil surface in order to increase infiltration and store more moisture in the soil profile.

The summer fallow program of the Jordan Wheat Research and Production Project (Goetze, 1976) initiated field experiments to determine the effect of fall tillage on the conservation of precipitation and the effect of spring and summer tillage implements on the conservation of soil moisture.

Selection of a spring or a fall plowing date is dependent on a number of factors including weed control,erosion hazard soil type and topography, and crop residue.In areas of heavy rainfall there is a danger of erosion if the soil is loosened by plowing in the fall.The crop and the remaining residue on the soil surface may determine the optimum time of plowing (Gallacher, 1979).

Fall plowing may be advisable for heavy, fine-textured soils.The wetting-drying action over the winter breaks large clods into smaller granules, and makes secondary tillage for seedbed preparation easier.

Spring tillage , during the fallow period , usually is performed during the period from March to May. The main purpose is to control any weed growth and reduce moisture loss

through evapotranspiration. The limited available experimental evidence under Jordanian conditions shows that the earlier the tillage, the higher the yield of wheat (Table 6.1). This yield increase could be attributed to an early removal of weeds and lower losses of the limited soil moisture during the summer months (NCARTT, 1983; Lindstrom et al, 1974).

6-3.2.Secondary Tillage

Secondary tillage refers to field operations after primary tillage to prepare the seedbed for planting. The purpose of secondary tillage is to further pulverize the soil and prepare a fine seedbed.

The disk is the most popular secondary tillage implement in dryland farming areas of Jordan. Offset or tandem disks break large clods;cut some trash into the surface,and smooth a rough soil surface. A disk penetrates to a depth of 8-15 cm.

More recently, other implements were introduced for secondary tillage.These were field cultivators and harrows. A field cultivator has single- or double-pointed shovels , spikes, or small sweeps. It digs,lifts,and loosens the soil, cuts roots below the soil surface,and leaves some stubble on the soil surface. It is an excellent implement for controlling weeds in fallow lands.

Table 6.1: Effect of various fall and spring treatments on percent moisture storage efficiency and wheat yield in a wheat /fallow rotation (NCARTT, 1983).

Fall Treatment	Spring treatment	% Moisture Stor. Effi.	Wheat yield (kg/ha)
Plow (October)	Sub-tillage	25.0	3090a*
Sub-tillage	Sub-tillage	32.0	3360ab
Atrazine	Sub-tillage	37.0	3360ab
Atrazine	Contact-herbicide	43.7	3560b

* : Wheat yields followed by the same letters do not differ significantly (DNMRT , $P < 0.05$).

Harrows are also used for secondary tillage. The spike-tooth harrow is used to smooth the seedbed and breaks any clods. It loosens the surface layer of the soil to a depth of 8-10 cm.

Early plowing (after harvest) is a common practice in Jordan to control summer weeds and minimize the loss of moisture through cracks which develop in heavy soils during summer (Loizides ,1974).

The effect of spring tillage, during a fallow year, on soil moisture was evaluated at Rabbah Research Station,(NCARTT,1979). Three tillage operations, using a chisel plow, were performed during the period from March to May. It was found that one tillage operation during March and another during May could result in slightly higher soil moisture (19.95 %) at the beginning of the fall season at a depth of 90-100 cm, when compared with no plowing (17.6 %)(Table 6.2). However, no significant differences were found between these treatments. Hopkinson (1975) compared the moisture content,in plots plowed right after harvesting lentils with plots left without plowing, and found no significant differences to a depth of 100 cm. It was concluded that, under low rainfall conditions of Southern Jordan, a single tillage operation is sufficient to control summer weeds, however, this practice has no value in increasing soil moisture content under these experimental

Table 6.2 : Soil moisture percentage at a depth of 90 - 100 cm at the end of summer 1979 as a result of three tillage operations at Rabbah Research Station (MOA , 1979).

Time and number of tillage	% Soil moisture
Control	17.61
March,April,May	19.67
March,May*	19.95
April,May*	18.12
May**	18.42
March**	17.42
April**	17.26

* : two tillage operations

** : three tillage operations.

conditions.

The same treatments (tillage operations) were compared with a control(no tillage) at Ramtha Research Station, (NCARTT, 1982) and their effect on barley yield was assessed. No significant differences were obtained among these treatments, however, the late tillage operation resulted in significantly lower grain and straw yield (Table 6.3).

The effect of two tillage operations during spring and fall, on barley yield was evaluated at Ramtha Research Station (NCARTT, 1982). Barley yield was slightly higher from plots when a disk then a sweep plow were used. However, in that study and under low rainfall conditions , it was recommended not to perform any tillage operations during a fallow year and to control weeds by herbicides or sweeps during spring.

Researchers at the Ministry of Agriculture (NCARTT, 1983),investigated the effect of different plows as compared with no tillage on wheat yield. It was found that chiselling to a depth of 12 cm during August of the fallow year, resulted in the highest grain and straw yield of wheat (Table 6.4). Also, it was recommended, in the same study, that sweeps should be used during early spring to control weeds. In addition , early chiselling (early August) as compared with other tillage implements, resulted in higher

Table 6.3 : Effect of three spring tillage operations during fallow year on seed and straw production of barley (kg /ha), and barley height(cm) at Ramtha Research Station (NCARTT ,1983).

Treatments	Plant Height(cm)	Seed production	Straw Production
CONTROL	75	256.53	334.50
E M L*	77	259.83	345.73
E E M	76	271.23	323.17
E M M	82	268.87	332.73
M L L	77	248.10	330.20
E E E	78	288.30	356.07
M M M	78	261.77	279.83
L L L	68	201.10	245.47
LSD 1%		56.8	59.0
LSD 5%		50.0	

* : E = Early
M = Medium
L = Late

Table 6.4 : Effect of different tillage practices on wheat production(kg/ha)at Rabbah Research Station(MOA,1984).

Treatment	Seed Production	Straw Production
Control	289.1	602.4
Disc Plow	218.5	621.7
Chisel Plow	406.1	737.1
Moldboard Plow	208.2	628.3
LSD %	20.56	30.31

soil moisture content to a depth of 90 cm at Rabbah Research Station. However, chiselling did not result in significantly higher soil moisture when compared with the control (NCARTT, 1984).

6-4.DIRECTION OF TILLAGE

Fragmentation of landholdings and lack of a land consolidation program or cooperative farming,obliged farmers to plow up and down the slopes of their narrow long strips of land (Lanzendorfer, 1985).This practice is a serious problem resulting in soil erosion and loss of rainwater.

Effect of slope and direction of tillage on loss of soil was not investigated thoroughly in dryland farming areas of Jordan. A long - term experiment (NCARTT, 1981-1984)was initiated at Marrow Dryland Research Station to assess the effect of different tillage operations on soil erosion (Table 6.5). The fallow treatment resulted in the highest soil loss (184.4 kg/ha) from a silt clay loam soil with a slope of 3-5 % and a calcium carbonate content of 10 %. Soil loss caused by plowing up and down the slope was next highest, and a no-tillage and soil mulch treatment resulted in the lowest soil loss.

The amount of eroded soil,as shown in Tables 6.5 & 6.6 cannot be explained on the basis of total rainfall . During the 1981/1982 season, total amount of rainfall was 297 mm

Table 6.5 : Effect of different tillage practices on eroded soil (kg/ha) at Maru Research Station(MOA,1984).*

Treatments	Eroded Soil (kg/ha)
Tillage with slope	140.5
Tillage against slope	112.5
No tillage	184.4
No tillage + Straw mulch	109.9

* : Soil slope : 2.5 - 3.5 % .

Table 6.6 : Effect of different tillage practices on moisture percentage to a depth of 30 cm, and eroded soil at Marrow Research Station (MOA , 1982).

Treatments	% Moisture (30cm)	Eroded Soil (kg/ha)
Tillage with slope	11.7	538
Tillage against slope	12.8	460
No tillage	10.2	546
No tillage + Straw mulch	12.9	273

while it was 340 mm during 1983/84. However, the different tillage treatments had no significant effects, as compared with the control, on percent soil moisture in the first 30 cm in the soil profile .

6-5.TILLAGE IMPLEMENTS

Farm machinery was introduced into Jordan, and most Middle Eastern countries,without pretesting for suitability and without sufficient training of operators to properly use and maintain it (Tamimi, 1981).

Moldboard and heavy disk plows,which were developed for high rainfall and heavy soils of Europe, were imported and used in the dryland farming regions of the Middle East without any testing (Lanzendorfer, 1985).

Lanzendorfer (1985) estimated the number of moldboard plows in Jordan at 1270 and disk plows at 1210. However,the Jordanian Cooperative Organization (JCO, 1985) estimated the number of chisel plows at 160 and this number is on the rise as more and more farmers are realizing the benefits of chisel plows over the moldboard or heavy disk plows.

Chisel plows are rigid-tined harrows capable of penetrating to plow depth.They came into use in the 1970s in the Corn Belt of the U.S.as primary tillage implements in place of the moldboard plow.The chisel plow loosens the plow layer

and shatters it if the soil is fairly dry. It offers advantages over the moldboard plow of speed,requiring less draft, and leaving more stubble on the soil surface for erosion control.

In most dryland farming regions of Jordan, crop residues are grazed by sheep and goats; in those areas where crop residues are left on the soil as mulch, the best tillage implements are those which till the soil while retaining most of the residue on the surface. Plain rodweeders were used on a limited scale (Bull et al., 1983) and proved to be the most effective in retaining straw on soil surface . Earlier findings, under similar dryland conditions, were reported by Fenster et al.(1965).

Tillage implements were used for weed control during early spring-late summer. One-way disc harrows were traditionally used for this purpose(Hopkinson,1973,1974).However, as the Jordan Cooperative Organization (JCO) and The Jordan-Australia Dryland Farming Project (Bull et al.,1983) are trying to convince farmers to shift to minimum tillage,it is expected that a change in weed population will be observed. Consequently, a change in tillage implements, timing or frequency might be needed; also a change in the use of herbicides is anticipated.

Effects of different tillage implements on soil moisture

are discussed elsewhere in this Monograph . However, using sweeps and chisel plows resulted in retaining more soil moisture as compared with other plows (NCARTT,1985).

6-6.TYPES OF TILLAGE

6-6.1.Conventional Tillage

Most farmers, in dryland regions of Jordan, were using moldboard or one-way disk plows which incorporate crop residues into the soil. These implements partially or completely invert the surface layer of the soil, and penetrate to a depth of 16-20 cm. Deeper tillage (> 25 cm.) is practiced in heavy clay soils or to break a hardpan layer (Lanzendorfer , 1985). Several (4-6) tillage operations are performed during the summer and fall months to control weeds and prepare the seedbed (Tamimi,1981).

This tillage system controls weeds effectively,but results in a bare soil surface with few clods making it highly susceptible to erosion (Papendick, 1984). However, conventional tillage is, gradually, being replaced by conservation or reduced tillage in major wheat growing areas of Jordan (JCO,personal communication,1986).

6-6.2.Conservation and Minimum Tillage

This tillage system has been defined as reducing tillage only to those operations that are timely and essential to producing the crop and avoiding damage to the soil. It nor-

mally refers to a tillage system in which the number of field operations is reduced as compared to the number required in a conventional seedbed preparation system.

Advantages for this tillage system are:

(i) Reduced soil compaction;

(ii) Better soil conservation due to soil roughness and more residue is left on the surface; and

(iii) Reduced energy requirements.

In some instances yield increases were obtained as a result. However, Fenster et al.,(1978) referred to conservation tillage as one of the following:

1- Minimum tillage

2- No-tillage

3- Stubble mulch tillage

4- Chisel planting, and

5- Till-planting.

Conservation tillage is designed to conserve crop residues, increase water uptake, reduce wind and water erosion , and save energy. However, conservation tillage may increase disease and insect problems.

The Jordan Cooperative Organization , Jordan-Australia Dryland Farming Project (1981-1985) and the University of Jordan , Faculty of Agriculture, are trying to come up with

alternatives to conventional tillage due to its disadvantages (see above) and high cost.

Researchers at the University of Jordan and JCO recommend the following tillage system for small grain production areas : a chisel plowing is recommended 2-4 weeks after harvest, another chiselling during September-October prior to seeding , to a depth of 15 cm ; a sweep plow should be the last implement for seedbed preparation. In a fallow year, sweeps are to be used for weed control during spring (April-May).

The Jordan-Australia Dryland Farming Project (1981-1985) recommended that the primary tillage to be performed during October using a 21-tyne cultivator fitted with 10 cm points in the front three rows and standard 19 cm cultivator shares on the rear two rows. This is necessary to penetrate the hard soil in October, and prepare the seedbed in one operation. This system resulted in reducing seedbed preparation cost by 25%. However, it is necessary to use a heavy spike-toothed harrow to level the ground, break down any clods of soil and remove any previous crop residues.

6-6.3.No-tillage System

No-tillage refers to a method of planting crops in previously unprepared soil by opening a narrow slot,trench,or band only of sufficient width and depth to

obtain proper seed coverage. No other soil preparation is required,and herbicides are used for weed control. Advantages listed for no-till system are:

1- Reduced production cost,
2- Reduced runoff,
3- Less wind and water erosion,
4- Better moisture retention ,and
5- Less soil compaction from machinery.

A summary of the number of field operations in producing a crop by no-till as compared to minimum and conventional tillage systems is shown in Table 6.7 .

No-tillage may result in yield increases as compared with conventional or minimum tillage. Also,there is ample evidence that no-till increases the efficiency of soil moisture storage, however, highly selective and efficient contact herbicides should be used for weed control.

Regardless of the tillage system used in small grains production , the following requirements should be met :

1- No weed growth during the fallow period should be allowed. Weeds should be controlled by either mechanical tillage or herbicides.

2- The plow layer should be loosened and any compact-

Table 6.7 : Number of operations (trips over the field) with conventional, minimum, and no-tillage methods .

Operation	Conventional Tillage	Minimum Tillage	No-Tillage
Plowing	1	1	0
Disking	2 or more	0 or more	0
Planting	1	1 or 0	1
Spraying	0 or more	0 or 1	1
Cultivating	2 or more	1 or 2	0
Harvesting	1	1	1
Local Trips	7 or more	4 or 5	3

ed layers or hardpans should be broken in order to insure infiltration of rainwater.

3- The seedbed should be prepared such that seed can be placed in firm moist soil ; and

4- Sufficient residues must be left on the soil surface .

This system is not in use at the present in Jordan, however,JCO (Personal Communications, 1986) recently introduced seed drills fitted with furrow openers to place small grain seeds directly in place without seedbed preparation. However, if no-till system is to be introduced in Jordan's dryland agriculture, it will be necessary to use herbicides extensively for weed control. Some of the difficulties in introducing the no-till system are :

(i) Lack of suitable herbicides for season-long weed control.

(ii) Residual carry-over of herbicides,

(iii) Difficulty with seeding through hard soil and in residues, if present, and

(iv) In certain areas, there will be greater water loss by runoff and evaporation from untilled soils.

6-7.TILLAGE EFFECTS ON SOIL MOISTURE AND FALLOW EFFICIENCY

There is ample evidence (Greb et al.,1979) indicating that, in the absence of weeds, water storage efficiency during fallow is increased with tillage practices that leave increasing amounts of crop residues on the surface and where less tillage is used. It is obvious that with decreased tillage, more crop residues are maintained on the surface; these residues enhance water conservation by reducing runoff and evaporation losses (Papendick, 1984).

Research on tillage as related to soil moisture conservation and fallow efficiency,in dryland agriculture of Jordan, is very limited. Generally, present cropping practices are not conducive to storing more moisture in the soil profile during the fallow year. A number of researchers concluded that a fallow year should be replaced by a forage or a legume crop because of the inefficiency of fallow(Bull et al.,1983;Harvey et al.,1982).

Several researchers (e.g.Hopkinson,1975;Sayimeh and Battikhi ,1985) indicated that minimum soil disturbance, using chisel plows or sweeps, could result in slightly higher moisture content at lower depths (90-100 cm.) in the soil profile. However,in one study ,soil moisture content was almost the same whether the soil was left without tillage or chiselled during the fallow period (NCARTT ,1982).

6-8.CROP RESIDUE MANAGEMENT

A common practice throughout the dryland areas of Jordan is intensive utilization of crop residues during the fallow period by grazing animals. Weeds are usually allowed to grow to supply additional forage along with the crop residues. The intensive grazing practice with animal trampling leaves.the soil surface bare and compacted during much of the fallow period,and highly vulnerable to wind and water erosion. The removal of stubble and weedy fallow is also costly in terms of water loss through increased runoff and evapotranspiration, particularly during the rainy season (Parr et al.,1986).

Wheat and barley grain yields in the dryland farming areas of Jordan are generally low, ranging from 200 kg/ha in low rainfall areas to more than 1000 kg/ha in high rainfall areas. Residue amounts associated with these grain yields are on the order of 300-1500 kg/ha. With these levels of dryland production, essentially all the crop residues would be required during the rainy season for effective water conservation and erosion control.

When crop residues are removed or plowed in before rains occur, evaporation and ,sometimes, runoff are increased and the water lost can significantly decrease the

overall water-use efficiency . Moreover,weed growth for animal feed can be costly in terms of water-use efficiency because most weeds use water inefficiently and produce low-quality forage (Fenster et al., 1965).

The moldboard plow,which is still in use in certain parts of the country, results in virtually no crop residue being left on the soil surface (Table 6.8). Other tillage implements,such as the chisel plow and the sweep, may retain 75-90 % of the crop residue on the soil surface and thus protect the soil against water erosion, retain more soil moisture,and reduce evaporation.

It is expected that chemical and certain mechanical fallow techniques ,if used in dryland farming of Jordan , could conserve more residue and protect the soil from erosion.

Research is needed to establish appropriate crop residue management practices in different regions of the country and for different cropping systems.

6-9.ECONOMICS OF TILLAGE PRACTICES

Tillage practices, as a part of a new technology package, were evaluated and compared with traditional tillage operations used by wheat farmers in Jordan (Schmisseur, 1976). In the new technology package, chisel

Table 6.8 : Crop residues left on soil surface following tillage with indicated implements.

Implement	% Crop Residue Left on Soil Surface
Moldboard Plow	0
One-Way Disc	60
Offset Disc (18-22 inches)	60
Offset Disc (24-26 inches)	50
Chisel Plow	75
Mulch Treader	75--80
Sweeps (30 inches Wide)	90
Rodweeder	90--95
Slot-Planter	100
Till-Planter	80

and furrow operations replaced moldboard and disk plowing. However, in his economic analysis, Schmisseur was not able to attribute a certain portion of the economic return to new tillage equipment. Generally, yield response to the new technology , introduced to Jordan from the Pacific Northwest of the U.S., ranged from 450 to 1190 kg/ha, depending on rainfall and locality.

Arabiat et al.,(1983) conducted a large survey in different wheat producing areas of Jordan. One of their objectives was to estimate the minimum yield increase requirement to pay for adopting a new cultural practice in wheat production. These researchers estimated that a farmer has to produce 135-217 kg/ha more than his current production, using the traditional methods of tillage,in order to meet the extra cost.

6-10.RESEARCH NEEDS

The dryland farming systems which developed around the Mediterranean over more than 2000 years were based on a delicate balance between crop and livestock systems,tree crops and rangelands, and cereals and grazed fallow. This balance is being disturbed by rapid growth of population , soil erosion , extension of cropping areas to the marginal lands and uncontrolled increase of livestock numbers.

Tillage ,as a component of mechanized dryland farming, has contributed to the imbalance of the cropping system in Jordan and other countries in the Mediterranean basin. Conventional tillage, used by farmers , should be studied as to timing , objectives , costs ,and implements . Experiments should be initiated to evaluate the effects of each tillage operation on the following : soil moisture , erosion control, weed control , sequence of tillage implements and its effects on weed control and weed population, and crop residues left on the soil surface following tillage.

Research is needed to develop conservation tillage systems for the major soil types throughout the country . Basic information is needed on tillage effects on soil properties that control infiltration and evaporation , in order to increase soil moisture storage and water use efficiencies .

Information is needed on how to manage crop residues under minimum or no-tillage systems if these new systems are to be adopted in certain dryland farming areas of the country . New and improved practices need to be developed for weed control, planting, and for fertilizer application.

Also, more efficient herbicides , including pre-emergence ones , should be introduced and tested under local

conditions. These herbicides should be highly specific, not affecting subsequent crops in the crop rotation. Improved equipment for drilling seeds in stubble are needed, these drills should be able to operate in heavy stubble and produce a uniform stand.

Obviously,a large number of variables are to be studied simultaneously to develop a sound tillage system for the major dryland farming areas in the country . A team of researchers is needed to plan and carry out a research program in order to develop a widely applicable , practical, and functional tillage system. Due to the complexity of this kind of research , the use of computerized simulation models will be absolutely essential.

6-11.SUMMARY

Mechanized farming in the dryland cropping areas of Jordan was characterized, until recently , by intensive tillage and the use of heavy disk and moldboard plows. This picture is changing as the Jordanian Cooperative Organization is introducing new implements for conservation and minimum tillage . Chisel plows and sweeps are replacing the moldboard plow at a steady rate. Limited research has been done to identify proper tillage implements, number and

timing of tillage operations. New tillage practices such as conservation and minimum tillage are being evaluated . These tillage systems have demonstrated ,under similar environmental conditions,great potential for controlling soil erosion and increasing the intake and storage of water in the soil profile. The adoption of a conservation tillage system will involve several factors such as : crop residue management, the effect of different crops and crop rotations on stubble cover, the efficient use of appropriate tillage equipment and the extensive use of herbicides.

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CULTURAL PRACTICES

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CULTURAL PRACTICES

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7-1. INTRODUCTION

In dryland farming, cultural practices include all activities carried out by farmers in the process of crop production. Under semiarid conditions , these practices have been developed on the basis that soil moisture is the main factor limiting production.

One of the widespread practices that has evolved in Mediterranean climates is summer fallow. Fallow efficiency under dryland conditions in Jordan, is very low (10%) compared to its efficiency in the Great Plains of the U.S . In the Great Plains, efficiency ranges from 19-33%, the highest being associated with the use of stubble mulch , minimum tillage , and the use of herbicides for weed control(Greb et al., 1970) .

Under the relatively similar environmental conditions of the Great Plains(Smika,1970),cultural practices have also

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been built around the practice of summer fallow. In dryland farming,summer fallow has proved to be a necessary, and economically sound practice.

The concept and importance of fallow are not thoroughly understood in Jordan. The low yields of major crops in the country, discussed later in this chapter, are due in part to the traditional cultural practices used by farmers and to the low efficiency of the fallow system (Loizides, 1979).

The following cultural practices will be discussed in this chapter: seedbed preparation, seeding methods , seeding dates,seeding rates, and seeding depth. Other cultural practices,i.e.,tillage,crop rotations, weed control,and fertilization, will be discussed in separate chapters. The concept and practice of fallow will be dealt with elsewhere in this monograph .

