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Terminal Report

FAO/NEAR EAST COOPERATIVE PROGRAMME

Republic of Lebanon
Office of the Minister of State for Administrative Reform
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(C.P.S.P.S.)

REGIONAL PROJECT
FOR LAND AND WATER USE
IN THE NEAR EAST AND NORTH AFRICA

PROJECT FINDINGS AND RECOMMENDATIONS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME, 1983

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AFGHANISTAN, ALGERIA, BAHRAIN, CYPRUS,
EGYPT, IRAQ, JORDAN, KUWAIT, LEBANON,
OMAN, PAKISTAN, PEOPLE'S DEMOCRATIC
REPUBLIC OF YEMEN, QATAR, SAUDI ARABIA,
SYRIAN ARAB REPUBLIC, TUNISIA,
YEMEN ARAB REPUBLIC

PROJECT FINDINGS AND RECOMMENDATIONS

Report prepared for
the participating governments
by
the Food and Agriculture Organization of the United Nations

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1983

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1. INTRODUCTION

1.1 PROJECT BACKGROUND

The Near East Region covers a large geographical area within which climatic and soil conditions often limit the use of land for agricultural production. Arable lands make up only 5% of the total area and 19% of the total utilizable land; moreover, the use of land and water resources in most countries of the Region is far from optimal. The recent rise in population has caused increasing pressure on these resources, and has aggravated the imbalance between agricultural production and food demand. The Region has changed from a net exporter of food to a net importer of more than 50% of its food requirements, and current estimates indicate that demand for food grains in the Arab countries of the Near East Region increased by 3.4% annually between 1972 and 1980, largely due to population growth and in some cases to improved purchasing power, especially in the oil exporting countries.

Although expansion in irrigated areas is occurring at a rapid rate, in a number of countries there is no corresponding increase in production. The total irrigated area in the Near East Region in 1962 was some 27 million ha. It has been estimated that it must reach 41 million ha by 1985 if the increasing demand for food is to be met. Because extensive areas of irrigated land have problems of salinity, alkalinity, waterlogging, poor management, etc., their yields are relatively low compared to the potential obtainable with proper land and water use practices. For example, Pakistan has 14 million ha of irrigated land, but in 1975 it was reported that 6.88 million ha had a water table of less than 3 m and were therefore considered 'hazardous areas'; of these areas 3.24 million ha had salinity problems and were described as seriously affected. In Iraq, more than 50% of the lower Rafidaih Plain is affected by salinity and waterlogging, and in the Syrian Arab Republic about 50% of the Euphrates Valley (250 000 ha) is similarly affected. In Egypt about 0.8 million ha or 33% of the total cultivated land has problems of salinity and poor drainage to varying degrees: the newly reclaimed area of about 400 000 ha is either affected already or will be with the advent of irrigation. Alkalinity problems are also present in several countries of the Region, particularly Sudan and Somalia.

The intensity of cropping of irrigated lands varies from a low of 40% to a high of 168%, with an average of 57% if Egypt is excluded from the regional average. Soil and water salinity make irrigation projects costly and unproductive in many parts of the Region, and the intensification of land and water use is as important as the extension of irrigated areas. Many land improvement measures will become economic only if land and water are used more intensively by reducing fallow, using more fertilizers and improving water use and management.

Calcareous soils constitute an important part of the land resources of Syria, Jordan, Lebanon, northern Iraq, Egypt and Libya. These soils are of low fertility, and have been poorly managed in the past. Other countries have large areas of sandy soils that are known to have poor physical and chemical characteristics which limit their utilization.

Further problems relate to a general irrigation efficiency of less than 50%, inadequate drainage, poor water quality, and lack of data on crop water requirements and on optimal cultural practices under both irrigation and dry land farming regimes.