7-2.SEEDBED PREPARATION

Under limited soil moisture conditions,seedbed preparation methods should conserve moisture. Water is the major factor limiting production and successful cropping practices make efficient use of it while conserving soil and water resources (Smika, 1983). Dryland tillage practices, before and during seedbed preparation , are designed to conserve the maximum amount of soil moisture in the root zone during the fallow period for use by the next crop .

Bolton (1983) pointed out that a proper seedbed is necessary for crop establishment at the optimum time, and for the efficient use of a limited water supply. This concept has rarely been practiced in Jordan except for experimental purposes.

The earliest documented results on tillage operations and seedbed preparation in Jordan were reported by Hopkinson (1973,1974) and Winters (1976). The established implements, at those times, were disk plows and one-way disk harrows.

Except where the land was fallowed, wheat farmers used to broadcast and plow in the seed in one operation. In a wheat-fallow system, the initial tillage operation can be performed any time during the summer or early fall. This tillage operation is usually for weed control. Although tilling should be done only to control weeds, Jordanian farmers perform 4-6 tillage operations during this period. Consequently, at seeding time, wheat and barley are planted primarily on clean fallow land (Babb, 1976).

A package of practices was introduced into the wheat growing regions of Jordan from the Pacific Northwest of the U.S. (Goetze, 1976). The tillage component of that package was modified to suit local Jordanian conditions(Winters, 1976) . A comparison between the traditional cropping sequence followed in a fallow-wheat rotation in Jordan ,

and the introduced package is presented in Table 7.1 . It was suggested that the initial tillage operation should be performed in mid-April at a shallow (7-13 cm) depth. A second spring tillage operation might be needed to completely kill weeds and to reduce evaporation. Summer tillage should be performed at a shallow (5-8 cm) depth and only when necessary to control weeds. This limits moisture loss from the tilled soil .

For Jordanian conditions,Harvey et al.,(1982) and Bull et al.,(1983 , 1984) recommended that the initial cultivation be done with a cultivator and a secondary cultivation with heavy spike-toothed harrow. The latter implement was recommended to level the ground, break down any large clods of soil and remove any residues. A final cultivation is performed with the seeding operation using a seed drill fitted with standard 8-cm shares to kill germinated weeds.

7-3.SOWING METHODS

Two methods are common in Jordan for the seeding of small grain crops: broadcasting and drilling. Broadcasting is done mostly by hand, and then the seed is covered by a tillage implement.· Almost all barley and most wheat acreage is broadcasted (Tamimi,1981). Broadcasting can be done in soils too wet for a drill (JCCIP, 1984). However, if sowing is done when there is not enough water close to the

Table 7.1 : Cropping operations sequences in a fallow-crop rotation in the Pacific Northwest of the U.S. and Jordan .

Time	Field Operation or Condition
1- Fallow-Wheat (<350 mm) in the Pacific Northwest*	
July	Harvest grain
Early September	Fall chisel
September to mid-April	Uncultivated wheat stubble
Mid-April	Initial tillage
Mid-April to Mid September	Cultivate fallow
Mid- to Late-September	Plant grains
Late September to Late June	Growth of crop
2- Fallow-Wheat (350 mm) in Jordan	
June	Harvest grain
September - October	Initial tillage
Early April	Second tillage
Late April to Early November	2-3 Tillage operations
Mid - November	Tillage + plant grain
Mid - November -- Late June	Growth of crop

* : Bolton , 1983 .

soil surface to ensure seedling establishment, the seed should be placed at a proper depth so that light showers will not cause germination .

Seed drills are becoming more available and an increasing number of farmers are using them after realizing the advantages of seed drilling (JCO,1986 personal communication). However, farmers did not accept seed drills as easily as they accepted mechanical tillage and combine harvesting.

De Brichambaut(1969)listed the following reasons for the slow acceptance of seed drilling by farmers:

(i) size and shape of holdings,
(ii) high cost of using the machine, and
(iii) insufficient research results to convince farmers of the benefits of seed drills.

Drilling the seed has been shown to produce a more uniform stand with less weed problems and less lodging than broadcasting (JCCIP, 1984).

Wheat and barley are generally drilled to a depth of 5-8 cm with a row width of 25-30 cm. However, it was suggested that narrower rows would provide ground cover faster , facilitating weed control(Duwayri ,1979).

The earliest research in seed drills was reported by Hopkinson (1975). He noted that seed drilling resulted in

Table 7.2 : Effect of different methods of seeding on wheat yield (kg/ha) in Karak district (Hopkinson , 1975).

Seeding Method	Row Spacing (cm)	Plants/m^2	Wheat Yield (kg/ha)
Deere Press Drill HZ.	35	108	1362
Deere Press Drill LZ.	25	90	1133
End Wheel Drill	25	106	1170
Broadcasting	--	68	1153
S.E.			94

better stand establishment,more uniform wheat populations and higher yields (Table 7.2).

Seed drilling and broadcasting methods were compared, over five growing seasons, as components of a package of practices in different agroclimatological zones of Jordan (JCCIP,1984). The highest yields were obtained in regions receiving more than 300 mm of annual rainfall when seed was drilled and proper amounts of nitrogen and phosphorus fertilizers were applied. However, yields were comparable in areas receiving less than 300 mm of annual rainfall whether broadcasting or seed drilling was used (Table 7.3).

7-4.SOWING DATE

Sowing date ensures a proper stand establishment and is one of the most important factors affecting crop yield under dryland conditions in Jordan (Jaradat, 1979) . Sowing date is the actual time seeds are placed in the soil, but this definition does not include time of emergence, crown root development or tillering,all of which must occur before a crop stand is established (Bolton, 1983).

Optimum sowing date and stand establishment may have a considerable effect on economic yield by ensuring that the growth of the crop is adjusted to the available soil moisture (Stewart,1988) .

Table 7.3 : Mean grain yield (kg/ha) for two seeding methods in each of three agroclimatological zones,(JCCIP,1984).

Location	Crop	Rainfall(mm)	Broadcast	Drill
Bushra/Irbid	Wheat	>350	2029	2219*
Alqasr/Karak	Wheat	250-350	959	806
Mushaqar/Madaba	Barley	<250	230	319

* : Significant at 5% level of probability

7-4.1.Wheat and Barley

Farmers,practicing dryland agriculture in Jordan and other countries of the Near East Region,learned by trial and error that seeding small grains before sufficient rain is received is very risky (Tamimi, 1981). With light early showers, seeds may germinate in the absence of sufficient moisture and dry out. However, to delay seeding until enough moisture is stored in the soil profile to ensure germination and seedling growth leads to yield reductions (Jaradat,1979; Duwayri ,1979).

Numerous field experiments have been carried out in the major crop-producing regions of Jordan to identify optimum seeding dates of wheat, barley, lentils and chickpeas. Several researchers have been involved in this research(e.g. Hopkinson,1975 ; Turk,1981;Humied,1982 and Haddad, 1984).

Hopkinson (1975), working with wheat in Karak district, found a marked yield reduction due to delayed seeding . A delay in seeding date from December to February affected most yield components with a large reduction observed in number of seeds/spike , and number of spikelets /spike . The number of fertile florets/spikelet was not significantly affected (Jaradat, 1979).

A series of seeding date experiments at three

locations differing in annual rainfall were conducted to advise farmers on proper seeding dates for their regions (NCARTT,1980;1981;1982). Results of these experiments, over several growing seasons and across locations, indicate that seeding before the onset of rain at a depth of 6-8 cm resulted in higher yields (Table 7.4).

The Jordan Cooperative Cereals Improvement Project (1984) conducted a number of field experiments and demonstrations over five growing seasons in order to develop a package of practices appropriate to different agroclimatological zones in Jordan. Results of these experiments and demonstrations showed that early seeding (i.e., before rain) was consistently better than late seeding as a part of an improved package of practices (Table 7.5). Early seeding can result in a poor stand establishment if early showers are not sufficient to sustain proper germination and early seedling growth . Therefore, it is highly recommended that seed be placed at a depth of 6-8 cm to ensure that only heavy rains will germinate the seed (see Chapter 10 on Response Farming , in this monograph for an alternative approach) .

Al-Rajoub (1983) reported the effects of early (December) and late (February) sowing dates on yield and other agronomic characteristics of eight promising barley varieties grown at Ramtha Agricultural Research Station and

Table 7.4 : Effect of seeding dates and depths at three stations in Jordan on grain yield (kg/ha) of wheat (JCCIP , 1984).

Station	Seeding Date	Seeding Depth (cm)		
		5	8	Mean
RAMTHA 79/80	Before Rain 6/11/79	1066.7	1266.7	1166.7
	After Rain 5/1/80	1650.0	1458.3	1554.2
Mean		1358.3	1362.5	
RABBAH 79/80	Before Rain	1394.4	1433.3	1418.9
	After Rain	322.2	222.2	272.2
Mean		858.3	827.8	
RABBAH 81/82	Before Rain 1/11/81	1391.9	1223.0	1307.4
	After Rain 9/1/82	973.0	932.4	952.7
Mean		1182.4	1077.7	
MARU 1981	Before Rain 4/11/81	2527.8	2972.2	2750.0
	After Rain 29/12/81	1694.4	1791.7	1743.1
Mean		2111.1	2382.0	

Table 7.5: Effect of planting date on mean grain yield (kg/ha) averaged across nine sites in zone A, six sites in zone B , and two sites in zone C , 1980/81.

ZONES	Planting Dates		L S D
	Early*	Late**	
(A) >350 mm	2390	2060	100
(B) >250 mm	2310	1390	150
(C) <250 mm	1320	1380	370

* : before rain.

** : after sufficient rain.

Hisban. For two successive growing seasons, early sowing resulted in increases in biological, grain, and straw yields of 27%, 23% and 29%, respectively, over late sowing .

7-4.2.Lentils and Chickpeas

Legume crops (e.g. , lentils and chickpeas) are planted in Jordan and neighbouring countries in the Mediterranean basin during the spring season (Hawtin and Singh, 1984). Farmers usually plant the wheat crop first, then the lentils. They prefer to seed the lentils after the first few rains and the germination of winter weeds; by doing so, farmers ensure a weed-free seedbed (Haddad, 1983a).

Haddad and Arabiat (1985) surveyed cultural practices for growing lentils in Jordan. They found that most farmers (~80 %) plant lentils during the period from late December to early February. Sowing is done by hand broadcasting with seeding rates ranging from 50-200 kg/ha; higher seeding rates were associated with higher rainfall.

Saxena and Hawtin (1980) found that winter - planted legumes accumulated more dry matter than those planted in spring. In winter sowing,the rate of dry matter accumulation was slow during the first 100 days after sowing, then it started to increase linearly with time. The substantial yield advantage of early over late planting is due, in part, to the extended period of vegetative growth which slightly

increases the seed filling period (Table 7.6) (Humeid, 1982).

In a detailed study, Haddad(1983 b)recommended a sowing date for lentils from late October to mid-December. His results indicated that earlier planting gave 100% more grain and straw yield than late planting (e.g. January).

Chickpeas are usually planted during the spring season to escape the Ascochyta blight which occurs during winter planting (Hawtin and Singh, 1984). It has been possible to shift the sowing date of chickpeas to an earlier date (early winter) due to the availability of Ascohyta blight-resistant varieties (Saxena,1979;Hawtin and Singh,1984). Soub (1984) showed that early-planted introductions of chickpeas (i.e. in December) gave 160 % and 223% more grain than chickpeas planted in February or March, respectively. Also, he noted that winter-planted chickpeas were 6-10 cm taller than the spring-planted chickpeas. This increase in height has the benefit of facilitating mechanical harvesting (Saxena and Hawtin,1980). These results were in agreement with findings reported by Haddad(1983a).

7-5.SOWING RATE

Optimum sowing rate, which results in a good stand establishment, varies for different environments. In areas with limited moisture, plant population can substantially

Table 7.6 : Effect of seeding rates and time of planting on grain yield (kg/ha) of lentils grown at Jubeiha during 1980/82 (Humied, 1982).

Time		Seeding Rate (kg/ha)		
Year	Month	40	80	120
1980/81	Nov.	1387	1278	1525
	Jan.	1450	1301	1382
	Feb.	1641	1296	1494
1981/82	Nov.	2951	3145	4757
	Jan.	3535	3368	3918
	Feb.	2271	2036	1861

influence water use efficiency and subsequent grain yield if seeding rate is adequate (Harper, 1961). Adjustments in seeding rate and row spacing have been used for two reasons (Arnon , 1972) :

(i) To provide ground cover for erosion control, and

(ii) To create increased competition between crops and weeds.

However,optimum seeding rates for these purposes might not optimize grain yield.

7-5.1.Wheat and Barley

Hopkinson (1975) tested a number of wheat varieties for optimum seeding rate at six locations in southern Jordan and noted that the results were not very conclusive. Seeding rates of 60, 80, and 90 kg/ha gave grain yields of 1215,1248, and 1357 kg/ha, respectively. Duwayri (1980) studied the effect of different seeding rates on grain and straw yield of Stork 's' durum wheat. He found that when seeding rate was increased from 80 to 130 kg/ha , grain and straw yields increased significantly from 1543 to 1814 kg/ha for grain , and from 2511 to 3027 kg/ha, for straw yield .

Turk (1981) investigated the effects of seed size and seeding rate on wheat yield and yield components. There were no significant differences in grain yield between 100 and 150 kg/ha seeding rates at two dryland research stations

over two growing seasons. However, both seeding rates differed significantly from 50 kg/ha (Table 7.7). In the same study, Turk found that large- and medium-size seeds yielded significantly higher than small-size seeds.

Research conducted at a number of agricultural research stations (NCARTT, 1977-1984) indicated that during years of below average rainfall ,yields from seeding rates of 80, 100, and 120 kg/ha did not differ significantly from one another. However, results obtained by JCCIP (1984) showed that seeding rates should be specific for the variety as well as the method and date of seeding. Seeding rates in the range of 100-140 kg/ha gave the highest grain yields with high-yielding varieties under favorable environments. Perhaps a rate of 100 kg/ha would be the optimum for high-yielding environments but this should be determined through economic studies. However , when broadcasting the seed, a seeding rate of 80-100 kg/ha is recommended .

7-5.2.Lentils and Chickpeas

In a field survey covering 50 villages in four different regions of Jordan, 109 farmers were asked what cultural practices they followed in growing lentils (Haddad and Arabiat ,1985). The results of that survey indicated that seeding rates ranged from 50-200 kg/ha according to

Table 7.7 : Effect of cultivar, seeding rates, seed size,location, and growing season on grain yield of wheat (kg/ha) (Turk ,1981).

Treatment		Jubeiha 1978/79	Jubeiha 1979/80	Hisban 1979/80	Average
Cultivar	DA2	1523a*	1530a	11517a	1523
	Stork	1494b	1767b	1767b	1667
Seeding Rates (kg/ha)	50	1337b	1358b	1317b	1337
	100	1633a	1740a	1729a	1701
	150	1561a	1840a	1834a	1745
Seed Size	Large	1592a	1734a	1708a	1678
	Medium	1572a	1662b	1667a	1634
	Small	1367b	1542c	1504b	1471

* : Numbers followed the same letter are not significantly different (DNMRT , P = 0.05).

the region and annual rainfall, with an average of 113 kg/ha. Higher seeding rates were associated with higher annual rainfall. The regression equation, expressing the relationship between seeding rate and yield was calculated as :

$$Y = 555 + 16 X ,$$

where Y is the expected yield and X is seeding rate in kg/ha. It is obvious that as seeding rate increases, within the range used by farmers, yield increases , especially with higher rainfall.

In a detailed study of the effect of planting date and seeding rate on the growth and development of lentils, Humeid (1982) found that doubling the seeding rate from 40 to 80 kg/ha resulted in a yield increase of 1.48 kg of seed/ha for each kg of seed . Increasing the seeding rate from 80 to 120 kg/ha resulted in a yield increase of 4.35 kg of seed/ha for each kg of seed . Humeid concluded that a seeding rate of 120 kg/ha was optimal for higher rainfall areas (e.g. Jubeiha) and a seeding rate of 80 kg/ha was optimal for low rainfall areas such as Ramtha.

Plant density (i.e.,plants /m^2) was found to affect biological and grain yield of lentils.A row spacing of 25-30 cm is recommended for higher yields (Lale et al., 1976). In northern Syria with rainfall exceeding 300 mm, Saxena (1981) found that a combination of narrow row spacing (15-20 cm)

and high seeding rate (120 kg/ha) resulted in the highest grain and straw yield. However,when rainfall was low(240 mm) wider row spacing (30 cm) resulted in the highest grain and straw yields.

Under favorable environmental conditions and early planting of lentils, Haddad (1983a) found that a density of 333 plants /m^2,which corresponds to a seeding rate of 150 kg/ha, resulted in the highest grain and biological yields. However,it was noticed that increased yield at high plant density(333 plants /m^2) was due to more plants per unit area and not to increased yield per plant (Table 7.8).

Optimum seeding rate and plant density of chickpeas were investigated by Haddad (1983b). He found that plant densities ranging from 25 to 33 plants /m^2, equivalent to seeding rates of 90 to 120 kg/ha,(Table 7.9), were optimal for dry matter production and grain yield under Jubeiha conditions.

Generally, seeding rate should be adjusted for genotype, location and sowing date. Genotypes with compact and upright growth habits responded positively to increased plant density, whereas spreading types showed smaller yield responses to increased plant population or seeding rate (Saxena, 1979a).

Under dryland conditions, optimum plant populations and seeding rates for cereals and legumes appear to depend

Table 7.8 : Effect of plant population on the grain and biological yield of Jordan local lentils at Jubeiha 1979/81 (Haddad ,1983 a).

Plant Population	Grain Yield (kg/ha)		Grain Yield (kg/ha)	
	1979/80	1980/81	1979/80	1980/81
333 plants/m^2	1530a*	1231a	4724a	4239a
222 plants/m^2	1289b	849c	4268ab	2795b
133 plants/m^2	1410ab	988b	4084b	2806b
122 plants/m^2	1268b	888bc	3998b	2580b
% C.V.	16	10	16	18

* : Numbers followed by the same letters are not significantly different (DNMRT , P = 0.05).

Table 7.9 : Effect of plant population on grain and straw yield of Jordan local chickpea grown at Jubeiha,1979/81(Haddad, 1983b).

Plant Population	Grain Yield (kg/ha)		Straw Yield (kg/ha)	
	1979/80	1980/81	1979/80	1980/81
33 plants/m^2	1055a*	1473a	1501a	2510a
25 plants/m^2	952ab	1574a	1164b	2112ab
20 plants/m^2	898b	1370a	1098bc	1899b
17 plants/m^2	841b	1410a	987c	1864b

* : Numbers followed by the same letter are not significantly different (DNMRT , P = 0.05).

largely on moisture supply during the growing season (Saxena,1979b).

7-6.SOWING DEPTH

Sowing depth has a marked effect on seedling emergence and stand establishment,especially under dryland conditions. In low rainfall regions , stand establishment is adversely affected by low moisture in the top soil layer at sowing time and yield potential is reduced (Hadjichristodoulou , 1979).

The broadcasting of small grain seeds and the subsequent tillage operation to cover them , result in placing the seed at varying depths across the field. As a result, seed germination, seedling emergence and stand establishment will not be uniform or optimal. With modern seed drills, it is possible to control sowing depth to ensure a proper stand establishment by placing the seed in moist soil (Zou'bi, 1985).

El-Quhaiwi (1979) investigated the effects of three sowing depths (2, 4 and 8 cm) on the yield of local wheat and barley varieties. His results showed consistently higher grain yields with deep (8 cm) sowing.

Sowing depth was the subject of several research projects at the Faculty of Agriculture, University of

Jordan. Al-Rajoub (1983), for example, studied the effect of sowing date and depth on yield and yield components of 8 barley varieties. For three locations and two growing seasons, deep sowing (8-10 cm) showed significant yield increase over shallow (2-4 cm) sowing depths . Sowing depth seemed to affect some yield components, but no significant differences were detected. However, increased yields in plots sown at a depth of 8-10 cm were related to the number of seedlings /m^2, number of days to 75 % heading and number of days to maturity (Table 7.10).

Generally, local wheat landraces and cultivars can emerge from deeper (10-12 cm) sowing depths due to their longer coleoptiles. In contrast, modern, semidwarf varieties fail to emerge if sown deeper than 5-6 cm due to their shorter coleoptiles (Jaradat, 1979).

7-7. RESEARCH NEEDS

The uncertainty of rainfall and its effects on stand establishment and harvestable yield are uncontrollable factors in Jordanian dryland agriculture. Research on response farming and seasonal forecasts of the probability of rainfall are highly needed to determine the type and timing of certain key cultural practices .

If no-till or minimum tillage are to be introduced into Jordanian dryland farming on a large scale , it will be

Table 7.10: Effect of sowing depth on number of emerged seedlings/m^2, number of days from emergnce to 75% heading, of days from heading to maturity, and number of days from emergence to maturity of wheat (Al-Rajoub, 1983).

Sowing Depth (cm)	No.of Emerged Seedlings/ m^2	No.of Days from Emergence to 75% Heading	No.of Days from Head to Maturity	No.of Days from Emergence to Maturity
2--4	181.0a*	80.8a	73.36b	116.47a
8-10	185.0a	71.1b	38.69a	109.80b

* : Numbers followed by the same letter are not significantly different (DNMRT , P = 0.05).

necessary to study their effects on soil microclimate and or cultural practices such as seeding methods , seeding rates and crop sequence in the crop rotation . Also , the need will arise to introduce and test improved and economical herbicides for better weed control,especially grassy weeds, under local conditions .

More research is necessary to establish site- and environment-specific recommendations for the cultural practices discussed in this chapter.

7-8.SUMMARY

Traditional cultural practices have been modified , and new practices have been developed for the major field crops in the dryland farming regions of Jordan .

Tillage practices for seedbed preparation were developed and tested in farmers' fields. One such practice is minimum soil disturbance during the fallow period while retaining the crop residues on the soil surface.

Recommendations for sowing dates , rates , depths and sowing methods were developed for major field crops . Farmers were encouraged to adopt a newly developed package of practices for wheat and barley production and efforts are underway to develop a similar package of practices to

improve the productivity and increase the production of legume crops .

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CROP ROTATIONS

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CROP ROTATIONS

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8-1. INTRODUCTION

The more or less regular changing of crops on a given piece of land has been practiced by farmers for many years. This practice has come to be called crop rotation (Metcalf and Elkins,1980). Farmers and researchers realized that the continuous or too-frequent growing of one crop results in the rapid breakdown of organic matter and leaves the soil bare and exposed to water and wind erosion. The loss of organic matter also reduces the water-absorbing and water-holding capacity of the soil(Boersma and Jackson , 1977).

The influence of crop rotations on crop yield has been reported from most of the experiment stations around the world (see:ICARDA,1982, for a review).

Some of the advantages usually listed for crop rotations are:

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1- Soil nitrogen and organic matter can be increased as a result of including a legume in the crop rotation.

2- Plant diseases , insects and weeds can be more easily controlled.

3- The presence of a growing crop reduces soil erosion and minimizes losses of nutrients by leaching.

4- Greater yields per unit area may be obtained.

Research on crop rotations in the rainfed areas of Jordan has been rather limited . The main purpose of this research has been to develop alternatives to the fallow system which is practiced by many farmers in the major rainfed areas of the country.

Traditional agriculture in the rainfed areas of the country is characterized by a heavy reliance on low inputs and a fallow system. Farmers in these areas believe that fallow increases soil fertility , reduces weeds and most importantly, stores moisture (Tamimi, 1981)

The area in Jordan planted to crops varies from year to year due to the fallow system and varying climatic conditions (Watkins et al., 1983). The largest area to be planted in any one year was about 500,000 ha , while the

average area planted during the period 1970-1980 was 340,000 ha (Department of Statistics' Yearbook,1981). Field crops occupy 80 % of that area, while vegetables and fruit trees occupy 10 % each. Wheat is the major field crop, followed by barley, lentils and chickpeas(AOAD, 1977).

8-2.TRADITIONAL CROP ROTATIONS

Farmers in the dryland farming regions of Jordan traditionally followed a 2-year or a 3-year crop rotation . In the northeastern region , where annual rainfall is below 250 mm, farmers practice a barley-fallow crop rotation.

In areas of more than 350 mm of annual rainfall,a 2-year or a 3-year rotation is followed. In these areas, a legume crop is a major component in the crop rotation. Recently , however,less area has been planted to legumes in the rainfed regions of Jordan because of the unavailability of suitable combines for harvesting the legume crop and the necessity of carrying out this operation by hand, which is costly and time consuming. Examples of typical crop rotations in the semiarid zone(350-500 mm of annual rainfall) are : wheat - legume crop (lentils , chickpeas or vetch); fallow-wheat;and summer crop(e.g.summer vegetables, tobacco) - wheat.

A 3-year crop rotation is practiced when annual rainfall exceeds 400 mm . Examples of such rotations

are:legume crop - wheat - summer crop ; or fallow - wheat - summer crop . A summary of traditional crop rotations in different agroecological zones of Jordan appears in Table 8.1 .

8-3.PAST RESEARCH ON CROP ROTATIONS

As mentioned previously , research on crop rotations in the dryland farming regions of the country has been rather limited. One of the major reasons for this is that experiments on crop rotations require long periods of time . For example, in a 2-year crop rotation,it is necessary to collect data for 4 - 6 years in order to obtain reasonable results and give practical recommendations to farmers. Longer periods of time are needed where variability of annual rainfall is high.

Early experiments by Loizides (1975) indicated that even with an average rainfall of 300 - 350 mm , wheat yields from crops grown after fallow were slightly lower than wheat yield after vetch , but higher than its yield in a continuous wheat rotation . Similar results were obtained at Ezraa Dryland Research Station in southern Syria , with an annual rainfall of 308 mm . Results obtained under similar environmental and edaphic conditions clearly indicate that even with 300 mm of annual rainfall , the present crop rotations of wheat-fallow or wheat-summer crop - fallow

Table 8.1 : Examples of crop rotations practiced in different agroecological zones of Jordan's dryland area .

Zone	Rainfall (mm)	Crop Rotation
Arid	< 200	No Crop Rotation
Marginal	250 - 300	Wheat -- Fallow
		Barley -- Fallow
Semiarid	300 - 500	Summer Crop -- Wheat
		Legume Crop -- Wheat
		Fallow -- Wheat
Semihumid	500 - 800	Fallow - Wheat - Summer crop
		Legume - Wheat - Summer crop

can become more profitable by replacing the fallow period with a legume crop .

A number of crop rotation experiments have been initiated(NCRATT, 1981 , 1982 & 1983) to determine the best rotation and crop sequence for the major wheat and barley growing areas of the country. Other objectives were :

(i) To evaluate the effect of different crop rotations on wheat yield ,

(ii) To evaluate the fallow system and the possibility of replacing it with legume crops, and

(iii) To assess the effect of these crop rotations on soil fertility and soil moisture status.

A list of these crop rotations is presented in Table 8.2 . Preliminary results (Table 8.3) show that the fallow system is not profitable under the experimental conditions , and that yearly cropping is possible and is economically feasible. The results also show that some economic crops can be reintroduced into the dryland farming regions of the country,providing necessary forage for livestock(Watkins et al.,1984).

8-4.CURRENT RESEARCH ON CROP ROTATIONS

Research on crop rotations at the Faculty of

Table 8.2 : A list of 10 different crop rotations (Traditional and alternatives) being tested at Mushagar Dryland Research Station.

Crop Rotation
Wheat (F) ---------- Wheat (F)
Wheat (NF) ---------- Wheat (NF)
Wheat ---------- Lentil
Wheat ---------- Fallow
Wheat ---------- Medic*
Wheat ---------- Barley(green fodder)
Wheat ---------- Barley + Vetch(mixture)
Wheat ---------- Sesame* (summer crop)
Wheat ---------- Okra (summer crop)
Wheat ---------- Sorghum

NF : No Fertilizers added.
F : Fertilizers added.
* : New Crop.

Table 8.3 : Wheat yield (kg/ha) as influenced by the preceeding crop in 10 different crop rotations at Mushagar Dryland Research Station.

Preceeding Crop	Yield (kg/ha)
NF Wheat	1787.0
F Wheat	2748.0
Fallow	2849.5
Lentils	2243.8
Medic	1790.8
Barley (green)	2659.5
Barley + Vetch (green)	2906.5
Sesame	2567.8
Okra	2527.3
Sorghum	1885.0

Agriculture , University of Jordan and the Jordan-Australia Dryland Farming Project was also aimed at developing alternatives to the fallow system which is practiced in most dryland farming regions of the country. Another objective of this research was to study the interaction of N and P fertilizers with the different crops in the crop rotation and their effects on soil moisture status and fallow efficiency.

Preliminary results (Abu Alen,1986; Gharaibeh,1986, unpublished data;Masri, personal communication,1986) indicate that a fallow year can be replaced by a legume crop in the crop rotation. Moreover , these researchers stressed the importance of adding necessary amounts of N and P fertilizers to the legume crop so that yield of the subsequent wheat crop is improved.

The Jordan-Australia Dryland Farming Project(Harvey et al.,1982;Bull et al.,1983,1984) is studying introduced fodder legumes from Australia. General observations (1981/1982 season)indicated that vetch,locally known as bekia,is a suitable fodder crop in a wheat-legume crop rotation,especially in the low rainfall zones of the country. During the 1982/1983 growing season , wheat after a legume in the Madaba area,outyielded wheat after fallow by 50-100 percent (Bull et al.,1983).

It was concluded ,from results of the previously cited

work and discussions with workers in this field ,that yields of wheat after lentils and chickpeas are somewhat lower than after fallow or forage . The differences are small,however, and the high value of the legume grain more than compensates for the slight reduction in cereal grain yield. On the other hand , yields of wheat or barley grown after legume forage are , as a rule , higher than after fallow . In moderate to high rainfall regions , yields of legume forage are also very high. Therefore , a crop rotation combining cereals with legumes would raise wheat production and at the same time provide valuable fodder badly needed in the country for the development of animal husbandry.

8-5.PROPOSED CROP ROTATIONS

Watkins et al.(1983) remarked that the Jordanian agricultural outlook, at the present , appears to be similar to that of Australia at the turn of the century. The Australian dryland farming system during the early 1900s followed a wheat-fallow rotation. However, declining wheat yields,increased soil erosion and the economics of wheat production forced farmers to shift to a wheat-legume system .

In Jordan, a fallow - wheat or a fallow - wheat - summer crop rotation is practiced throughout the dryland farming regions of the country. This practice is associated

with the problems of reduced soil fertility , decreasing wheat yields and increasing soil erosion (Haddad , 1983). The inclusion of a legume phase , in the present crop rotations, was suggested by Harvey et al. (1982) . The proposed crop rotations are expcted to increase soil fertility through the release of nitrogen in soils predominantly deficient in this element. Also , cereal productivity is expected to improve , and forage production could lead to increased animal production in the country (Harvey et al., 1982) . Furthermore, Watkins et al. (1983) emphasized the importance of using a legume phase in the crop rotation. They argued that the use of the legume phase will remove the fallow period between wheat crops. However, these researchers indicated that a short winter fallow is undoubtedly necessary for the production of a summer crop , although it is questionable whether a summer fallow conserves moisture through the summer period for the following winter crop.

The Jordan Australia Dryland Farming Project is evaluating a number of legume species to be included in the proposed crop rotations (see below). The legume phase could include self-seeding medic species , vetch , lentils or chickpeas.

8-6.RELATING LAND CAPABILITY CLASSES AND CROP ROTATIONS

The land capability classification system (USDA,1961)

was used by Watkins et al. (1983) to suggest alternative crop rotations in relation to land capability classes in Jordan.

For land classes I and II (see:Chapter 4, Soil and Water Conservation for more detailes),which are relatively flat ,well-structured with nonrocky and moderately deep soils, a cereal-legume-winter fallow-summer crop rotation is suggested.

For land classes III ,IV and V , with more limitations, a cereal-legume crop rotation is suggested,except where slopes are more than 15 %. Fruit trees are suggested as another alternative in the above mentioned land classes. Finally land classes VI-VIII are limited to forestry , grazing or natural pastures.

Watkins et al. (1983) presented possible crop rotations with calendar perspectives for the arid (200 - 350 mm annual rainfall) and semiarid (350 - 500 mm annual rainfall) parts of the country (Table 8.4). These researchers also presented alternative 2-year and 3-year crop rotations according to land class and annual rainfall (Table 8.5 .

8-7.THE FALLOW SYSTEM

Fallowing is a common practice in the dryland farming regions of the world. It involves leaving the land without a

Table 8.4 : Recommended crop rotations for different land capability classes and climatic zones, in Jordan .

Land class	Year No.	Rainfall(mm)	Crop rotation 1	Crop rotation 2
I	1	>500	Wheat	Wheat
	2		Legume	Legume
	3			Summer Crop
I	1	300-500	Wheat	Wheat
	2		Legume	Legume
	3			Summer Crop
I	1	200-300	Wheat	
	2		Fodder Crop Hay (Vetch)	
II	1	>500	Wheat	Wheat
	2		Legume	Legume
	3			Summer Crop
II	1	300-500	Wheat	Wheat
	2		Legume	Legume
			Summer Crop	
II	1	200-300	Wheat	
		Fodder Crop Hay (Vetch)		
III	1	>500	Wheat	
	2		Legume	
III	1	300-500	Wheat	
	2		Legume	
III	1	200-300	Natural Pasture	
IV	1	>500	Grape Vineyards	
IV	1	300-500	Olive Plantations	
IV	1	200-300	Natural Pasture	
V	1	>500	Olive Plantations**	
			Grape Vineyards#	
V	1	<500	Natural Pasture	

** : <800 m elevation.
# : >800 m elevation.

Table 8.5 : Crop zoning proposals based on land cabability sub-classes per agroclimatic zone.

Land Class	Rainfall Zones			
	Semihumid >500 mm	Semiarid 300-500	Marginal 200-300	Arid <200 mm
I	Wheat Grain Legume Summer Crop Horticulture	Wheat Grain Legume Summer Crop Horticulture	Wheat or Barley Sown Pasture (Vetch)	Natural Pasture
II	Wheat Grain Legume Summer Crop Horticulture	Wheat Grain Legume Summer Crop Horticulture	Wheat or Barley Sown Pasture (Vetch)	Natural Pasture
III	Wheat Grain Legume Horticulture	Wheat Grain Legume Horticulture	Wheat or Barley Sown Pasture (Vetch)	Natural Pasture
IV	Horticulture Grape,Olive	Horticulture Olive,Grape, Figs & Apricots	Olive(Pistachios) Horticulture Natural Pasture	Natural Pasture
V	Forestry Grazing Horticulture Grape,Olive	Forestry Grazing Horticulture Peaches, Figs & Apricots	Pasture/ Forestry	Natural Pasture
VI	Forest Grazing	Forest Grazing	Pasture/ Forestry	Natural Pasture
VII	Forest Pasture	Forest Pasture	Natural Pasture	Natural Pasture
VIII	Forest	Forest	Natural Pasture	Natural Pasture

crop for one or more growing seasons at regular intervals. However, the value of fallow has been questioned during the last three decades in many countries (see : Wright, 1977 , for a review).

The benefits of fallow vary with different soils and climates , but include improved moisture storage , increased mineralization of soil nitrogen , weed control and better seedbed conditions.

In the semiarid regions of Jordan , Syria and Lebanon , fallow is generally practiced where annual rainfall is less than 350 mm . Fallowed lands are often grazed with little effect on moisture conservation (Bakhtri , 1981).

Tamimi (1981) estimated that 50 % of the rainfed area in Jordan is left fallow every year.The area of fallow in Jordan is inflated by the inclusion of lands cropped at irregular intervals in the marginal zones , receiving 200-250 mm of annual rainfall. In addition, the extent of fallow varies from one year to another and varies among regions within the country. In the Irbid area where small farms predominate , fallow does not exceed 30 % of the total area under annual crops ; in the South, it amounts to more than 50 % . This system involves the use of maximum tillage or conventional bare fallow . Although both fallow types kill weeds , they also destroy all stubble and pulverize the

surface soil making moisture conservation very difficult (Boersma and Jackson , 1977).

8-7.1.Fallow Efficiency

Much work has been done on the role of fallow in the cereal-fallow rotation in countries with Mediterranean climates. However, very limited research has been carried out in Jordan to determine the value of fallow and its efficiency.

In general , fallow efficiency is very low in areas with less than 300 mm of annual rainfall . The main reasons for this low efficiency are (Tamimi , 1981):

(i) The current season's rainfall seldom penetrates below 70 - 90 cm in the soil profile making moisture conservation very difficult , and

(ii) Traditional cultural practices are not ideal for conserving soil moisture under the prevailing environmental conditions.

Nevertheless , optimum fallow cultivation practices have indicated that improved moisture conservation is possible . It can be achieved through the development of a uniform soil mulch which reduces evaporation from the soil during summer months (ICARDA , 1982).

Experience from the Pacific Northwest of the U.S. showed that it was possible to increase fallow efficiency (percent precipitation stored in the soil profile)from a low of 15 - 25 % to about 40 - 50 % . More precipitation can be conserved in the soil profile during the fallow period through better methods of weed control , crop residue management and the use of conservation tillage (Greb et al, 1979).

A package of practices which was tested in central parts of Turkey (Mann,1977;Wright,1977) showed successful results in increasing fallow efficiency and wheat yields. This package is composed of timely sowing;proper plant population per unit area ;varietal selection ;early spring tillage ;a combination of stubble-mulching and chemical weed control during the fallow period ; summer rodweeding ; and appropriate nitrogen fertilization .

8-7.2.Moisture Conservation Under Fallow in Jordan

8-7.2.1.Theoretical Background

In the Amman region, Hopkinson (1975) noted that in years of average precipitation, mean rainfall is higher than crop evapotranspiration for the period November to February. In the Irbid region , this was true for the period from November to March. Crop evapotranspiration exceeds mean rainfall , in both regions , as of March or April, and the

wheat crop has to rely for a large part of its requirements on soil moisture stored in the root zone.

The depth of the root zone may be taken as 80 - 90 cm for the heavy soils in Irbid , Madaba and Karak . Such soils have a field capacity of 53 % or more and a permanent wilting point of 27-28 % on a per volume basis. In soils of a rather lighter texture such as those of Ramtha , the corresponding figures will be slightly lower , 46 % for field capacity and 25 % for permanent wilting point . Consequently, the available moisture storage capacity to a depth of 90 cm over a short period of time would be 230 mm for clay soils and 190 mm for clay loam soils. However, actual determinations of available water stored in the root zone at Ezzra Dryland Agricultural Research Station, which resembles areas around Irbid , were not higher than 130 mm (Loizides, 1975). Also, the amount of soil moisture at the onset of rapid growth of wheat (i.e., March) at Ezzra, was essentially the same whether wheat was grown after fallow , lentils or vetch cut green for forage.

The amount of soil moisture at the beginning of rapid growth in wheat (i.e. March) has a marked effect on its yield potential . At sowing , the top soil (10-15 cm) would be well below permanent wilting point and the 15-30 cm soil layer is close to permanent wilting point. Seed germination and seedling establishment under these conditions and

without sufficient early rain , would be severely affected irrespective of any available soil water stored below the seed zone.

8-7.2.2.Experimental Results

Generally speaking , fallow efficiency in storing more moisture in the soil profile is very low in areas receiving less than 300 mm of annual rainfall(Tamimi , 1981) . In order to quantify fallow efficiency under dryland conditions in Jordan, some researchers were monitoring soil moisture status either by using neutron probes (Saimeh , 1983 ; Fardous , 1986) or by gravimetric methods (Abu Aien ,1986; Gharaibeh unpublished data, 1986; Masri, personal communication , 1986) .

Saimeh (1983) , studying a fallow - wheat rotation in northern Jordan over two seasons, found that the amount of precipitation stored in the soil profile during the fallow year depends on the soil series and total amount of rainfall. The percent rainfall stored during one season , when the amount of annual rainfall was 741.5 mm , ranged from 14 to 25.5 % . In another season , when the amount of rainfall was 427 mm , it ranged from 17.5 to 34 % .

In a field which was left fallow for two consecutive years , Saimeh (1983) found that soil moisture at the end of the second year was not significantly different from its

value at the end of the first year , although it was a little higher .

Fardous (1986), on the other hand , emphasized the importance of rainfall distribution as a major factor in determining the amount of precipitation stored during the fallow period. He demonstrated an increase in stored moisture of about 30 % as a result of better rainfall distribution . Moreover , he demonstrated the importance of P fertilization in increasing water use efficiency in a fallow - barley rotation at Ramtha Dryland Research Station (Table 8.6).

Hopkinson (1975) showed that it was possible to conserve up to 80 mm of moisture to a depth of 100 cm in fallow plots in the Karak region . However, Abu Aien (1986) recorded up to 60 mm of soil moisture stored at the end of the fallow period in a clay loam soil at Ramtha Dryland Research Station . Fallow efficiency , calculated from data presented by Abu Aien (1986) and by Gharaibeh (1986) , was relatively low under traditional cultural practices and never exceeded 20 % . However , fallow efficiencies under the same conditions but using minimum tillage and chemical weed control were higher and approached 35 % in both studies .

8-7.3.Advantages and Disadvantages of Fallow

The practice of summer fallow has been controversial ,

Table 8.6 : Water use efficiency (WUE) as influenced by P fertilizers in a fallow-barley crop rotation at Ramtha Dryland Agricultural Research Station.

P (kg/ha)	Growing Season	Yield (kg/ha)	WUE (kg/ha/mm)
00.0	1983/1984	1430.0	0.56
	1984/1985	1650.0	0.71
60..	1983/1984	1698.0	0.76
	1984/1985	1721.0	0.76
80.0	1983/1984	1773.0	0.91
	1984/1985	1553.0	0.72

even before the turn of the century. Willis et al.(1983) listed the following advantages of fallow:

(i) Greater yield per planted hectare ,

(ii) More stable production because of higher soil water content and higher levels of available nitrogen,and

(iii) Better weed control .

However, Black and Siddoway (1976) argued that fallowing resulted in increased wind and water erosion , greater decline in soil fertility , low soil water storage efficiency and low precipitation use efficiency .

Preliminary research results in Jordan (e.g., Abu Aien, 1986) indicated that summer fallow in areas receiving less than 300 mm of annual rainfall is not recommended . However, more research is needed to identify proper cultural practices and crop sequences , in the proposed crop rotations , in order to efficiently utilize available soil moisture.

In any case , and in spite of population pressure, fallow is likely to be practiced for a long time and to remain one of the controversial issues in dryland farming regions of Jordan . However, it is obvious that systematic measurements and experiments in the main rainfed regions and on representative soils are essential to solving the fallow issue.

8-8.LEY FARMING

The ley farming system involves planting annual forage legumes in rotation with wheat as a substitute for fallowing. The suitable legume species have the property of seed dormancy for one or more years (Bakhtri, 1977; 1981). Wheat can be rotated with the self-regenerating legume species and this operation can be repeated for a number of cycles.

The development and the wide spread application of the ley farming system in Australia during the 1930s resulted in a 50 percent increase of wheat yield , doubled the number of sheep and quadrupled wool production in South Australia (Cocks ,1980) . The success of the ley farming system depends on a number of factors such as management , selection of the suitable legume species and variety , and on environmental factors .

Leeuwrik (1975) suggested that the system is feasible on at least 3 million hectares in the 350 - 500 mm rainfall zones in Morocco , Algeria , Tunisia , Syria , Jordan , Lebanon and Iraq. He estimated that this would add about 174,000 tons of nitrogen annually to the soils of the first six countries and an additional 1.74 million tons of cereals

could be produced. It would also provide about 11.6 million tons of dry matter as animal feed.

The medic-wheat rotation is being tested with encouraging results in Jordan . Other countries in the region have already achieved good results with the extended use of this rotation (Bakhtri , 1981).

Bakhtri (1977) presented valuable information on this system and later (1981) reviewed the results of introducing it in North African and Middle Eastern countries. Some of his results were :

(i) Improvement of soil structure and fertility,
(ii) Reduced erosion ,
(iii) Weed control , and
(iv) More livestock and wheat production .

Jordan and other countries in the region are testing different varieties of medic , as a part of the ley farming system . Preliminary results in some of these countries are promising (Bakhtri, 1981) .

Watkins et al. (1983) suggested , in their final report,that the ley farming system could be introduced, on a large scale , in Jordan's dryland agriculture after suitable legume species and varieties have been selected and proper management practices were developed. However,these researchers indicated that the medic-wheat rotation , as it was

developed in Australia , will not be applicable in Jordan and will need some modifications to suit the local socio-economic and agricultural conditions .

8-9.RESEARCH NEEDS

An enormous amount of research work has been carried out on crop rotations and cropping systems in the Mediterranean regions of the world . However , the amount and quality of research which has been done in Jordan , was limited and not adequate . Much needs to be known about local farming systems and their individual components in different agro-ecological zones of the country. To make a proper choice of crops in the crop rotation and in relation to land capability classes, much more local research is needed.

The concept and practice of fallow , its role in storing moisture and its efficiency should be researched more thoroughly. Land use should be intensified by replacing fallow with grain legumes and/or fodder crops , by fertilization based on soil testing and experimental results and by improved cultural practices. The cereal-fallow system is inadequate for the integration of livestock and crop production . Further research is needed to delineate rainfall areas in which fallow should not be practiced. This objective is one of particular significance to agriculture in this country.

A move from a wheat-fallow system to a low-input , stable dryland agriculture based on ley farming is feasible in Jordan ; the adoption of this system could improve soil fertility , increase grain yields and livestock production . However , this system must be modified to suit local socio-economic and agricultural conditions in the country.