In order to assist the countries concerned to address these problems on a regional basis, in 1967 FAO established its Regional Commission on Land and Water in the Near East. National committees were also set up in the various countries. The Eleventh FAO Regional Conference for the Near East, held in Kuwait in 1972, accorded top priority to regional cooperation in land and water development, and suggested that a detailed programme of studies should be prepared. Following this Conference the Government of Iraq made an offer of US$ 760 000 to finance a regional applied research programme, and the UNDP agreed to undertake a two-year preparatory project designed to prepare a programme of studies. This project started in September 1974, and produced a series of documents concerning the work to be undertaken, the facilities available and the financial contributions expected from the donor governments.

1.2 OFFICIAL ARRANGEMENTS

In October 1976 FAO hosted a Regional Technical Consultation in Islamabad, at which the documents prepared by the preparatory project were reviewed. On the basis of this review FAO was asked to prepare a project document for a longer-term programme designed to promote the coordination of all national, sub-regional and regional activities in the field of land and water use, with the secondary aim of integrating its activities with those of regional projects dealing with field and horticultural crops, animal production, etc.

The project document was duly formulated and was signed by 17 countries. It was completely financed by certain of the participating countries, as follows:

	US$ million
Bahrain	0.25
Iraq	1.50
Kuwait	0.50
Qatar	0.75
Saudi Arabia	1.0

The project was considered to be operational as from 19 May 1977, when the project director was appointed, but field work started in late 1978 with the recruitment of the various experts. Following two extensions, the project was terminated on 30 June 1982.

1.3 OBJECTIVES OF THE PROJECT

The long-term objectives were to help participating countries to achieve better use of their present and potential land and water resources for increased food and fibre production, with the aim of reducing their imports and eventually developing export potential. This goal was expected to be attained through measures such as land reclamation, improvement of problem soils, economic water and land use, soil and water conservation, integrated land and water use for crop and animal production, and upgrading of national skills in the relevant disciplines.

The immediate objectives may be summarized as follows:

(a) To review and evaluate previous research in the field of land and water, so as to determine gaps in present knowledge and identify constraints and new problem areas for a future cooperative research programme by the participating countries in the field of land and water use using standardized methodology and guidelines to be established by the project.

(b) To improve irrigated agriculture through applied research on:
- efficient water use, including improvement of irrigation and drainage methods and the optimal utilization of underground, brackish and sewage water for irrigation purposes;

- reclamation and management of problem soils (salt affected and/or waterlogged soils, alkaline, sandy, calcareous, gypsiferous soils).

(c) To improve dryland farming through the application of proper soil and water conservation methods and management practices in small pilot areas.

(d) As requested by participating governments, to study the efficiency of selected ongoing irrigation and drainage projects in relation to land and water use, identify constraints and suggest remedial measures.

(e) To upgrade national skills in the field of land and water use through training programmes as well as through seminars and meetings at national, subregional and regional levels and the provision of fellowships inside and outside the Region.

(f) To acquire and disseminate the knowledge and experience available within and outside the Region in the field of land and water use.

(g) To strengthen in all possible ways the relevant national institutions, by channelling project activities through them.

1.4 IMPLEMENTATION

The Project Director was based in Baghdad, Iraq. Of the other eight international staff assigned to the project by FAO, four were stationed in Baghdad, two in Qatar, one in Jordan and one in Kuwait (see Appendix 1).

The six fellowship programmes for overseas study arranged by the project are listed in Appendix 2. The major items of equipment supplied are listed in Appendix 3.

The project issued 39 Field Documents; these are listed in Appendix 4. Numerous working papers and discussion documents were also prepared.

In most countries of the Region various activities in the field of land and water use are being carried out through national programmes, with bilateral assistance and under FAO/UNDP projects. The project developed close relationships with some of these programmes, in an attempt to prevent unnecessary duplication through coordination of work and exchange of information. This collaboration was also useful in identifying problems and gaps that should be covered by future projects.

Contact was also maintained with the International Centre for Agricultural Research in the Dry Areas (ICARDA), with the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD), and with other international and regional programmes, in order to enhance the Region's contribution to their research and training activities.