8-10.SUMMARY

Traditional crop rotations in the dryland farming regions of Jordan are limited to grain cereal-fallow with the inclusion of a legume or summer crop where annual rainfall is higher than 350 mm .

Fallow is generally practiced where annual rainfall is less than 350 mm . Fallow efficiency in storing moisture in the soil profile is very low , especially where traditional cultural practices are used.

Research on crop rotations , crop sequence and the fallow system is very limited . Long-term field experiments on representative soils and in different agroecological zones are recommended . A project of this nature has been suggested and will be sponsored by ACSAD .

The ley farming system has been introduced in Jordan with encouraging preliminary results . However , if this system is to be adopted widely by farmers , there will be a

need to modify it so that it fits the local socioeconomic and agricultural conditions in the country .

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WEED CONTROL

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9-1. INTRODUCTION

Until 20 years ago ,weed control in Jordanian rain-fed agriculture was limited to mechanical and cultural methods. With the advent of herbicides, however , chemical weed control became possible and resulted in better weed control and increased crop yields (Tamimi,1981; Duwayri and Saghir, 1983).

Hand weeding used to be one of the mechanical methods for weed control, however, this practice was abandoned because it was no longer economical.

Tillage practices, and to some extent, crop rotations are among the cultural practices which are still in use for weed control in Jordan.

Weed species which infest fields of economic crops in Jordan are numerous(see Appendix I).

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Both broadleaved and grassy weeds cause losses in soil moisture and , consequently , crop yields (Abu-Irmaileh, 1982). Although it was estimated that problem weeds could reduce wheat yield by 30-80 % (Duwayri and Saghir , 1983), very limited research has been done on weed control , especially in the rainfed areas of the country .

9-2.WEED COMPETITION

Weeds are prime users of soil moisture. Winter annual weeds are of most concern in rainfed farming areas of Jordan because their growth requirements, physiology and seed production are similar to those of wheat and barley.

Rainfed agriculture, especially in the Near East, is characterized by limited soil moisture and nutrient supply (Tamimi,1981). Under these conditions, weeds compete strongly with field crops because of their vigorous growth habit; weeds are usually characterized by root systems which are often more extensive than those of crop plants.

Weeds growing at anytime in the land may transpire large quantities of water which would otherwise be available for crop production (Hopkinson and Haddad, 1974).

9-3.WEED CONTROL METHODS

9-3.1.Mechanical and Cultural Weed Control

Traditionally, weed control in dryland farming systems has been achieved through tillage, crop rotations and hand

weeding. Hand weeding and tillage operations were the only available alternatives for weed control in Jordan until about 20 years ago (Duwayri and Saghir,1983). However, hand weeding, which supplemented tillage operations in wheat fields, is no longer economical (Haldorson, 1974;Arabiat et al.,1983).

Some farmers, in the rainfed regions of Jordan, practice delayed tillage during the fallow year to provide grazing material for their animals (Saghir,1977). In addition, the use of improper tillage implements has resulted in poor weed control (Lanzendorfer, 1985). Both practices cause the loss of soil moisture and allow weeds to drop their mature seeds, thus increasing future weed populations

One of the primary objectives of the Wheat Research Project in Jordan (Winters, 1976) was to ascertain which cultural practices , or combination thereof , can be used for effective weed control in wheat producing areas. Spring tillage during the fallow period was identified as an effective cultural practice to control weed growth and reduce moisture loss through evapotranspiration. The resulting increased wheat yields were attributed to an early removal of weeds and to decreased losses of the limited soil moisture (Table 6.1) .

Tillage implements which have been used for weed control

during early spring to late summer, include rodweeders and one-way disk harrows (Hopkinson, 1974). Recently, there has been a move towards minimum and conservation tillage (Bull et al.,1983). As a result,it is expected that a change in weed populations will be observed in rainfed areas; a change in timing and/or frequency of tillage might be necessary for optimal weed control.

Two of the objectives of fallow ,as it is practiced by farmers , are to reduce weed populations and conserve moisture (Tamimi,1981). Fallow efficiency and its role in weed control are dealt with elsewhere in this monograph.

Certain cultural practices can be used successfully for weed control,especially in years with early fall rains. Cultivation and seeding can be delayed until after weeds have germinated. However,in years with late fall rains, this practice usually results in late planting dates and lower crop yields. One of the widespread practices farmers use is to plant lentils after the first few rains and the germination of winter weeds; by doing so, they ensure a weed-free seedbed (Haddad, 1983).

9-3.2.Chemical Weed Control

During the past 2-3 decades, the development and availability of effective herbicides and application methods have made it possible and practical for farmers in rainfed

regions of the country to use chemicals for weed control.

The use of herbicides as substitutes for tillage or hand weeding is actually limited (Duwayri and Saghir,1983; Qasim,1982). An estimated 16% of the wheat area in Jordan is sprayed with herbicides, mainly 2,4-D . Weeds in most of the remaining area are checked by cultural practices and a small area is hand-weeded (Arabiat et al., 1982; Anonymous, 1982).

9-3.3.Chemical Control of Grassy Weeds

Wild oat (Avena spp.) is the most important grassy weed in rainfed agriculture in the country. It is a serious problem in wheat fields,especially in the northern part of Jordan (Anonymous, 1982). The following characteristics make this plant a competitive weed:

(i) Early maturity and shedding of seeds;

(ii) Seed dormancy;

(iii) Large number of seeds produced per plant; and

(iv) Long viability of buried seed.

Wild oat originated in Central Asia and has moved to wherever small grains are grown in the world. The major species of wild oat that infest cultivated crops in Jordan are : Avena sterilis, A. longiglumes, A. hirtula, A. weistii, A. barbata and A. clauda (Kanan and Jaradat, 1988

in preparation).

Before the development of efficient herbicides to control wild oat in wheat fields, delayed seeding of wheat, fall tillage after the first few rains and summer fallow were the only cultural practices that helped reduce wild oat populations (Hopkinson, 1975; Haldorson, 1976).

Wild oat , a grassy weed, and wild mustard , a broad-leaf weed, are the most vigorous competitors in wheat fields in Jordan (Abu-Irmaileh, 1982; Duwayri and Saghir, 1983). Fifty plants/m^2 of wild oat reduced wheat yield by 11% when compared to a control treatment with a preemergence application of triallate. When 92 plants/m^2 of wild oat were allowed to grow in the experimental plots, a further reduction of wheat yield was observed in spite of a postemergence treatment with triallate (Table 9.1) (Duwayri and Saghir, 1983).

Wild oat becomes more competitive with wheat as fertility improves(Nalewaga and Arnold ,1970). On summer-fallow land fertilized with ammonium phosphate, 12 to 48 wild oat plants/m^2 significantly reduced wheat yield. However, when wheat was not fertilized, 84 to 120 plants/m^2 were needed to reduce wheat yield significantly .

Several herbicides have been tested for their effectiveness in the control of wild oat. Triallate (Avadex BW) was one of the most promising herbicides used for that

Table 9.1 : The effect of the application of different rates of triallate on wild oat control and yield of wheat grown in Irbid 1976/77.

Rate kg/ha (a.i.)	Pre-Emergence		Post-Emergence	
	Yield kg/ha	No. of Oat panicles/m	Yield kg/ha	No. of Oat panicles/m
Control	18.8	50	16.7	92
1.0	18.9	27	16.7	57
1.5	18.4	24	18.1	32
2.0	19.7	19	19.7	29
Average	18.9	30	17.8	50

purpose (Duwayri and Saghir , 1983).

However, Abu-Irmaileh (1982) reported that Illoxan and IPC were the best herbicides he used for wild oat control. Both herbicides resulted in good control of the weed and higher wheat yields.

Triallate was used as a preemergence and postemergence herbicide in wheat fields. Its effect on reducing wild oat populations and increasing wheat yield was very pronounced, particulary in the preemergence application at a rate of 2 kg/ha (a.i.) (Duwayri and Saghir, 1983).

To achieve wild oat control and crop selectivity, it was recommended that triallate should be incorporated in the top 2.5 cm of soil and wheat should be planted at a lower depth than herbicide was incorporated.

Disk drills, which are used for wheat seeding in Jordan, might not place wheat seeds at a proper depth and injury to wheat might occur (Hopkinson,1975;JCCIP,1984). Hoe and shovel drills place seeds deep enough so that injury could be avoided.

More selective herbicides, than triallate, have been developed. For example, Kirkland and Ashford (1976) listed a number of the newly developed and highly selective herbicides for wild oat control. One of these herbicides is

diclofop, which was reported to be more effective than trial-late. Todd and Stobbe (1977) reported that wild oat was 190 times more sensitive to diclofop than wheat, and that this herbicide resulted in better wild oat control.

Grassy weeds and volunteer wheat and barley plants in lentil and chickpea crops are usually hand-weeded. Recently, a number of herbicides have been introduced and tested by the Legume Improvement Program (Haddad,1986 a,b). These herbicides were effective in controlling grassy weeds in some , but not in all , experiments. The same herbicides were tested earlier by workers at the International Center for Agricultural Research in Dry Areas (ICARDA) with promising results. However, they are expensive to use in a subsistance farming system . Two of the most promising herbicides for grassy weeds are :

1- Fusilade : This is a postemergence herbicide . It can be used at a rate of 1-2 liters (a.i.)/ha according to the intensity of the weed infestation and weed composition.

2- Pronamide : This is a preemergence herbicide. It can be sprayed after sowing of the legume crop at a rate of 500 - 750 g.(a.i.)/ha.

9-3.4.Chemical Control of Broadleaved Weeds

Chemical weed control of broadleaved weeds in Jordan,

dates back to the early 1970s . The herbicide 2,4-D was the first to be introduced into Jordan's rainfed areas for the control of the broadleaved weeds (Goetze, 1976; Qasim and Abu-Irmaileh, 1983). The recommendations which were developed at that time (Goetze, 1976) were as follows:

"It is very important to remove the weed competition as early as possible. Spraying of 2,4-D , for the proper control of broadleaved weeds, should be done when the wheat has reached 15-20 cm in height and most of the weeds have germinated. Spraying of 2,4-D should never be done after wheat is in the boot stage or earlier than when it is 15 cm in height. The use of seed drills, for sowing wheat, is highly recommended, as it results in a uniform wheat stand which facilitates the spraying operation and results in better weed control."

These recommendations were specific for the use of the amine formulation but not the sodium salt or the ester formulations of 2,4-D under rainfed conditions in Jordan.

More recently, researchers working with JCCIP (JCCIP, 1984), reported on broadleaf weed control using 2,4-D . Based on experiments carried out over a period of five seasons, the herbicide 2,4-D was found to increase wheat yield significantly. The favorable effect of the herbicide was enhanced in experiments carried out on fallowed land

which was well-managed (Table 9.2).

It has been reported (Qasim and Abu-Irmaileh, 1983) that 2,4-D is not effective in controlling all species of broadleaf weeds. One of the noxious weeds which can not be controlled by 2,4-D is Syrian sage (Salvia syriaca L.). This weed is an important one, especially in the central wheat growing region of Jordan. Its chemical control and competitive effects have been studied thoroughly by Qasim (1982) and by Qasim and Abu-Irmaileh (1983). These researchers reported that reductions in wheat grain yield due to Syrian sage range from 59% to 78%. The higher yield reduction was encountered in areas of low rainfall. Application of the herbicide MCPA, at a rate of 1 kg/ha (a.i), resulted in complete control of the sage and in the highest wheat yields .

Other researchers (Duwayri and Saghir, 1983) found that the two herbicides brominal and brominal plus, at 1.5-2 L/ha, controlled broadleaf weeds effectively in wheat fields. As a result, grain yield was increased by 25-43 % over the unweeded control.

The chemical control of broadleaf weeds in fields of legume crops is still experimental. Some of the newly introduced and tested herbicides are :

Table 9.2 : Mean grain yields (kg/ha) for herbicide treatments, at 3 locations in zone A (>350 mm annual rainfall). In Jordan.

Treatment	Location			
	Emrawa	Marrow	Taibeh	Mean
Unsprayed	1536	1320	2418	1757
Sprayed	1518	1942	2860	2099
Mean	1527	1631	2639	1928

LSD (5%) for treatment Means = 88.

1- Cyanazine : This is a preemergence herbicide which should be applied at 500-750 g(a.i)/ha in lentil and chickpea fields.

2- Methabenzthiazuron: Also known as Tribunil,this is a pre-emergence herbicide which can be used at a rate of 1500 to 2000 g(a.i.)/ha.

3- Prometryne : Known as Gezagard, this is a preemergence herbicide which can be used at a rate of 1500 g(a.i.)/ha.

9-3.5 Trends and Economics of Weed Control

Arabiat et al.(1983), in a survey covering the major wheat growing regions of the country ,concluded that there has been an increase in adopting chemical weed control. They observed an increase of 7% to 26% in herbicide application in 1980. They explained this increase in usage on the basis of the substantial increase in the cost of hand weeding. An earlier report by the same researchers (Arabiat et al, 1982) showed that the cost of herbicide application was J.D. 5.22/ha while hand weeding cost was J.D. 20.47/ha.

Herbicide application is done mainly by JCO and to a lesser extent by custom services (Oglah, 1984).

In his survey, Oglah (1984) identified some problems

in using herbicides for weed control. The major ones were : the use of inadequate amounts of herbicides /unit area ; and spraying without using a mixer in the tank. Oglah concluded that in order to avoid errors and to encourage the use of herbicides for weed control, demonstrations should be conducted in all wheat producing areas to show farmers the proper dosage ,suitable time and method of application.

The efficiency of the sprayers used by JCO for herbicide application is satisfactory in large, well-managed fields. However,the efficiency of these sprayers is limited in small fields characterized by rough and stony conditions (JCO, 1986 Personal communication).

9-4. ALLELOPATHY AND CROP TOLERANCE TO HERBICIDES

Weeds vary in their ability to compete with major field crops. Under Jordanian conditions, wild oat, wild mustard and Syrian sage are much more vigorous competitors than other weeds. On the other hand, wheat varieties also differ in their ability to compete with weeds; the dwarf and semidwarf wheat varieties are less competitve with weeds than the taller varieties (Duwayri and Saghir, 1983).

Syrian sage ,for example, reduced wheat grain yield by

59% and 78% at two locations in central Jordan (Qasim and Abu-Irmaileh,1983). Data presented by these researchers showed that this weed competed more effectively with stressed crops. Qasim and Abu-Irmaileh (1985) also demonstrated that Syrian sage has strong allelopathic effects on wheat. Weed remnants or an aqueous extract of these resulted in delayed seed germination and poor seedling development of the wheat crop. In another study , Abu-Irmaileh and Qasim (1986) showed that the aqueous extract of Syrian sage caused a reduction in seed germination of barley, wheat, chickpeas and lentils. The lentils were the least affected by this allelopathic effect.

9-5. RESEARCH NEEDS

There has been a steady increase in the use of herbicides for weed control in rainfed agricultural areas of Jordan. This increase in use is expected to continue , if conservation or no-tillage systems will be adopted on a large scale. Advantages of such systems are: moisture conservation, reduced erosion and reduced production cost. However, there will be some difficulties to overcome, among which are :

1-Lack of suitable herbicides for season-long weed control; and

2-Residual effects of herbicides .

The need may arise for more efficient herbicides, particularly preemergence ones; these herbicides must be tested under local conditions and proper application rates and methods must be developed and communicated to the farmers. Moreover, these herbicides have to be highly specific , not affecting subsequent crops in the crop rotation .

The introduction of new herbicides will necessitate basic and applied research in relation to climate ,edaphic factors , crop rotations and crop plants.

The steady increase in the use of a particular herbicide (e.g. 2,4-D) may result in the increase of weed species or biotypes which are resistant to that particular herbicide . The spread of wild oats in Jordan and other countries is one example. This genotypic shift might be overcome by:

1- Crop rotations ;
2- Appropriate cultural practices , especially during the fallow period ; and
3- Herbicide rotation to help prevent the buildup of resistant weeds.

The integration of herbicides with cultural practices (e.g. ,N fertilization) has proved to be one of the most successful practices in rainfed agriculture of Jordan

(JCCIP,1984). Farmers realized that either practice alone (i.e.,the use of herbicides or N fertilization) cannot substitute for the other. Hence, a better understanding of the interaction between chemical weed control and other cultural practices is highly needed.

The integration of chemical weed control with other weed control techniques in rainfed agriculture is essential. Some examples of such integrated practices are : crop rotation,timely tillage,the use of competitive crop cultivars , the use of clean seed ,the use of clean equipment for sowing and harvesting and even hand weeding in areas where weeds are sparse and labor is available.

The limited available information on the costs and benefits of weed control calls for an in-depth cost-benefit analysis of weed control by conventional methods and herbicides.

The exchange of information between specialists in the universities, the National Center for Agricultural Research and Technology Transfer , the Jordan Cooperative Organization and private chemical companies should be encouraged . As new chemicals are introduced to the country, problems such as when to use any particular herbicide or what is the most appropriate application rate for a specific crop , have to be resolved by researchers . Finally , it is

neccessary to study the ecology of weeds in Jordan in order to elucidate at which stages in their life cycles weeds are most vulnerable to chemical or cultural methods of weed control.

9-6.SUMMARY

Problem weeds in the rainfed parts of Jordan are numerous. They compete with major crops for the limited resources of soil moisture and nutrients. Yield losses of major crops due to weed competition may range from 30% to 80%.

Chemical weed control in rainfed agriculture in Jordan, is relatively recent; most farmers use cultural practices and on a limited scale, hand weeding for weed control.

Research on weed ecology ,competition ,allelopathy and control methods is very limited. However, recommendations have been made for the proper timing and application rates of 2,4-D and a few other herbicides.

The need is urgent for more research on the above topics. The rainfed sector is experiencing major changes in cropping systems and cultural practices; these , necessarily, lead to changes in weed populations and intensity of weed competition. Therefore, new strategies, herbicides, and weed control methods, including integrated control methods, have to be developed.

9-7.LITERATURE CITED

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APPENDIX I

No.	English Name	Scientific Name
1.	Goat Grass	Aegilops umbellulata Zhuk
2.	Wide Oat	Avena sterilis L.
3.	Opened(Brome grass)	Bromus squarrosus L.
4.	Downy brome grass	Bromus tectorum L.
5.	Bermuda Grass	Cyndon dactylon (L.) Pers.
6.	Bulbous wild Barley	Hordeum bulbosum L.
7.	Wild Barley	Hordeum liporinum Link
8.	Annual Darnel	Lolium temulentum L.
9.	Short-Spiked Canary	Phalaris brachystachys Link
10.	Bristle-Spiked Canary	phalaris paradoxa L.
11.	Short-Spiked Canary	Phalaris brachystachys Link
12.	Pipe - Vine	Aristolochia maurorum L.
13.	Knot grass	Polygonum aviculare L.
14.	Anabsis	Anabsis syriaca lljin
15.	Forked mouse ear chickweed	Cerastium dicotomum L.
16.	Hairy Soapwort	Gypsophila pilosa Huds
17.	Mountain Knot-grass	Paronychia argentea Lam.
18.	Conoid Catchfly	Silene conoidea L.
19.	Bladder Campion	Silene vulgaris(Moench) Garcke
20.	Common Chickweed	Stellaria media(L.) Vill
21.	Cowherb	Vaccaria pyramidata Medik
22.	Bongardia	Bongardia chrysoganum(L.) Boiss
23.	Lions leaf	Leontice leontopetalum L.
24.	Tall Pheasants Eye	Adonis aestivalis L.
25.	Large Pheasaant Eye	Adonis aleppica Boiss
26.	European Pheasants Eye	Adonis annua L.
27.	Toothed Pheasants Eye	Adonis dentata Del
28.	Corn Butter cup	Ranunculus arvenis L.
29.	Butter cups	Ranunculus millefolius Banks et Sol.
30.	Scarlet Horned Poppy	Glaucium corniculatum(L.)J.H.Rud.
31.	Corn Poppy	Papaver rhoeas l.
32.	Dense-flowered Fumitory	Fumaria densiflorrra DC.
33.	Hypecoum	Hypecoum procumbens L.
34.	Shepherds Purse	Capsella bursa-Pastoris(L.) Medik
35.	White Top/Hoary grass	Cardaria Draba L.
36.	White Rocket	Diplotaxis erucoides(L.) DC.
37.	Pink Mustard	Erucaria hispanica(L.) Druce
38.	Aleppo woad	Isatis lusitanica L.
39.	Stock	Matthiola parviflora(shousb)R. Br.
40.	Ball Mustard	Neslia apiculata Fisch
41.	White Mustard	Sinapis alba L.
42.	Globe Mustard	Texiere glastifolia(DC) Jaub
43.		Torularia torulosa(Desf.)Schulz
44.	Wild Mignonette	Reseda lutea L.
45.	Triangular-podded Milk Vetch	Astragalus boeticus L.
46.	Star Milk Vetch	Astragalus Cruciatus Link
47.	Dwarf Yellow Milk Vetch	Asrragalus hamosus L.
48.	Coronilla	Coronilla scorpioides(L.) Kock

Habitat and Distribution

Cultivated fields in dry hilly areas in Madaba
Cultivated fields in Irbid,Amman,Ajlun, and Madaba
Fields boarders in Hisban,Madaba, and Karak
Fields boarders in Madaba, and Karak
Cultivated fields in Irbid,Ajlun,Jerash,Amman, and Karak
Cultivated fields in the semi- desert areas of the uplands
Cultivated fields in the uplands
Grain fields in Ajlun,Madaba, and Karak
Cultivated fields in Ramtha,Irbid,Jerash,Ruseifa, and Salt
Fields in Ramtha,Irbid,Ajlun, and salt
Fields in Ramtha,Irbid,Rusiefa, and Salt
Cultivated fields in Irbid,Jerash,Ajlun, and Amman
Cultivated fields in Irbid,Ajlun,Amman,Salt,Madaba, and Karak
Cultivated fields in desert areas like Ramtha and Mafraq
Cultivated fields in Irbid,Ajlun,Naor, and Karak
Cultivated fields in Irbid,Ajlun,Amman, and Karak
Irbid and fallow fields in Ajlun,Amman, and Karak
Fields in Irbid,Ajlun,Mafraq,Amman,Madaba, and Karak
Fallow fields in Ajlun and Um- Rumman
Fields in Um- Rumman and salt
Grain fields in Ramtha,Irbid,Ajlun,Jerash,Amman,Madaba, and Karak
Cultivated fields in Ajlun,Amman,Naor,Madaba, and Karak
Cultivated fields in Irbid,Madaba, and Karak
Fields in Ramtha,Irbid,Ajlun, and Amman
Fields in Ramtha,Ajlun,Irbid, and Mafraq
Fallow Fields in Ramtha,Irbid, and Ajlun
Fallow fields in Irbid,Ramtha,Mafraq,Amman, and Karak
Fields in Irbid,Ajlun,Amman,Naor,Madaba, and Karak
Fallow Fields in Irbid,Ajlun,Jerash, and Amman
Fields in Ajlun,Amman,Madaba,Naor
Cultivated and fallow fields in Ramtha,Irbid,Ajlun,Jerash,Amman, Salt,and Madaba
Cultivated fields in Irbid,Ramtha,Jerash,Amman, and salt
Fallow fields in Amman,Naor, and Madaba
Fallow fields in Ajlun,Amman, and Karak
Fields in Ramtha,Irbid,Mafraq,Amman,Madaba, and Karak
Cultivated fields in Ramtha,Irbid,Jerash,Madaba, and Karak
Fallow fields in Ramtha,Irbid,Ajlun,Jerash, and Amman
Cultivated fields in Ramtha,Husha,Mafraq, and Karak
Dry fields and desert areas in Amman, and Karak
Cultivated fields in Ramtha,Irbid,Ajlun,Mafraq,Amman,Madaba, Salt, and Karak
Cultivated fields in Irbid,Ajlun,Jerash,Amman,Salt,Naor,Madaba, Hisban, and Karak
Cultivated fields in Ramtha,Irbid,Mafraq, and Karak
Cultivated fields in desert areas in Ramtha, and Mafraq
Fields in Ramtha,Irbid,Mafraq,Ajlun,Amman, and Madaba
Cultivated fields in Irbid,Ajlun,Amman,Madaba, and Naor
Fallow fields in Irbid,Amman, and Karak
Cultivated fields in Irbid,Ajlun,Amman, and Karak

49.	Horse-Shoe Vetch	Hippocrepis unisiliquosa L.
50.	Circular Medick	Hymenoccarpos circinnatus(L.)Savi.
51.	Yellow Vetchling	Lathyrus aphaca L.
52.	Dwarf Chickling Vetch	Lathyyarus pseudocicera Pamp
53.		Lathyrus gorgonel Parl
54.	Jerusalem Vetchling	Latnyrus hierosolymitanus Boiss
55.	Small-Flowered Vetchling	Lathyrus inconspicuus L.
56.	Flat-podded Medic	Medicago orbicularis(L.) Bart
57.	Toothed Medic	Medicago polymorpha L.
58.	Medic	Medicago Truncatula Gaertn
59.	Two-Flowered Caterpillar	Scorpiurus muricatus L.
60.	Palestine Winged Pea	Tetragonolobus palaestinus Bioss
61.		Trifolium clusii Godr. et Gren.
62.	Arabian Trefoil	Trigonella arabica Del.
63.	Trigonal	Trigonella kotschyl Fenzi ex Boiss
64.	Trigonel	Trigonella moabitica Zoh
65.	Bitter Vetch	Vicia ervilia(L.) Willd
66.	Broad-leaved Vetch	Vicia narbonesis L.
67.	Narrow-leaved purple Vetch	Vicia peregrina L.
68.	Puncture Vine	Tribulus terrestris L.
69.	Croton	Chrozophora tinctoria(L.)AD.Juss.
70.	Aleppo Sprurge	Euphorbia aleppica L.
71.		Euphorbia densa Schrenk
72.	Pletty Spurge	Euphorialis peplus L.
73.	Stemless Hollyhock	Alcea acaulis(cav.)Alef.
74.	Decarrent Water Parsnip	Falcaria vulgaris Bernh
75.	Common Giant Fennel	Ferula communis L.
76.	Ridolfia	Ridolfia segetum(L.)Moris.
77.	Shepherds Needle	Scandix pecten-veneris L.
78.	Egyption Hartwort	Tordylium aegyptiucum(L.)Lam.
79.	Scarlet Pimpernel	Anagallis arvensis L.
80.	Mallow-Leaved Bindweed	Convolvulus althaeoides L.
81.	Field Bindweed	Convolvulus arvensis L.
82.		Convolvulus betonicifolius Mill
83.		Cuscuta brevistyla A. Braun
84.	Strigose Alkanet	Alkanna strigosa Boiss
85.	Alkanet	Anchusa italica Retz
86.	Arabian Primrose	Arnebia decumbens(Vent)Gross et Kral
87.	Judean Vipers-Bugloss	Echium judaeum Laciata
88.	Europian Heliotrope	Heliotrobium europaeum L.
89.	Desert - Spicke	Eremostachys laciniata(L.) Bunge
90.	Great Henbit	Lamium amplexicuale L.
91.	Shell-Flower	Molucclla laevis L.
92.	Syrian Sage	Salvia syriaca L.
93.	Egyptian Henbane	Hyoscyamus reticulatus L.

Fields in Ramtha,Irbid,Ajlun,Jerash,Amman, and Karak
Cultivated Fields in Amman, and Karak
Cultivated fields in Irbid,Ajlun,Salt,Amman, and Karak
Fields in Irbid,Ajlun,Jerash,Salt, and Madaba
Cultivated fields in Ramtha,Ajlun,Amman,Irbid, and Naor
Cultivated fields in Ramtha,Irbid,Ajlun, and Amman
Fallow Fields in Irbid,Amman, and Karak
cultivated fields in Irbid,Amman,Salt,Madaba,Naor, and Karak
Cultivated and fallow fields in Irbid,Ajlun,Amman, and Karak
Cultivated fields in Irbid,Ajlun,Jerash, and Karak
Fallow fields in Irbid,Ajlun,Amman, and Naor
Cultivated fields in Irbid,Ajlun, and Jerash
Cultivated fields in Irbid, and Ajlun
Cultivated Fields in Irbid,Ajlun, and Amman
Cultivated fields in desert areas in Ramtha
Cultivated fields in Ramtha,Irbid,Mafraq, and Jerash
Fields of dry areas in Ramtha,Mafraq, and Karak
Cultivated dry land Wheat in Ramtha,Irbid,Ajlun, and Jerash
Cultivated and fallow fields in Irbid,Jerash, and Amman
Cultivated and fallow fields in Ramtha,Irbid,Ajlun,Jerash,Amman, Salt, and, Mafraq
Cultivated and fallow fields in Salt
Fallow fields in Irbid,Ajlun,Amman,Salt, and Karak
Cultivated Fields among Summer crops in Ramtha,Irbid, and Amman
Fallow Fields in Irbid, and Karak
Cultivated fields in Irbid,Ajlun, and Amman
Fallow fields in Ramtha,Irbid,Jerash,Amman; and salt
Fallow fields in Irbid,Madaba,Hisban,Karak, and Amman
Some cultivated fields and fallow fields in Irbid,Jerash,Amman, Karak, and Salt
Cultivated fields in Irbid,Ajlun,Jerash, and Amman
Fields in Irbid,Ajlun,Amman, and Naor
Fields in Irbid,Ajlun,Jerash,Amman, and Salt
Cultivated and fallow Fields in Irbid,Jerash,Ajlun,Amman,Hisban, Madaba, and Karak
Cultivated and fallow fields in Irbid,Jerash,Ajlun,Amman,Hisban, and Madaba
Cultivated fields in Irbid,Amman,Hisban,Naor, and Karak
Great variety of herbaceous species in cultivated and fallow fields in Irbid,Amman, and Salt
Cultivated fields of Cereals in Jerash,Amman,salt, and Karak
Cultivated and fallow fields in Irbid,Jerash,Ajlun,Amman,salt, Naor,Madaba, and Karak
Fallow fields in Amman, and Salt
Cultivated fields in Irbid,Jerash,Amman, and Karak
Cultivated Vegetable fields in Irbid,Amman, and Ruseifa
Cultivated and fallow fields in Irbid,Jerash,Madaba,Errabbah, and Karak
Cultivated fields in Irbid,Jerash, and Ruseifa
Fields Cultivated by Summer crops in Irbid,Ajlun,Amman,Madaba, Hisban, and Karak
Cultivated fields in Irbid,Amman,Hisban,Madaba,Errabbah,and Karak
Cultivated fields grown to cereals in eastern regions of Irbid,Amman,Madaba, and Karak

94.	Mandrake	Mandragora autumnalis Bertol
95.	Calves-snout/Lesser-snapdragon	Antirrhinum orontium L.
96.	Bears - Breech	Acanthus syriacus Boiss
97.	Bucks - horn Plantain	Plantago coronopus L.
98.	Field Woodruff	Aasperula arvensis L.
99.	Rough - Fruited Bedstraw	Glain tricornutum Dandy
100.	Syrian Cephalaria	Cephalaria syriaca(L.)Schrad
101.	Prolific Scabious	Scabiosa prolifera L.
102.	Squirting Cucumber	Ecballium elaterium(L.)A.Rich.
103.	Strigose Bell Flower	Campanula Strigosa Banks and Sol
104.	Yarrow	Achillea bieberstenii Afan.
105.	Yarrow	Achillea Santolina L.
106.	Palestine Chamomile	Anthemis palestina Reut.
107.		Carthamus nitidus Boiss
108.	Slender Sefflower	Carthamus tenius(Boiss & BL.)Bornm
109.	Iberian Star Thristle	Centaurea iberica Trev.ex Spring
110.	Pale Star Thristle	Centaurea pallescens Del
111.	Corn Marigold	Chrysanthemum segetum L.
112.	Dwarf Chicory	Cichorium pumilum Jacq
113.	Rough Hawkweed	Crepis aspera L.
114.	Cudweed Cotton Rose	Filago pyramidata L.
115.	Old Mans - Beard	Gerapogon hybridus(L.)Sch
116.	Willow - leaved Lettuce	Lactuca saligna L.
117.	Syrian Plumed Thistle	Notobasis syriaca(L.) Cass.
118.	Prickly OX - eye	Pallenis spinosa(L.) Cass
119.		Rhagadiolus stellatus(L.)Willd
120.	Oriental Vipers-Grass	Scorzonere papposa DC
121.	Common Sow Thistle	Sonchus oleraceus L.
122.	Narboneo star of Beitlhem	Ornithogalum narbonense
123.	Flat Pouded Midic	Medicago orbicularis
124.	Jointed Bedstaw	Galium articulatum
125.	Common Vetch	Vicia sativa

Cultivated and fallow fields in Irbid, and Hisban
Cultivated and fallow fields in Irbid, and Karak
Grain fields in Jerash,Amman,Madaba,Hisban, and Karak
Dry fields in Irbid, and Karak
Cultivated fields in Ramtha,Irbid,Jerash,Ajlun,Amman, and Karak
Cultivated fields of Cereals and Lentils In Ramtha,Irbid,Ajlun, Jerash, and Amman
Cultivated and fallow fields in Ramtha,Irbid,Ajlun, and Amman
Fields in Irbid,Ajlun,Jerash, and Salt
Cultivated fields in Irbid, and Amman
Grain fields in Irbid,Ajlun,Jerash,Amman,Naor, and Madaba
Fallow Fields in Irbid,Madaba,Ajlun, and Karak
Fields in Irbid,Amman,Madaba, and Karak
Cultivated fields in Irbid,Jerash,Ajlun,Amman,Naor, and Salt
Fallow fields in Ajlun,Amman,Madaba, and Karak
Fields in Ajlun,Amman, and Karak
Field in Irbid, and Amman
Fields in Irbid,Ramtha,Ruseifa,Amman,Salt, and Madaba
Fields in Irbid,Ajlun,Jerash, and Amman
Fields in Irbid,Jerash,Amman, and Salt
Fields in Irbid,Ajlun,Jerash,Amman,Salt, and Karak
Fallow fields in Ajlun, and Amman
Fields in Irbid,Ajlun,Jerash,Amman, and Madaba
Fields in Irbid, and Amman
Fields in Irbid,Ajlun,Jerash, and Salt
Fallow fields in Irbid,Jerash,Ajlun, and Salt
Fallow fields in Irbid,Ajlun,Jerash,Amman,Madaba, and Karak
Fields and hilly areas in Irbid,Ajlun, and Amman
Fields in Irbid,Ajlun,Jerash, and Amman
Fields in Salt area
Fields in Irbid, and Ajlun area
Fields in Irbid, and Um-Qies area
Fields in Irbid, and Ajlun arae

RESPONSE FARMING

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RESPONSE FARMING

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10-1.INTRODUCTION

Crop yields and economic returns in the rainfed sector of Jordan are, generally speaking, limited by water. However , extreme rainfall variability from one year to the next, rather than rainfall amount per se, is the greater part of the problem. The practical meaning of the variability is that any single fixed farming system which one might devise will be poorly suited to the actual water supply in a majority of cropping seasons. A flexible farming system is needed in which crop input levels, such as seed rates and fertilizer application rates, herbicides and pesticides maximize yields or economic returns per unit of available water.

Published in:A. Jaradat (ed): An Assessment of Research Needs and Priorities for Rainfed Agriculture in Jordan.

It has been demonstrated (Stewart, 1986) that there is sufficient predictability in Mediterranean rainfall, including rainfall in Jordan , to make the needed flexible farming system a reality. The indicator of rainfall amount and duration through the approaching rainy season is the date of onset.

Mediterranean rainfall records show clearly, with a statistical significance at the 1% level, that total annual rainfall, and rainfall during the wheat growing season, both decline in actual rainfall amount and duration with later onset of the rainy period. In practical terms, this means a farmer faces a markedly different set of rainfall probabilities if the rain begins in November than if it begins in December or later. The record shows that each period when onset might occur carries with it a range of possible rainfall occurrences, but the range for each period is greatly narrowed over that one sees when considering the entire rainfall record. A narrowed range of possible rainfall amounts and durations means easier and more accurate decision-making by the farmer.

"Response Farming" is a term used by the author to describe a flexible farming system based on a rainfall forecast followed by an appropriate agronomic response. The rainfall forecast is that described above. The response lies in the decisions the farmer then makes about how he will

operate in the upcoming season to make best use of the expected water supply. It should be noted that the response farming method has as much applicability in animal production systems as in cropping, and in irrigated as well as rainfed agriculture. However, the focus of this paper is on rainfed crop production.

The response a farmer makes to a given rainfall forecast may affect many aspects of his operation, for example, preplant tillage. Pending wet conditions may dictate sloping cultivation to facilitate runoff of excess water for avoidance of waterlogging the crop or even soil erosion. On the other hand, a forecast of dry or moderately moist conditions would call for flat tillage to assure retention of all rainfall in place.

Early onset, suggesting a long rainy season with relatively higher total rainfall would call for emphasis on longer season crops/varieties with higher water requirements and greater value in the market place, because production for the market, in addition to subsistence, would be anticipated. This higher production level should be supported by higher input levels, including (often) higher seed rates for increased plant populations, higher nitrogen fertilizer applications plus associated nutrients as called for, herbicide and pesticide use as required to protect the

enhanced production, arrangement for augmented harvesting, storing and marketing assistance, and other factors as applicable.

Late onset, suggesting a short rainy period with relatively low rainfall amount, would suggest much different decisions, often the opposite of those above. In many cases in Jordan it will be shown that late onset may call for switching crops altogether. It will also be shown that Jordanian farmers, particularly those in the cropping areas with lower rainfall, say 250-300 mm mean annual rainfall,are already aware of the implications of late onset of the rains,and do respond to it with reduced planted acreage, changes in crop types and perhaps other measures.They may be less aware of the good implications of early onset of the rains and how they might profit from increased input levels, in those years.

This paper deals with both rainfall forecasting and the response aspects of response farming. Published meteorological and crop yield data from Jordan are used to illustrate how this approach might work for farmers in the lower rainfall zones of Amman and Irbid Governorates.

For this illustration, the data mentioned have been used to develop water production functions which show real historical relationships between crop yields and rainfall in

the study areas of Jordan. This is done for seven crops which are wheat, barley, chickpea, lentil, vetch, tobacco and olive. As might be imagined, these relationships which are drawn from both rough and limited data,are only presented as illustrative. The purpose is twofold : 1) to suggest the nature of the very real benefits to be gained from the response farming approach, and 2) to encourge the establishment of a research program to develop water production functions and related transferable equations in Jordan. The usefulness of the latter is also illustrated in this paper by introducing transferable information on wheat-water relationships developed in research at the University of California at Davis.

10-2.JORDANIAN RAINFALL CHARACTERISTICS AND PREDICTABILITY IN RELATION TO WHEAT PRODUCTION

The study area in this paper is the northern Jordanian Highlands from Balqa Governorate in the north through Irbid Governorate into the portion of Amman Governorate around and just south of the city of Amman.Mean annual rainfall is high in Balqa (560 mm) and in Ajlun District (543-599 mm) in the northwest of Irbid Governorate. Rainfall is moderately high in Kura (402-490 mm), Irbid (455-481 mm) and Jerash (444 mm) Districts of Irbid Governate, then fairly low in the Ramtha/Rihab areas (219-263 mm) of southeast Irbid and in Amman (278 mm). Some of the discussion will cover all of

these areas but most will focus on rainfall up to 400 mm.

Scatter diagrams which relate total annual rainfall to the actual dates the rains effectively began for wheat production (date of onset) in each of 31 years of common record at sites in Morocco, Cyprus and Jordan are presented in Stewart (1986). There is a west-east transect across the Mediterranean which indicates that onset may occur anytime in a period of several months, and that each day that onset is delayed reduces the amount of rainfall to be expected in the season as well as the duration of the rainy period. Details of the history of this phenomenon as it relates to rainfall in the wheat production season in Jordan are shown in Figure 10.1 .

Mean annual rainfall at Amman over the period of record was 278 mm while mean wheat season rainfall was 247 mm, or 89% of the former on average. Therefore it is not surprising to see that the phenomenon of declining season rainfall with delayed onset is similar in both representations. The regression equation quantifying this effect (Fig.10.1) is based on 44 of the 47 years of data , because effective onset for wheat production never occurred in the other three seasons . They are represented by the large inverted triangle at the lower right side of the figure. In statistical terms.the regression is significant at the 1%

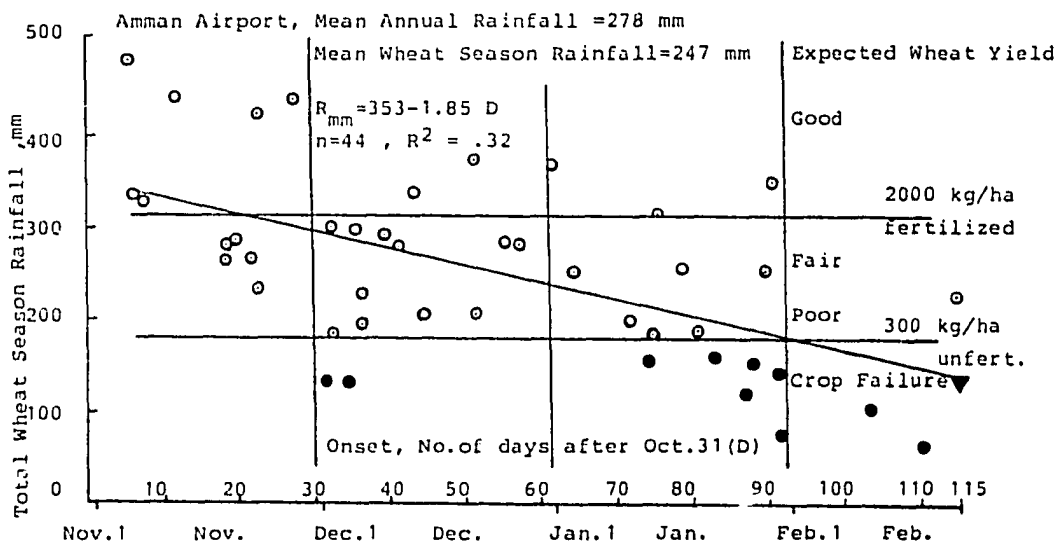

Fig. 10-1. Decline of wheat season rainfall amount with later onset of the rains,Amman,Jordan; 47-year rainfall record, 1937-1984.

Figure 10.1 shows that onset for wheat production at Amman (defined as 30+mm of rainfall accumulated in the seedbed) may occur anytime from November to February inclusive, with December 22 as the median date in the study period. Vertical lines divide the onset period by months to make it easier to see the changes in rainfall months associated with onset in each of the four months.

Figure 10.1 also includes two horizontal lines which relate (roughly) to wheat yields expected with the amounts of seasonal rainfall represented by the lines. For example, the lower line at 180 mm represents the least amount of rainfall which should produce a subsistence level wheat yield of 300 kg/ha , using traditional farming methods and levels of technology . In Figure 10.1, rainfall levels less than 180 mm are presumed to result in total crop failure, denoted by blackened data points .

The upper horizontal line at 313 mm rainfall indicates the lower level for "good" wheat yield , being approximately the amount of rainfall required to produce 2,000 kg/ha of grain utilizing advanced technologies ,in particular, commercial fertilizers. Between the two lines , crop yields expected range from "fair" to poor" .

A single exception to the above occurs in the far right data point (Feb. 23 onset , 232 mm) which would in fact

have been a totally failed crop because rainfall in that particular season only persisted for 38 days beyond onset . Thus,all February onsets in this record would have produced crop failures. This raises the question of rainfall duration as related to date of onset . The median date of rainfall cessation in this record was April 21 , with March 21 the earliest and May 28 the latest , a much shorter time period than the possible onset period . Roughly speaking, a one-day delay in onset may be expected to shorten the rainy period by one day . This means onset in February will always be very precarious for wheat production.

The main lesson to be learned from Figure 10.1 is that the amount of rainfall expected in any given wheat season is not a totally random feature. It is linked to the actual date of onset, at which time we may - if history is any guide - quantify a narrowed range of possible occurrences, a narrowed range of possibilities represented in the record if one ignores the date of onset .

The linkage between season rainfall and date of onset means that the potential for crop failure rapidly increases with later onset. Accordingly, the probability of a good crop steadily decreases.

10-3. JORDANIAN WHEAT FARMER RESPONSES TO LATE ONSETS OF THE RAIN AND IMPLICATIONS FOR FOOD SECURITY

The actions of the wheat farmers of Jordan demonstrate they are well aware of the implications of late onset for lowered yields or even complete failure. They respond to late onset by reducing the hectarage they plant to wheat and also to barley. And in each season in which rains are reasonably below normal during the prolonged planting period following onset, they reduce the planted area still further. Figure 10.2 shows the result of these actions in the nine year period from 1968/69 to 1976/77 period, averaged for Balqa, Irbid and Amman (south) Governorates.

Figure 10.2 shows considerable year to year variation in rainfall over the study area during the nine year period, and a corresponding adjustment in the area planted to wheat and barley each year which conforms closely to the rainfall amount. Note that Figure 10.2 is inclusive of all of the study areas from the wettest to the driest.

FAO (1982), in the section on Jordan , reads as follows:

.... It is interesting to note that wheat farmers delay seeding till a good part of the rainy season is gone . If sufficient rain is received, they go ahead with their

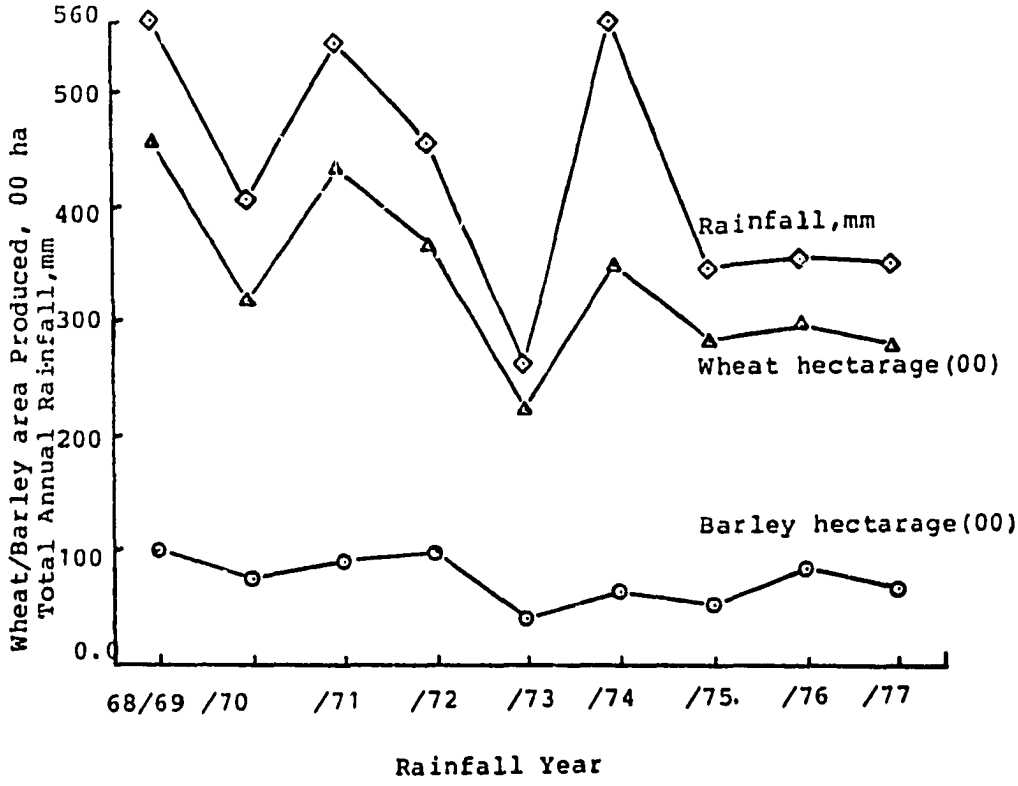

Fig. 10-2. Close correspondence between areas planted by farmers to wheat and barley,and rainfall over the period 1969 1977 in Irbid , Balqa and part of Amman Governorates.

planting , if not then,they do not plant. It is not unusual, therefore , to see farmers planting wheat as late as mid or even late February. This practice is very common in the arid and marginal zones of the country. Accordingly, the area planted to wheat in these two zones depend on the rainy season. Data on areas planted and production and yield of wheat in each zone when the rainy season is good, medium or poor are presented in Table 26 [seen in referenced publication]. It is interesting to note in this table that fluctuation of area according to rainfall does not apply to the semiarid or the semi-humid zones .... "

Although some details of the FAO (1982) explanation differ from the writer's data and observations, the essence remains true and means this : Jordanian cereal farmers are now practicing, and have historically practiced, what this paper labels "Response Farming". They are judging the coming rainfall season two ways - first by the date of onset and second by winter rainfall into January when final decisions are made about the area to plant . Note that planting begins whenever adequate rains begin, and a minimum area for subsistence is planted every year. It is the additional area from which the crop presumably would be marketed which is decided upon at the last moment.

The final report of a major research effort carried out by ICARDA , the University of Jordan and the Ministry of

Agriculture in Jordan,has recently been published(JCCIP, 1984) . Their "best bet" recommendations are for all wheat farmers to plant before rains, with the implication that the entire area available will be planted each year. For rainfall areas greater than 250 mm(their zones A and B), a blanket application of nitrogen at 30 kg/ha is recommended at seeding time . In all rainfall zones including 200-250 mm , an additional 30 kg/ha N is recommended at tillering time,provided the "season is good". In sum then, planting practice recommendations suggest that the date of onset and early season rainfall are of no consequence, but the latter should be considered when the decision is made on final nitrogen fertilizer rate .

However, the ICARDA report clearly alludes to the problem associated with fixed recommendations for farming in highly variable rainfall zones. In a forerunner report, Arabiat et al. (1983) concludes that future research must be devised to deal with the actual rainfall variability as faced by farmers. The writer agrees with these researchers' thesis and believes that the variability should be dealt with in two steps. First, the rainfall season at hand should be categorized, at least roughly , based on the date of onset(see Figure 10.1). Decisions about wheat versus alternative crops, wheat area and varieties to be planted and seeding rates and initial fertilizer rates should be

based on this categorization. A revised rainfall season categorization should be made as of tillering time based on actual early season rainfall characteristics, at which time final decisions may be made about nitrogen rates and levels of other costly inputs ,such as herbicides, to be employed. More detailed discussion will follow in the section on development of recommendations.

10-4.WATER PRODUCTION FUNCTION TO GUIDE FARM DECISIONS ACCORDING TO RAINFALL EXPECTATIONS

Farm level decision-making in variable rainfall conditions can be greatly strengthened by two types of research. The first has already been addressed - the study of rainfall history to sharpen our ability to predict actual rainfall expectations in the approaching season, early enough to modify our actions in ways calculated to maximize output with the expected water supply.

The second type of research needed involves careful study of relationships between crop yields and water supply, that is to say, water production function studies. Three types of water production function studies are needed. The types of studies and sequencing are : a) present relationships existing in traditional agriculture, b) studies of potential crop yield with the available (variable) water supply , assuming improved management can overcome

other limitations such as low soil fertility; and c) the actual effects of management decisions and practices on yield/water relationships in the local environment.

It is the combination of water production functions with water supply forecasting which is needed for developing farm level recommendations. This paper presents examples of water production functions for seven crops as they exist today in traditional agriculture in Jordan. A suggested relationship showing potential wheat yields with different rainfall amounts is also presented, based on transferable equations from research at UC Davis. The above water production functions and information on rainfall expectations at Amman are combined to illustrate the approach the writer suggests for development of improved farm level recommendations.

Figures 10.3 and 10.4 show present day relationships between wheat yields and rainfall, as they exist in traditional agriculture in three distinct rainfall zones in the northern highlands of Jordan.

Figure 10.3 shows how wheat yield varies with total annual rainfall in the moderately high rainfall areas of Irbid, Kura and Jerash Districts of Irbid Governorate. The yield data derived from a 9-year study by the Arab Organization for Agricultural Development over the period

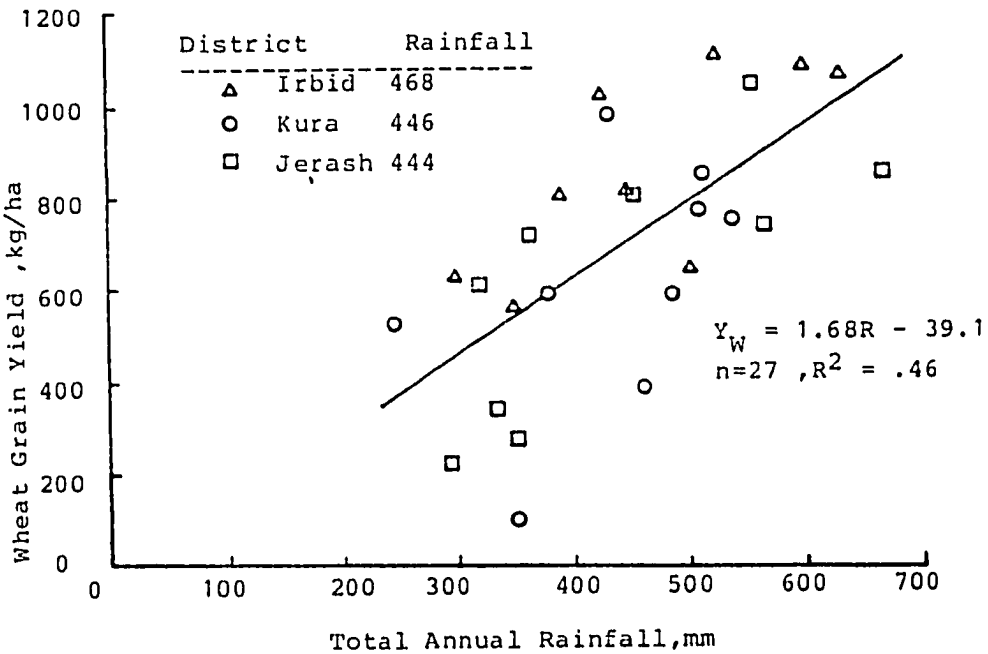

Fig.10-3. Relations between wheat grain yields and rainfall over the 1969-1977 period in Irbid, Kurah and Jerash Districts, Jordan.

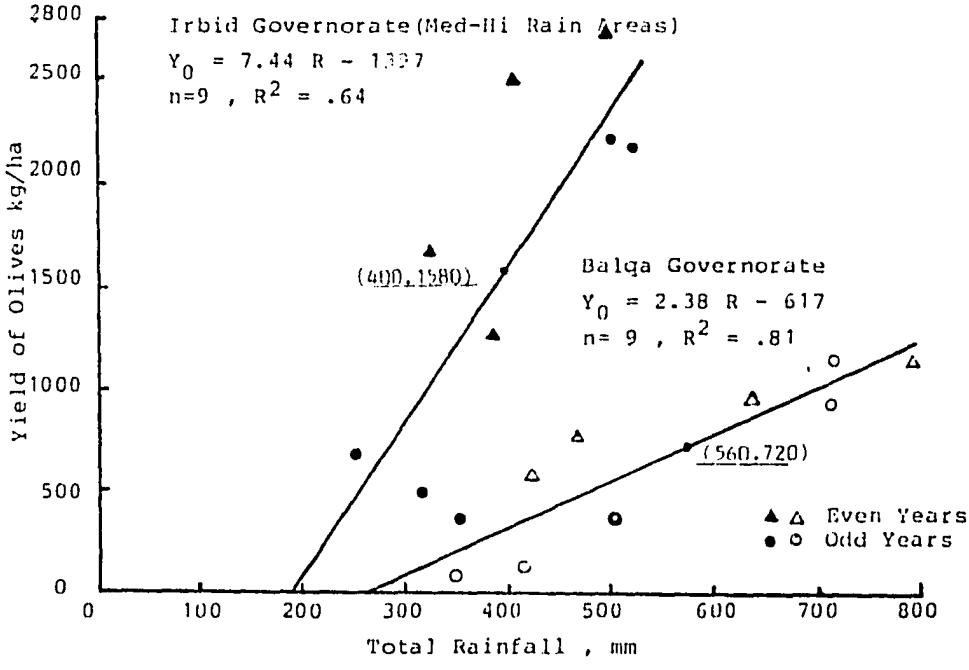

Fig.10-4. Relations between wheat grain yields and rainfall over the 1969-1977 period in the low rainfall areas of Irbid (east) and Amman (south) Governorates, and the high rainfall areas of Balqa and Irbid Governorates.

1969-77 inclusive (AOAD, 1978). Corresponding rainfall data is published by the Water Authority of Jordan (1985).

There are a number of interesting points to be made about the information in Figure 10.3 as follows:

1. The yield vs rainfall relationship is fairly good considering it represents only surveyed district averages and rainfall data from six locations. This type of relationship could be useful to food planners and those engaged in early warning activities.

2. Although average annual rainfall is similar in the three districts, there are important differences in both rainfall behavior and associated wheat yields. Irbid District produced the overall highest yield, besting the highest in Jerash three of the nine years, and the best in Kura four of the nine years. Jerash wheat yields appear most unstable , falling below the subsistence threshold (300 kg/ha) two of nine years, and below a suggested economic threshold of 400 kg/ha three of nine years. Kura was next lowest with one subsistence failure and two economic failures. Irbid showed no failures during the study period.

3. Despite rainfall above 500 mm in more than 1/3 of all cases, yield never exceeded 1150 kg/ha. More on this later.

Figure 10.4 is similar to Figure 10.3 , but covers

both higher and lower rainfall areas. Yield data for the Amman South area may be seen in AOAD (1978). As in Figure 10.3 , the relationship between yield and annual rainfall is quite good in the higher rainfall zones of Ajlun District and Balqa Governorate, and still better in the drier zones of Irbid East and Amman South. The findings are very similar to those of a 3-year research effort in Syria by scientists of the Arab Center for Study of Arid Zones and Dry Lands (ACSAD, 1984). This study reveals many variables responsible for the scatter in the relationship, including weed competition, soil fertility, especially phosphorus and nitrogen levels, and others. As above, the closest relationship is found when rainfall is below 400 mm.

As in Figure 10.3 , Figure 10.4 shows no yield exceeding 1,200 kg/ha. On the lower end of the scale in the drier areas there are a number of subsistance and economic failures. This will be discussed more when considering recommendations. In the wet zones, only one failure is seen in Balqa when rainfall fell to 350 mm. However, the highest yields are below those in the dry zones, and overall water use efficiency is very low by comparison.

Figure 10.5 is a compilation of the information in Figures 10.3 and 10.4 , with the data points removed for clarity. Also, the 9-year mean rainfall levels and wheat grain yields are shown for each rainfall zone.

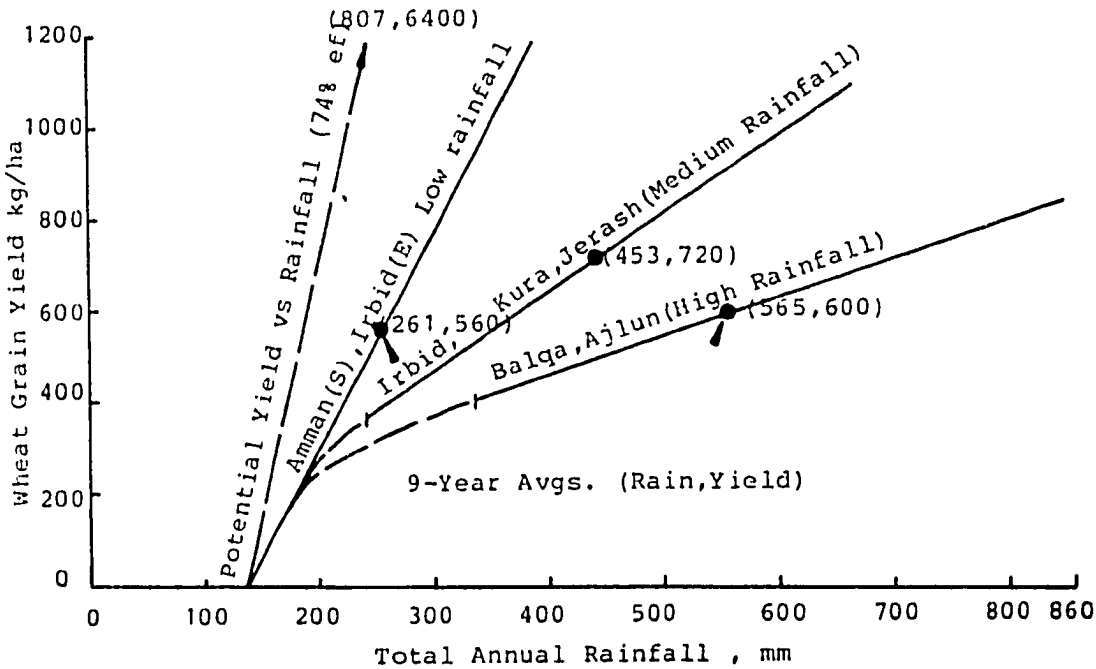

Fig.10-5.Relations between wheat grain yields and rainfall over the 1969-1977 period in three rainfall zones of Amman,Irbid and Balqa Governorates, Jordan, plus a simulated wheat production function for high technology rainfed conditions.

On the left side of the figure is a suggested relationship for potential wheat yield which assumes water is the only factor limiting yield, and that 74% of rainfall is used in evapotranspiration. The maximum water use in this case is estimated at 807 mm, and maximum yield at 6400 kg/ha.

The characteristics of the potential wheat yield function are derived from water production function research by the writer, by colleagues at UC Davis, by other researchers elsewhere and by observations in Jordan.The linearity of the function and maximum yield are derived from research as above, the 74% efficiency of water use is suggested by the dry zone function in Figure 10.4 which reaches zero yield at 135 mm rainfall. Other research shows yield beginning with 100 mm of actual evapotranspiration, thus 100/135 = 74% efficiency. The maximum water use of 807 mm is equal to the wheat water requirement estimated for Irbid of 597 mm, divided by the water use efficiency of 0.74.

The curve used to estimate the wheat water requirements for Irbid may be seen in Figure 10.6 .

Figure 10.6 contains two curves showing crop coefficients for estimating water requirements of wheat. These curves were developed by the writer using data gathered by W.O. Pruitt and J. Hatfield in four years of

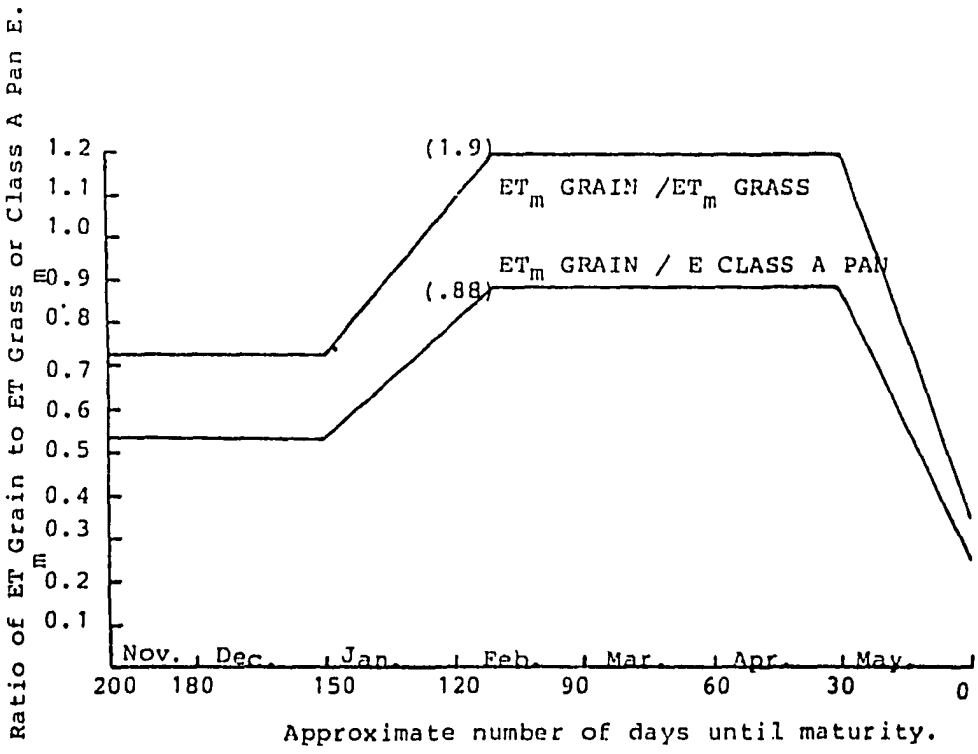

Fig.10-6. Curves for use in estimation of water requirments (ET_m) of wheat and barley in Mediterranean zones.

lysimeter studies with wheat and barley. Daily measurements of evapotranspiration from the cropped (adequately watered) lysimeter were related both to evapotranspiration from a grass lysimeter (upper curve) and to standard Class A pan evaporation (lower curve). The estimated wheat water requirement of 597 mm at Irbid is based on Figure 10.6 pan coefficients, and adjusted pan evaporation data from the Irbid meteorological stations, averaged for a number of years.The adjustment of the data consists of multiplying the original data by 0.94 to account for two non-standard features of the Irbid pan. These are, that it is located in a bare soil rather than green grass compound, and it is screened against the depredations of birds and animals. The screen reduces the rate of evaporation but the bare soil condition more than compensates. The net rate of evaporation is greater than from a standard pan.

Figure 10.7, like Figures 10.3 and 10.4 , shows water production functions based on recent data from traditional agriculture in Jordan for olives.

The relationships in Figure 10.7 between olive yields and annual rainfall in the medium-high and high rainfall areas, are still better than those for wheat, probably because olives use a larger and more constant fraction of the yearly total rainfall. This would include rainfall

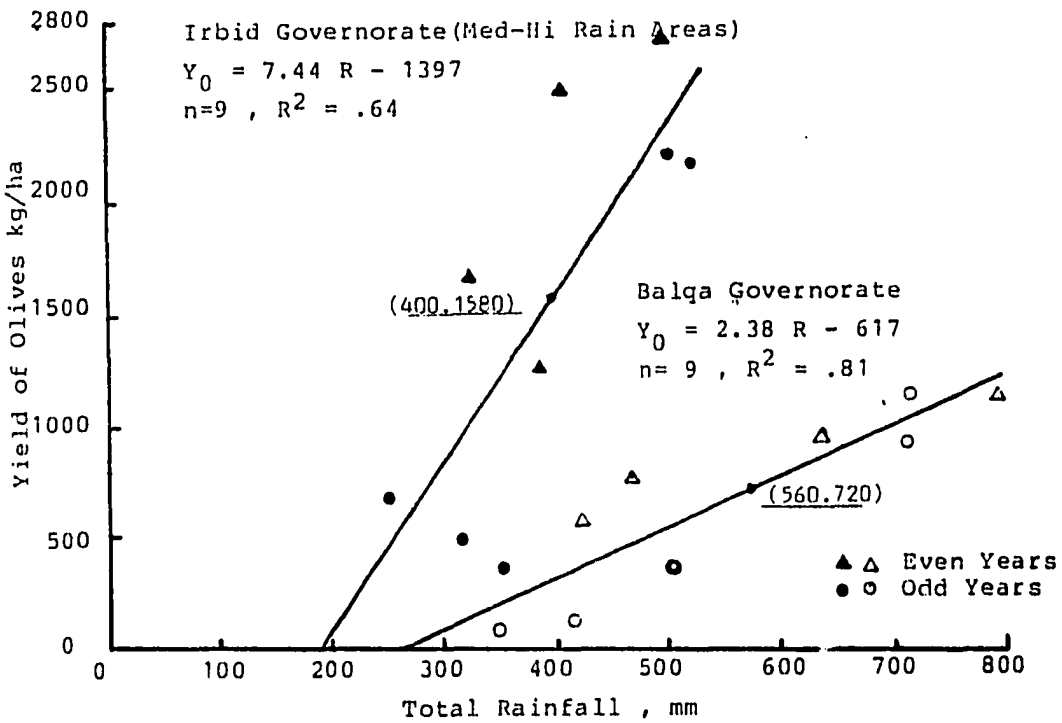

Fig.10-7. Relations between yield of olives and rainfall in the medium high rainfall areas of Irbid and the high rainfall areas of Balqa Governorates, Jordan , over the period 1969-1977.

occurring before and after the wheat season, and much of that which percolates below the wheat root zone, especially into the interstices between rocks in shallow soils, as are found widely in the higher rainfall zone of Balqa Governorate.

Note that both olives and wheat in Balqa have lower water use efficiency than in the medium-high or low rainfall zones. Some of the main reasons for this are probably greater losses of water to both runoff and deep percolation, respectively ,in the steeper and shallower soils of the high rainfall area, plus greater losses of nitrogen and perhaps other nutrients through leaching.

Still another point of interest in the olive production functions is the strong evidence of their often cited propensity for alternate bearing, i.e., yielding relatively high one year and low the next. In both the Irbid and Balqa functions in Figure 10.7,it may be seen that the years in which yields are relatively high with respect to rainfall are the even numbered years. Only the Irbid function will be considered in the remainder of this paper, which focuses on the performance of crops when rainfall does not exceed 400 mm.

In addition to the wheat and olive water production functions seen in Figures 10.3 - 10.5 and 10.7 , the yield

data developed in the previously cited AOAD studies were utilized to quantify functions for barley,vetch,lentils, chickpea and tobacco. All of these are for the rainfall zones below 400 mm per annum. All are based on area-wide yield sampling over the seven years 1969/75 (Amman South) or nine years 1969/77 (all other areas). Rainfall in all cases is represented by the published annual totals for the study areas in the indicated years. The functions found for all seven crops are presented in Table 10.1 .

10-5.INFORMATION REQUIREMENTS FOR GENERATION OF RESPONSE FARMING RECOMMENDATIONS

Response farming recommendations are generated by combining improved information about rainfall expectations with research findings on crop responses to water. Figure 10.8 is an example of this kind of combination, incorporating the water production functions in Table 10.1 and averaged rainfall figures from the Amman-Ramtha-Rihab meteorological stations.

The four vertical lines in Figure 10.8 show the historical rainfall means for years with onset in each month from November to February inclusive. Thus, while the overall mean is 261 mm, the means for years with onset in each month decline from a high of 318 mm (November onset) to a low of 174 mm (February onset).

Table 10.1: Water production functions relating yield (Y , kg/ha) to total annual rainfall (R , mm) for seven crops grown in the low to medium (to 40 mm) rainfall areas of Irbid and Amman Governorates.

Crop	Water Production Functions	
Wheat	Y = 4.45 R - 602	n = 16 , R = .85
Barley	Y = 4.54 R - 598	n = 16 , R = .61
Lentil	Y = 4.21 R - 553	n = 16 , R = .75
Chickpea	Y = 1.83 R + 033	n = 16 , R = .25
Vetch	Y = 4.43 R - 643	n = 16 , R = .91
Tobacco	Y = 1.41 R - 016	n = 16 , R = .39
Olive	Y = 7.44 R -1397	n = 09 , R = .64

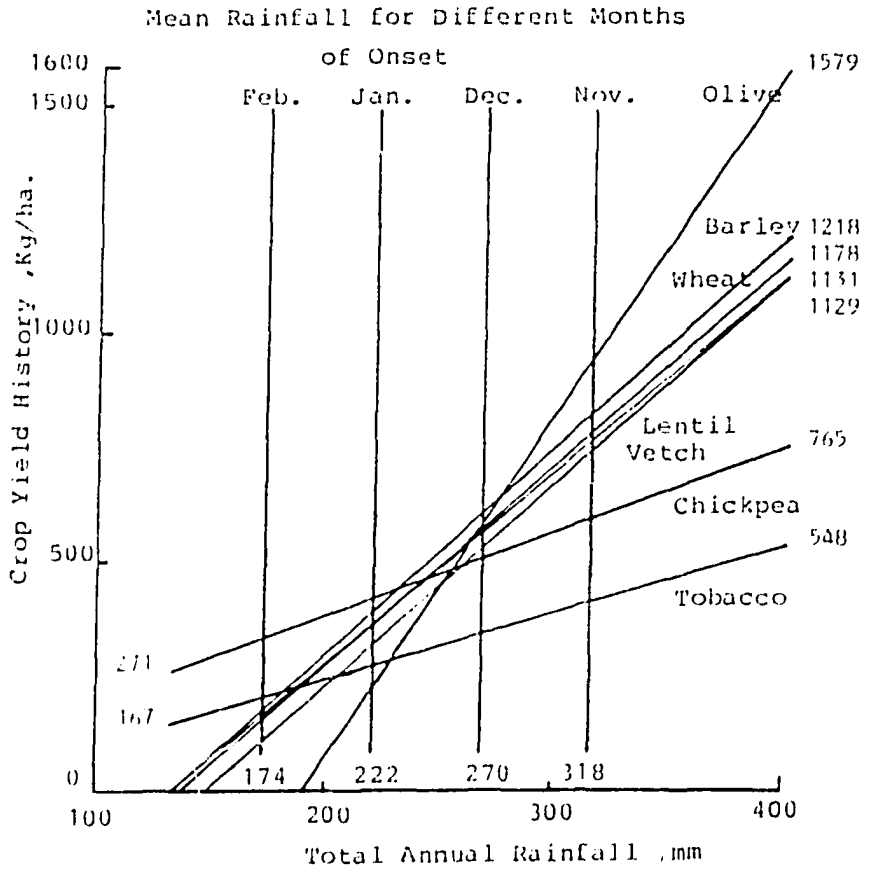

Fig.10-8. Comparison of water production functions for seven crops grown over the period 1969-1977 using traditional technology in the low to medium-high rainfall areas of Amman and Irbid Governorates, Jordan.

The sloping and sometimes crisscrossing lines are the crop water production functions. Each is labeled with the name of the crop and each shows the yield expected at 400 mm rainfall and the rapidity with which it declines with lower rainfall expectations. Wheat, for example, has a mean yield expectation of 813 kg/ha if onset is in November, 600 kg/ha with December onset, 386 kg/ha with January onset, and 172 kg/ha with February onset.

By way of contrast, chickpea yields are less than wheat with higher rainfall, but more with lower rainfall. Mean yields for years with onset in each month from November to February are 615,527,439 and 351 kg/ha , respectively. This might suggest that the anticipated wheat crop failures with January and February onsets (subsistence failure is 300 kg/ha or less, economic failure is 400 kg/ha or less) might best be avoided by planting chickpea instead.

Additionally, if one were dissatisfied with the overall long-term wheat yield of 560kg/ha, one might opt for a total change to a perennial crop like olive, with long-term mean yield of 545 kg/ha. Table 10.2 will enable the reader to make more rapid comparisons of yield expectations of different crops with different onset dates of the rainy season. Remember that these yields derive from traditional agriculture with few if any cash inputs.

Table 10.2 : Yield expectations as related to date of onset of of the rains for traditionally managed rainfed crops in the transition zone between relatively well-watered highlands and arid desert in Irbid and Amman Governorates , Jordan .

CROP CATEGORY	CROP TYPE	Mean Yield Expectations , kg/ha				
		Long-Term	Month of Onset			
		Mean (261mm)	NOV. (318mm)	DEC. (270mm)	JAN. (222mm)	FEB.+ (174mm)
Cereal Grains	Wheat	(559)	813	600	386	172
	Barley	(587)	846	628	410	192
Grain Legumes	Lentils	(546)	786	584	382	180
	Chickpea	(511)	615	527	439	351
Forages	Vetch	(513)	766	553	340	128
Annual,Cash	Tobacco	(352)	432	365	297	229
Perennial,Fruit	Olives*	(545)	969	612	255	000

* : Average of all years.

Final decisions about such matters as changing crops generally require knowledge of economic as well as yield expectations. Water production functions lend themselves readily to economic interpretation. Figure 10.9 shows this applies in very simplified form to the information in Figure 10.8. The only difference is that prices have been applied to each of the seven commodities, forming water return functions rather than production functions. The prices used are farm gate prices as of November, 1985.

Figure 10.9 bears some resemblances to Figure 10.8,but also some interesting new information. As with yields, gross returns are highest with higher rainfall and decline with less. But tobacco, with its high support price, is clearly the most valuable crop at rainfall levels below 360 mm. Above 360 mm olives become still more valuable than tobacco.

If rainfall onset is in November or December, lentils are the most valuable of the grains or grain legumes, but chickpeas are more valuable with later onset and lower water expectations. Table 10.3 summarizes the information in Figure 10.9 .

10-6.HYPOTHETICAL EXAMPLE OF RESPONSE FARMING GUIDANCE DEVELOPMENT FOR WHEAT PRODUCTION IN THE AMMAN AREA

The following example is based on the rainfall record displayed in Figure 10.1 , and on these considerations and assumptions:

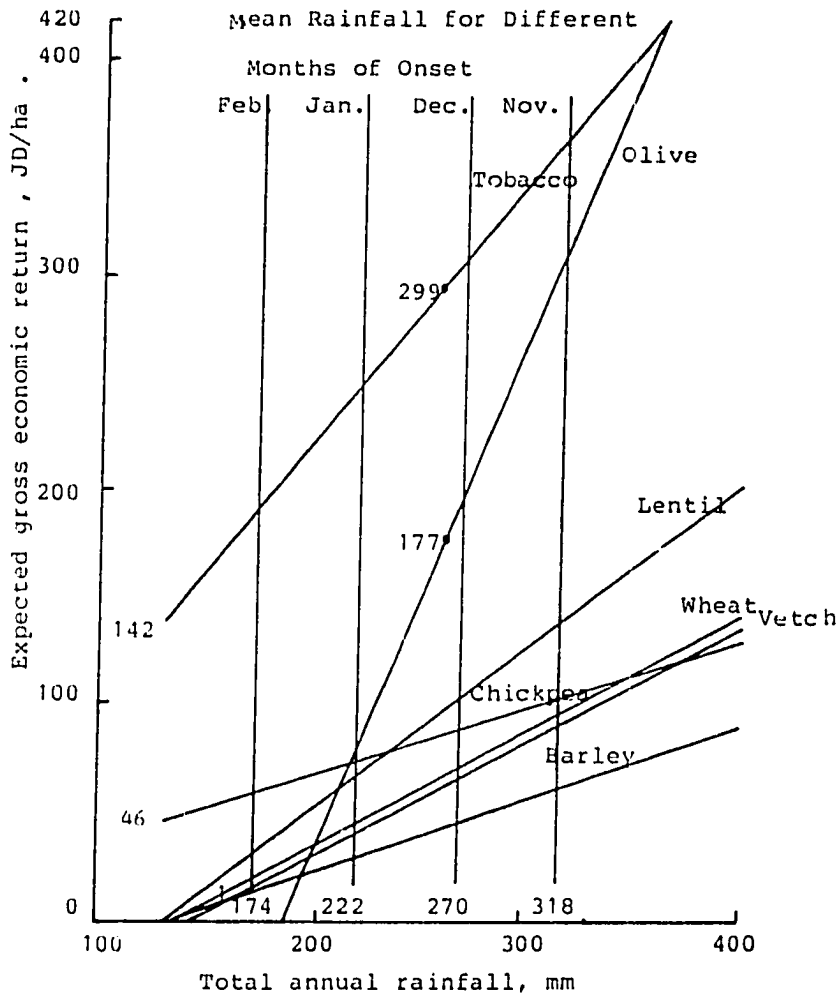

Fig.10-9. Gross returns from seven crops expected at different rainfall levels as they relate to rainy period onset in different months. Units are in Jordanian Dinars , with commodity prices as of Nov. ,1985.

Table 10.3: How expected gross returns from rainfed crops differ with differing dates of onset of the rainy season. Traditional management in transitional zones of Irbid and Amman Governorates , Jordan , with long-term mean rainfall of 261mm .

CROP CATEGORY	CROP TYPE	--Mean Gross Returns Expectation,JD/ha-				
		Long-Term	Month of Onset			
		Mean (261mm)	NOV. (261mm)	DEC. (270mm)	JAN. (222mm)	FEB.+ (174mm)
Cereal Grains	Wheat	67	98	72	46	21
	Barley	44	98	72	31	41
Grain Legumes	Legumes	98	141	105	69	32
	Chickpea	87	105	90	75	60
Forages	Vetch	62	92	66	41	15
Annual,Cash	Tobacco	299	367	310	252	195
Perennial,Fruit	Olives	177	315	199	83	0

1. Rainfall for wheat production occurs at three levels which, with two exceptions in the 47 years, are those shown in Figure 10.1. The upper or high level is rainfall above 320 mm which effectively represents 23 of the 47 years. The exceptions are here ; this category includes the year with 316 mm in mid-January, but excludes the year with 232 mm and onset Feb. 23. The latter moves to the lower level of 180 mm or less, which represents 14 of the 47 years.

2. It is not possible to break even economically on wheat production at the lower rainfall level,and not likely that even a subsistence crop can be harvested.In terms of national food security considerations, the loss to the nation by not planting in the lowest rainfall years is insignificant. Therefore, the only reason a farmer plants in these years is to gamble on a subsistence crop because he greatly prefers durum wheat to the soft wheat imported by the government. Our example assumes the rightful aim of the farmer is to plant all of his wheat land to wheat whenever rainfall is high or medium and to plant half of the area to wheat (as a gamble) in low rainfall years, with the other half devoted to alternative crop (or fallow) of choice.

3. Rainfall onset on or before January 15 will be termed "early", and from January 16 onward, "late." Early onset occurred 32 of the 47 years, with late (or no) onset in 15 years.

4. Nitrogen fertilizer is assumed to increase wheat yield by 20 kg/ha for each kg/ha of N applied, provided water is available to support the increases in yield.

5. Water production functions describing the relationships btween wheat yields (both unfertilized and fertilized) and wheat season rainfall at Amman are : a) Y unfert = 3.84 , R season = 392 mm ; and b) Y fert = 9.5 , R season = 969 mm .

6. The aim of fertilization application is to enable maximum yields with the expected water supply, thus to bridge the gap between unfertilized yields and fertilized ones. The nitrogen rates shown in this example were calculated to accomplish this.

Table 10.4 shows the hypothetical response farming recommendations which would emerge from a study of Figure 10.1 and the considerations/assumptions listed. The table also shows the traditional agricultural practices and the "best bet" recommendations developed in the major research effort recently concluded in Jordan (JCCIP , 1984). All of the above area is compared in the upper part of the table , then evaluated below.

Traditional wheat production practices have the great virtue of adapting the planting area almost perfectly in accordance with wheat season rainfall. This is one of the

Table 10.4: Comparison of wheat farmer traditional practices with recommended practices based on conventional research. Also , evaluation of expected acheivements from each approach . (Hypothetical example for the Amman , Jordan area with mean rainfall of 278mm.

WHEAT PRODUCTION PRACTICE	Actual Practices & Recommendations from 3 Approaches			
	Traditional Farming	ICARDA Research Findings	-------Response Farming------ Early Onset	Late Onset
SOWING DATE	Onset to Tillering	Nov.	Onset	Jan. 16
SOWING METHOD	Broadcast	Drill	Drill	Broadcast
SOWN AREA	Variable, 50 - 100%	100 %	100 %	50 %
ALTERNATIVE CROPS	Various on Unplanted Wheat Area	None	None	As Selected For Unplanted Wheat Area
NITROGEN , kg/ha	None	30 at Sowing+ Tiller if ----Good	40 at Sowing+ Tiller if Season---	None at Sowing+
WEED CONTROL	None	2 , 4-D Easter	2 , 4-D Easter	None

----Comparative Evaluation of Matching Practices to Rainfall,---- Yield and Other Aims

Planted Area, % of Yrs Correct	100	70	85
N Rate , % of Yrs Correct	30	70	91
Avg. N Rate , (kg/ha)	0	36	38
Avg. Land Area Yield , kg/ha	530	1150	1200
Avg. Land Area for Alternative Crops	15	0	15

aims of response farming also. However, to accomplish this as well as the farmers do, requires planting very late, well into February in many years. This creates a number of problems, but chief among these is that the potential for higher yields is lost. Accordingly, the farmers have not adopted the nitrogen or other fertilizers which would be required, together with earlier planting, better weed control, etc, to realize their yield potentials.

The "best bet" recommendations following from the Jordan Cooperative Cereals Improvement Project (JCCIP, 1984), provide the bulk of the needed inputs for higher yields, but go to the other extreme by recommending planting before the rains every year in November. The obvious problem with this approach is that all of the wheat area is both planted and fertilized every year, despite the fact that total failure can be expected in 14 of 47 years, or 3 years in 10 . These failures are costly in terms of labor and capital, and may not be evident in time to turn to alternative crops.

The response farming approach takes advantage of the fact that rainfall is related to onset date to combine the better features of both the traditional and conventional research-based systems. The time scale for onset is divided on January 15 into two subsets. Early onset implies either high or medium rainfall is expected and recommended planting practices reflect that expectation. The date of planting,

based on actual time of onset, is early enough to assure high yields provided the season lives up to its promise. Six out of ten high rainfall seasons have onset in November, with two more in December and only one more before January 15. As seen in Figure 10.1, the tenth high rainfall season had a late onset; this constitutes an exception.

Other exceptions are three low rainfall seasons with early onset. These would receive the initial nitrogen fertilization and all of the land would be planted, rather than the 50% desired. This is the major problem of the "best bet" recommendations, but the latter have the problem in all 14 low rainfall years rather than just in 3 of them.

When January 16 arrives without onset, planting of a reduced hectarage (50%)can proceed without the use of nitrogen because the expectation is for either low or medium, but not high, rainfall. Waiting for the actual onset beyond this date will have no real effect on practices because the farmers have demonstrated that even in the worst of conditions they still wish to plant a minimum hectarage. The response farming approach moves their planting date forward in the low rainfall years and permits them to better plan ahead.

Both the "best bet" and response farming systems provide for adjustment of input levels in accordance with

actual amounts of rainfall received by tillering time, usually in February. If, at that time, rainfall has been above normal, additional nitrogen can be profitably added. This is in keeping with the writer's early determinations about the value of the response farming approach, and how it can be utilized to better match farm practices with a variable water supply (Stewart, 1980; Stewart & Hash, 1982).

The evaluation at the bottom of Table 10.4 indicates that the response farming approach has the capability for more closely matching practices to rainfall than either the traditional methodology or the "best bet" approach. In terms of nitrogen fertilizer costs, the response farming and "best bet" are nearly the same, but the former provides higher levels of N when needed, and none when not required. The result should be a measurable overall average yield increase of the order of 50 kg/ha. At the same time, the response farming method reduces the basic planting effort and costs by 15% and does so in seasons when the effort and time would have been wasted.

It is well-documented that Jordanian farmers have been reluctant to adopt the "best bet" recommendations and similar recommendations from earlier studies, even though the potential benefits have also been clearly documented. The reasons for the low adoption rate are not entirely clear. However, a modified approach which incorporates the farmers

traditions of planting with the rains and adjusting the planting area accordingly, may find favor with them. When they see that the recommended system is based on their own traditional beliefs about rainfall, it may give them the confidence required to purchase and apply needed inputs in years of early onset.

10-7. CONCLUSIONS

The-long term record shows that Jordanian rainfall for wheat production is strongly linked to the time of onset, the earlier the onset the higher the rainfall expectations.

Jordanian wheat farmers traditionally have demonstrated their awareness of, and sensitivity to, this phenomenon by delaying the start of planting until onset is clearly manifested, and the finish of planting until January or even February when the nature of the season is fairly clear. In this way, they adjusted their area planted to wheat in nearly perfect accordance with actual rainfall, planting the maximum area when high rainfall amounts are experienced. The reductions in planted area are in all areas, wet to dry, so are based on early rainfall relative to normal for the particular area. The greatest reduction is to approximately 50% of maximum possible area, leaving the farmer the hope of at least a subsistence level of production even in the poorest years. Available data show these reductions have little

impact on the national food supply because wheat yields in low rainfall years are extremely low.

The "best bet" recommendations for wheat production developed in the recent Jordan Cooperative Cereals Improvement Project have the major strength of introducing realistic quantities of key inputs such as fertilizers and herbicides into the picture, essential for attaining the higher yield levels indicated by actual rainfall. The writer believes a weakness in these recommendations is that they require planting the maximum wheat area together with costly inputs every year, and doing this prior to the onset of the rains , so no consideration is taken of the farmers' traditional behavior. The low rate of adoption of these recommendations indicates the farmers are unwilling to commit their resources blindfolded when they in fact have a better grasp of the situation operating in their traditional fashion.

Response farming offers the advantages of both systems by: a) institutionalizing and quantifying the farmers' lore, and by actually following it in practice, and b) incorporating needed inputs into the package at times and in amounts adjusted to the date of onset and early season rainfall amounts. Thus, costly inputs are not called for when indications for the season are poor. The writer believes this approach may inspire more confidence in the growers since it is based on their traditional knowledge and beliefs.

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GOVERNMENTAL POLICIES IN THE DRYLANDS OF JORDAN

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GOVERNMENTAL POLICIES IN THE DRYLANDS OF JORDAN

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11-1. INTRODUCTION

The economic contribution of the agricultural dryland subsector in Jordan has been poor during the past 30 years, and the farmers who live in these areas receive the lowest income level in the country. The rainfed land resources are not producing up to their biological or economic potential. Jordan's dryland subsector may be classified as a traditional agricultural system because of the dominant use of traditional cultural practices for many years. For example, the national average wheat yield is very low. It ranges from 0.6 to 0.8 ton per hectare.

Dryland wheat production exhibits annual fluctuations in total production and has declined for the last 10 years (1975-1984). Because of this wide variation and low annual production , a gap (shortage) has existed between food demand and falling cereal production since the

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early 1950s. Since 1968 this gap has widened until reaching its maximum in 1984.

Although most of the problems from which Jordan's dryland areas suffer are strongly related to the environment of production conditions, we believe that Jordan must take a comprehensive look at the whole dryland subsector which includes cereal production, marketing and processing, consumption and determination of food policy.

In order to make a full assessment of Jordan's dryland production we need to study the interrelationships of, and interactions between,the above factors.

11-2.DRYLAND REGIONS OF JORDAN

To appreciate the significant role of developing better policies for the improvement of Jordan's rainfed subsector, and to recognize the importance of the dryland region in the Jordanian economy, we must look at the problem of dryland production from macroeconomic and food policy points of view.

A twenty-year performance record of the gross domestic product (GDP), (1960-1980) indicates that Jordan's economy has enjoyed a high real growth rate. For example,during the period 1960-1966, the average annual real growth rate of GDP was estimated at 7% (Mazur,1979). During the period 1973-

1981, it was estimated at 8.7%, and during the two-year period from 1982 to 1983 Jordan's economy has witnessed a slow growth rate of 5.7 and 5.4 percent, respectively (Central Bank of Jordan,1983). However, despite this good performance, Jordan's economy suffers from major structural economic shortcomings which affect the country's food and agriculture policies. Agriculture's share in Jordan's gross fixed investment appears to be low in comparison with other Least Developed Countries (LDCs) (Mazur, 1979).

The structure of the economy is flawed by imbalances among producing sectors,i.e., it has a long standing high share of the services sector in the GDP. Total commodity sectors contributed 39% of the GDP in 1983 , while the services' share was 61%. Table 11.1 shows the relative shares of both sectors during the period 1964-1983. The relative share of the agricultural sector to the GDP is decreasing. In 1964, it was 25.2% of the GDP and has since decreased to reach a low of 6.5% in 1979.

Jordan's foreign trade has continued to show an increasing deficit over a long period. This deficit has grown at a rate of 16% annually. Jordan also has chronic food deficits . It is estimated that 25% to 30% of the total food requirements are produced domestically while 70 to 75% are imported. Table 11.2 illustrates the total food imports, exports, and the food trade balance for

Table 11.1 : The Relative Shares of the Commodity and Service Sector to the GDP During 1964-1983 (Central Bank of Jordan , 1984).

Year	Agriculture		Total Commodity Sector		Total Service Sector		GDP
	Million J.D.	% of GDP	Million J.D.	% of GDP	Million J.D.	% of GDP	Million J.D.
1964	34.1	25.2	52.9	39.0	82.6	61.0	135.5
1965	34.1	22.6	59.9	39.6	91.1	60.3	151.0
1966	27.6	18.4	56.2	37.6	93.4	62.4	149.6
1967	23.4	20.2	44.5	38.5	71.1	61.5	115.6
1968	16.2	11.7	43.6	31.5	94.6	68.5	138.2
1969	22.5	13.8	53.6	33.0	108.9	67.0	162.5
1970	15.6	10.0	41.1	26.5	113.6	73.4	154.7
1971	23.9	14.4	49.9	30.0	116.1	69.9	166.0
1972	26.6	14.5	56.8	31.0	126.0	68.9	182.8
1973	17.9	9.5	57.1	30.2	131.8	69.8	188.9
1974	30.3	12.5	90.6	37.4	151.8	62.7	242.4
1975	26.0	8.6	104.4	34.4	198.7	65.6	303.1
1976	37.3	9.3	135.6	35.8	242.8	64.2	378.4
1977	41.7	9.5	162.1	36.8	277.8	63.2	439.9
1978	58.6	10.6	211.1	38.3	340.1	61.7	551.2
1979	43.6	6.5	245.8	36.8	422.8	63.2	668.6
1980	64.6	7.3	346.3	39.0	542.1	61.0	888.4
1981	76.6	7.2	416.5	39.3	642.9	60.7	1059.4
1982	83.8	7.0	461.3	38.4	739.9	61.6	1201.2
1983	99.1	7.5	511.2	38.8	806.8	61.2	1318.0

Table 11.2 : Jordan's Food Foreign Trade During 1964-1983(Central Bank of Jordan , 1984).

YEAR	Food Exports	Food Imports	Trade Balance
	In J. D. Millions		
1964	3.150	14.241	-11.091
1965	3.733	14.974	-11.241
1966	4.062	18.202	-14.140
1967	4.839	14.097	-9.254
1968	5.749	16.238	-10.489
1969	5.743	18.093	-12.350
1970	4.751	18.884	-14.133
1971	3.978	21.465	-17.487
1972	5.003	27.600	-22.597
1973	4.709	30.843	-26.134
1974	10.062	42.360	-32.298
1975	10.732	49.299	-38.567
1976	16.411	81.546	-65.135
1977	18.537	72.216	-53.679
1978	16.892	85.616	-68.724
1979	21.551	100.632	-79.081
1980	24.293	112.636	-88.343
1981	34.040	156.468	-122.428
1982	40.088	177.329	-137.241
1983	36.080	157.103	-121.023

the period 1964-1983. It is estimated that the food deficit grew at 12.6% annually, with wheat imports ranking first among all imported food items. Imports of live animals and dairy products also are rising. A population growth rate of 3.4% annually, and a real improvement in per capita income have enhanced the demand for imported food.

With respect to the problem of cereal production, Jordan's major wheat requirements are met through imports. It is estimated that domestic wheat production covers only one-fifth of the total requirements and most of this wheat is either consumed at the village level or stored for seeds (ICARDA, 1981).

11-3.RAINFED AGRICULTURAL LANDS IN JORDAN

Agricultural land suitable for year-round cultivation is very limited. The major constraint is limited and variable rainfall. About 91% of total land area receives less than 200 mm. This area is technically considered an arid desert and is generally utilized as natural grazing grounds. The remaining 9% of total land area which receive more than 200 mm of rainfall is divided between three agroclimatic zones:

I - Marginal Land : Receives between 200-350 mm and has an estimated area of 563,000

hectares.

II - Semiarid Land : Receives between 350-500 mm and has an estimated area of 136,000 hectares.

III - Semihumid Land : Receives between 500-600 mm and has an estimated area of 99,000 hectares.

Due to limited precipitation, total cultivated area is estimated at about 4% of Jordan's total area, or 400,000 hectares. Nintey-four percent of this area is considered dryland and 7% is partially or fully irrigated. Field crops are the major agricultural commodity and occupy 80% of the total cultivated dryland area ; wheat and barley are the major field crops.

11-4.PRODUCTION ENVIRONMENT IN THE DRYLAND REGIONS OF JORDAN

Two major factors play a substantial role in the process of the development of the rainfed subsector of Jordan . These factors are :

(i) Small farm size and fragmentation of a single ownership, and

(ii) Availability of improved inputs .

11-4.1.Small Farm Size and Land Fragmentation

This problem adversely affects the technical and the

economic feasibility of using modern inputs and services in the rainfed areas and is believed to be one of the principal causes of Jordan's low productivity and a major impediment for the development of the rainfed subsector. Available data indicate that the average size of a landholding in the dry areas is 8 hectares, and this one landholding is divided into 2.5 fragmented pieces. This would reduce the farm size in one location to 3.3 hectares. Apparently this small farm size hinders the use of improved inputs and services such as modern agricultural machinery.

Existing laws give an individual the right to own a land area as small as one dunum (0.1 hectare). Another aspect of this land fragmentation is the law which governs the partitioning of land into single landholdings with a defined border and location. The minimum size of a landholding which can be partitioned into separate holdings is 1 hectare for areas outside city or village limits. Common ownership is one result of this law. Common ownership may be a consequence of either inheritance or purchase. Land owned by an individual passes to his heirs after his death. In 1975 the agricultural census reported the distribution of landholdings by size. Table 11.3 summarizes this distribution. Since 1975 the situation has become worse with increased fragmentation. Annual reports of the Department of Land and Survey indicate that as many as

Table 11.3 : Distribution of Landholding by Size in Jordan During 1975 (Qasem , 1985).

Size of Landholding	Number of Landholding	% of Total
< 10 dunum	12374	24
10 - 29 = =	12226	24
30 - 49 = =	7634	15
50 -199 = =	14123	28
200-499 = =	3359	7
>500 = =	1075	2
Total Number.	50791	100
Total Area.	3904031	
Average Size of a Landholding.	77 dunum	

8830 partitioning transactions took place during the period 1976-1981. Table 11.4 illustrates clearly the increasing trend of land fragmentation in Jordan. It shows that,on the average . each landholding is divided into 3.34 new landholdings during a 6-year period. It is reported that the majority of these transactions were the result of land sales to new owners. Another study revealed that the number of landholdings with an area of less than 20 dunums (less than 2 hectares) was 18,000 in 1975 and increased to 23,000 landholdings in 1983. This means there was a 28% increase in small unfeasible landholdings during 8 years (El-Hurani and Duwayri,1986).

In addition to the decreasing size of landholdings , the expansion of urban areas, the construction of new municipalities in the heart of fertile lands, and the establishment of more infrastructure for these emerging municipalities have led to the loss of the best agricultural land. Available data indicate that about 20,000 hectares of high quality agricultural land have been transferred to urban uses. The inflation of land prices around villages and towns since 1973 has reflected this impact on the utilization of Jordan's dryland and made the economic returns from rainfed agriculture less attractive . Moreover, farmers have altered their land use pattern and now use their productive ,level land to produce fruits and

Table 11.4 : Number of landholdings before and after partitioning during 1976-1981 (Qasem, 1985)

Year	Number of Landholdings Before Partitioning	Number of Landholdings After Partitioning
1976	2657	7033
1977	2445	8313
1978	2898	9853
1979	3028	10298
1980	3160	10744
1981	3480	11832
Total	17668	59070

vegetables instead of field crops.

In conclusion, the current laws foster the increase of small landholdings which are not economically feasible. These laws do not classify drylands on the basis of availability of water resources, agroclimatic zone,or slope. Undoubtedly, these factors affect land productivity and should influence laws regarding the minimum size of a landholding (El-Hurani and Duwari, 1986). Qasem (1986) has suggested a minimum farm size of 20 ha will generate enough income to support a farm family in agroclimatic zones where annual rainfall is 300-400 mm . If farmers use improved inputs , a farm of 60 ha can support a family in agroclimatic zones with less than 300 mm of annual rainfall. Qasem's analysis and estimation of a feasible farm unit assures the need to stop any further fragmentation and suggests, strongly, that the government should issue an agricultural law which prohibits the sale or misuse of designated agricultural lands. To overcome the problem of fragmentation, comprehensive investigations and assessment of all available alternatives would be required. One suggestion is to reaggregate landholdings on a sound farming basis without changing legal ownership . This could be done by forming well-organized cooperatives which would lead to a system of farm size restructuring and a better decision-making mechanism.

Sharecropping , on a large scale, has been suggested as another option . An example of this is leasing a number of adjacent farms to custom farmers who grow field crops and use better inputs . Previous experience indicates that custom farming might not create a better production environment for improved technology, because these lease arrangements usually are short term , that is, for one or two seasons . Consequently , custom farmers ar t motivated to employ modern inputs . Leasing arrangements must be contracted for longer periods to encourage custom farmers to develop these dryland farms and improve cereal yields. The development of adequate contract farming practices and marketing activities would also make it possible for abandoned farm land to be returned to productive use. There is evidence that 34% of agricultural drylands are uncultivated each year . Part of this area is fallowed while a larger part located in higher rainfall zones is simply not cropped because of absentee ownerships and small landholdings.

11-4.2.Availability of Improved Inputs

One of the main requirements for improving dryland agriculture is the availability of inputs and agricultural services in the rural areas where farmers can easily obtain them . This includes the availability of improved seeds,

herbicides, fertilizers, and proper machinery. Unfortunately, private agribusiness is not as interested in investing in dryland areas as it was in the case of the irrigated projects. Reports indicate that the tractor operators are very traditional and run old equipment . The private agribusiness in the rainfed areas has not shown any interest in providing proper machinery such as grain drills and machinery for reduced tillage. The Jordan Cooperative Organization (JCO) runs three machinery stations and provides seed drilling and tillage services to field crop farmers. However, the efforts provided by JCO are small. There is still a shortage of proper agricultural equipment, as well as technical expertise on how to use and maintain it, in Jordan's dryland farming areas. Moreover, the use of chemical fertilizer is still very limited . (see chapter 5 on : Soil Fertility and Fertilizers , in this Monograph).

The present fertilizer production plants in Jordan operate for export rather than to fulfill the needs of dryland farming in Jordan. The Jordan Fertilizer Industry Company (JFI) produces diammonium phosphate fertilizer. Fertilizer requirements for wheat cultivation were estimated by Duwayri et al, (1984). It is interesting to note that imported fertilizers are the only alternative since locally manufactured fertilizers do not provide the required mix of

nitrogen and phosphorus. The adoption of herbicides is also slow in the dryland farming areas of the country.

The general conclusion from this discussion on improved inputs is that farmers can not afford the high cost of these inputs ,especially fertilizers and herbicides. It is believed that cooperatives, through JCO , are more capable of providing these inputs at a lower cost on the farm level than agribusiness .

11-5.CONDITIONS OF DRYLAND FARMERS

Dryland farmers are essentially the ultimate decision-makers when it comes to crop production and adoption of improved technologies. The population of the Jordan drylands region is reportedly the poorest economic class of Jordan's people . This poor standard of living is a general phenomenon within the dryland areas in developing countries, especially the Middle East and North Africa (Gotsch, 1980).

Obviously , the farmers' financial ability to improve their land is very low. The outstanding expansion of education to the rural areas has led to the emergence of a young educated generation seeking employment in urban areas. This has created a situation where elderly people have the responsibility for farming. Furthermore, the availability of good job opportunities in off-farm

employment has measurably reduced the supply of labor in the dryland farming areas.

The economic returns from field crop production are very low. This is basically due to the low yield per planted hectare of wheat. It is estimated that the cost of planting a hectare of wheat by traditional methods is $152. Based on the assumption that the avearge yield is 1 ton/hectare ,it costs a farmer $152 to produce a ton of wheat . If the price received by the farmer is $275 per ton , the gross profit margin would be $123 per hectare, or about JD 4.92 per dunum (Watkins, et al. 1983).

In comparison , the cost of production in the dryland region of the Northwest U.S. (Eastern Oregon) is $136.6 per hectare (Cook et al., 1984-85). The yield of these dryland farms is estimated at 2.3 tons per hectare, reducing the average cost of a ton of wheat to $60. The low yields in Jordan's dryland areas are reflected in the higher cost of production which makes farmers hesitant to use modern inputs. In addition, low economic returns from wheat cultivation have caused farmers to shift increasingly towards planting fruit trees, especially olives and grapes.

Farmers' attitudes towards new dryland cultivation techniques are positive and they appreciate the benefits obtained from these modern technologies . They are also well

aware of the effectiveness of the recommendations,but do not adopt them due to many factors , including the profitability of these inputs.

11-6.REVIEW OF AGRICULTURAL DRYLAND POLICIES

The government of Jordan recognizes the important role of the agricultural rainfed subsector to the Jordanian economy since 93% of the all agricultural lands are considered rainfed land resources.

The first five-year economic development plan (1976-1980) specifically set the following national goals to improve the production conditions and to increase food production:

a. To increase the production of the principal dryland crops by 1980 as follows: wheat, 36%; barley , 25% ;lentils,25%; olives,115%; grapes 110%; and vegetables which are partly produced in rainfed areas by 50%.

b. To increase fodder and forage crop production.

c. To develop improved agricultural methods , supporting and extension services .

d. To change the pattern of utilizing rainfed lands by relating the crops planted to the agroclimatic conditions and to reduce the grain-growing area from 340,000 ha to 240,00 ha,shift about 90,000 ha from wheat to barley, and increase tree plantings.

e. To promote the establishment of agricultural cooperatives in the rainfed areas.

f. To increase livestock production as follows: beef by 100% and mutton by 20%.

This five-year plan did not allocate enough capital resources to improve the production environment in the rainfed subsector. The largest proportion of agricultural investment , about three-fourths of the total , was spent on irrigated projects. The second five-year economic development plan (1981-1985) has essentially restated the same national goals of the first plan for the rainfed subsector:

a. To increase productivity of the dryland sector and accelerate the introduction of farm mechanization.

b. To increase average production of the main field crops (wheat, barley, lentils) by 30%

during the period 1981- 1985.

c. To limit the production of these field crops to those areas most suitable for them.

d. To plant 24,500 hectares with fruit trees, giving priority to lands with greater than 9% slope.

This plan expected to increase total production of field crops from 109,000 tons in 1980 to 142,000 tons in 1985. This meant achieving a total production growth rate of 30% during this period. Actual production averaged 90,000 tons during 1981-1985, a decrease of 18% over previous production. Simply stated , this means that total production of field crops has been decreasing during the past 10 years. To obtain a better understanding of the presently stagnating dryland sector, we need to review the current agricultural dryland and food policies in Jordan. There are three significant policies:

1- Price subsidy for agricultural input ,

2- Price support policy for wheat production , and

3- Price subsidy for bread and wheat consumption .

11-6.1.Price Subsidies for Agricultural Inputs

The government of Jordan provides some general subsidies to the agricultural sector in the form of duty-

free importation of agricultural inputs and machinery. However, all agricultural inputs are sold by private firms who import directly from international companies, so the prices of all these inputs reflect international supply and demand conditions. A number of the projects,which have been subsidized by the government, are aimed at increasing the area planted to fruit trees,especially in hilly regions with steep slopes. The FAO/UNDP program provides consultants, olive tree seedlings and paid food subsidies to farmers planting these trees and incorporating soil conservation measures on their lands.

JCO also provides some inputs to dryland farmers at subsidized prices , but this support is very limited with respect to the size of Jordan's rainfed sector. Fertilizers, herbicides, and machinery are sold to the dryland farmers at high prices. A serious concern has been raised by a case study by Gotsch (1980) in which he concluded that relative output-input prices were moving against the purchase of modern inputs.

Gotsch (1980) calculated the ratio of wheat /fertilizer prices for the period 1967-1976 and found that these relative prices were preventing farmers from using fertilizers. The diffusion of the improved package could be speeded by applying a subsidy directly to the input itself. We believe that the government of Jordan might be

wise to subsidize fertilizer prices if the only alternative is to subsidize large scale wheat purchases from abroad. There must be an emphasis on providing inputs and services at prices which guarantee a reasonable profit margin to dryland farmers. Input price policy for dryland areas must receive more attention by decision-makers .

11-6.2.Local Price Support Policy for Wheat Production

The government of Jordan encourages dryland farmers to produce wheat in rainfall zones of 300 mm and above and in areas with slopes from zero to 8%. The goal of this policy is to increase wheat production in order to reduce the amount of imported wheat. For many years the government has supported wheat prices by offering to purchase domestically produced wheat at a higher price than the international market price. Although this price support program has been practiced by the government for many years, it has never succeeded in reducing imports due to the inefficiency and poor timing of implementation.

Farmers usually have the freedom to sell either to the local merchants or the government. Price supports have not been attractive to farmers or effective in motivating them to increase their wheat acreage.

Previous studies asserted that farmers prefer selling

to local merchants rather than to the government because of the following reasons:

a. The price differential between government support prices and local markets is negligible.

b. The government restrictions on quality, procedures of procurement, and routines of payment do not motivate farmers to sell to the government .

c. The local wholesale merchants usually pay cash to farmers and transport the purchased wheat from the farm.

11-6.3.Price Subsidies for Bread and Wheat Consumption

The Jordanian government subsidizes the wheat consumed by Jordanians. This policy has been in effect for many years. The purpose of this market intervention is to provide bread at reasonably low prices to Jordanians living in urban areas. The government buys most of the required wheat on the world market and sells it to mills at a reduced price in order to control the price of flour and consequently, stabilize the price of bread.

During the 1950s and 1960s about half of Jordan's total wheat requirements were met by domestic production. Foreign donations of wheat were used to fulfill about 25% of the total needs and Jordan imported around 25% of the total

requirements. Since the 1970s, Jordan's direct imports of wheat have risen to about 70% of total annual needs because the local production has fallen to 20% of total needs , and wheat donations have decreased to only 10% to 12% of the total wheat demand. Consequently, a greater burden has been placed on the government's budget and more foreign currency must be allocated to purchase an increasing amount of wheat.

In 1983, wheat was the largest imported food item costing about $95 million. In 1984 the estimated cost for imported wheat was $30 million in contrast to $9 million in 1973 . To help in assessing the Jordanian consumption subsidy, Table 11.5 shows a breakdown of the cost of imported wheat for the period 1981-1983 . This table shows the increase in government budgetary support from J.D. 7.5 million in 1981 to 10 million in 1983.

11-7. CONCLUSIONS AND RECOMMENDATIONS

All Jordanian development plans have placed emphasis on developing the agricultural sector. Although the actual farming is done by the private sector, the government of Jordan assumes the responsibility for providing infrastructures, as well as basic services to facilitate and accelerate agricultural growth. The government grants full exemption from import duties on all agricultural materials.

Table 11.5: Govermental Consumption Subsidy on Imported Wheat in J.D. for the Period 1981-1983 (ACSAD, February 1984).

Item	1981	1982	1983
Price of imported wheat CIF Aqaba.	67.25	64.63	62.43
Total cost of handling.	10.37	10.34	9.46
Total cost of imported wheat.	77.62	74.97	71.89
Government subsidized sales price to millers.	40.00	38.40	37.40
Government subsidy per imported ton of wheat.	37.62	36.54	34.49
Amount of imported wheat (1000 tons).	199.1	249.9	290.6
Total government subsidy for imported wheat (J.D. million)	7.490	9.139	10.023

To protect farmers from the use of low quality imported inputs and potential health hazards, the government regulates the import of certain inputs such as pesticides and other chemicals. It also provides public sources with easy credit to encourage the private sector to enter the farming business.

Despite all these efforts, the performance of the agricultural sector is still weak, and more efforts are needed to increase production, particularly in the rainfed subsector. As stated earlier, agriculture's share in Jordan's gross fixed investment is low and most of this investment has been channeled into the irrigated sector. The rationale of concentrating developmental efforts on irrigated agriculture is quite understandable.

After experiencing several years of drought which had a negative impact on dryland agriculture, Jordan turned its agricultural development efforts to the Jordan Valley, an area of high agricultural potential. The international community reportedly offers the best opportunities for financial support and borrowing for irrigated agriculture .

The present food and agriculture situation demonstrates the necessity of reactivating efforts for the development of the rainfed sector. The future will show an even greater need for developing the dryland subsector as the demands for

wheat and meat increases at higher rates.

The dryland subsector has shown signs of deterioration over the years. The general consensus is that the government has channeled only minimal efforts for the purpose of improving production conditions in the dryland farming region.

Most efforts to date were in the area of research and technology transfer. Dryland agriculture is a low priority for resource allocation .

The rainfed subsector requires more public investment, as well as increased attention from Jordanian higher officials. Specific projects which are involved in actual agricultural production must be developed ,e.g., the Jordan Highlands Agricultural Development Project . This project utilizes a new method and fresh approach in dealing with the issues of production in rainfed areas , especially the provision of inputs and services.

The high cost of producing domestic wheat is due to the low yield of the drylands. This low yield is caused by the lack of improved inputs. Farmers do not use improved inputs because of their high cost and unavailability . This seems like a vicious cycle where low profitability is caused by a high cost of production. The latter is caused by low yields, and low yields are caused by the lack of improved inputs .

A quick remedy is to provide inputs and agricultural services to dryland farmers at the right times , and at reasonable prices, especially with regard to fertilizers, herbicides, and machinery. We stress subsidized inputs rather than subsidized prices to consumers of bread .

In Jordan, providing cheap bread through strong government intervention in marketing, processing, and pricing of wheat flour and bread, has adversely affected domestic wheat production. In addition to improving Jordan's production environment, the government must recognize the factors that influence farmers' decisions to produce field crops including markets, processing, prices of inputs and outputs, and food policy.

From the available data, it seems that there is a clear separation between Jordan's agricultural policy and food policy. A study of Jordan's food policy shows that it is a purely consumer-oriented policy that reflects the government's desire to maintain low food prices rather than the major goal of providing an adequate supply of food, which would require programs designed primarily to expand production.

Estimations of Jordan's future food requirements stress the need for Jordan to work for long-term solutions to reach a higher percentage of food self-sufficiency. It seems that

Jordan, like many other Third World countries, did not recognize the interrelationships among food policy, farm policy, resource policy, and economic development policy, or between agriculture and the rest of the economy . It is imperative that we establish a more consistent national agricultural and food policy which identifies macroeconomic conditions in Jordan.

11-8.LITERATURE CITED

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