2. ACTIVITIES AND RESULTS

2.1 IMPROVED IRRIGATED AGRICULTURE

It was felt that the imbalance between agricultural growth and food demand was not only due to lack of expansion in cultivated area but also to inefficient agricultural projects that had led to low production per unit of land and water. It was also thought that improvement of irrigation efficiency through the use of suitable methods would contribute to improved production and higher yields. Since higher crop yields are a function of the optimal use of all production factors in an integrated system, the project studies were directed towards an integrated approach.

Research in irrigation was conducted in Bahrain, Cyprus, Iraq, Jordan, Kuwait, Qatar and Syria. At the conclusion of the project some studies were in the third year, while the others were in the second year. The work in Syria was in its first year. Irrigation studies covered measurement of potential evapotranspiration and consumptive use and crop water requirements using (i) different types of lysimeters viz., precision weighing lysimeter, hydraulic lysimeter, drainage lysimeter and (ii) moisture measuring devices like neutron probes, tensiometers, gypsum blocks. Studies also covered (i) methods of irrigation including surface irrigation, sprinkler and drip irrigation, (ii) improvement of water conveyance and management for field crops, vegetables and orchards, (iii) use of water of different quality from different sources - surface, ground and partially treated sewage water - and its suitability for irrigating different crops.

An attempt was made to ensure that the work carried out in any country would benefit the other countries of the Region with similar conditions. For example, data on potential evapotranspiration were not available in Iraq and were very limited in the Region as a whole. A high precision weighing type lysimeter was therefore installed at Al-Raed Experimental Station in Abu-Ghraib, Iraq. In addition drainage type lysimeters, hydraulic lysimeters and meteorological instruments were set up. The measured data were correlated with the weather parameters and compared with the values of potential evapotranspiration estimated by commonly used formulae. These data can be used in Iraq and in other arid countries of the Region.

Although no definite conclusions can be made on the basis of one and/ or two seasons' data, from the results of the investigations carried out under this project, useful information was obtained. The salient features are given below.

2.1.1 Measurement of evaporation and potential evapotranspiration under the arid conditions of Central Iraq

Available data on evaporation from various standard devices were reported for four sites in Central Iraq, namely the Baghdad Airport, Abu-Ghraib (Raed), Khalis and Wahda Stations. For these sites the meteorological data were used to calculate potential evapotransporation by Penman and Blaney-Criddle original formulae and by four methods given in FAO Irrigation and Drainage Paper No. 24, 1977. These four methods are the Penman, Blaney-Criddle, Radiation and Pan Evaporation methods.

Measurement of Reference or Potential Evapotranspiration rates was initiated in May 1981 using grass-covered lysimeters surrounded by a buffer area of grass under sprinkler irrigation.

The average evaporation from a Class A pan located at the Baghdad Airport was 3 610 mm per year while at Abu-Ghraib (Raed), which is only a few kilometres from the airport, the average yearly evaporation was 2 807 mm. The 28% difference in evaporation rate was mainly due to differences in the pan environment at the two sites, with bare dry soil at the airport and irrigated grass at Abu-Ghraib. Even at Abu-Ghraib, the irrigated grass field was not sufficiently extensive to represent the conditions of a large irrigation scheme. The pan environment should be properly identified before selecting the appropriate pan coefficients to calculate potential evapotranspiration.

The average evaporation for the four-year period 1977-81 at Abu-Ghraib Experiment Station was 3 366, 2 710, 2 290 and 2 179 mm per year from the piche Class A pan, Class B pan and Class C pan evaporimeters respectively. The peak monthly rate occurred in July with 16.6, 14.6, 11.8 and 11.4 mm/day. Evaporation rates calculated by Penman equation were much lower than those from Class A pan and even of the sunken pans (Class B and class C pans). This is due to the advection effect in an arid region such as Central Iraq.

Yearly and monthly evaporation from sunken pans (Class B and Class C pans) was almost equal to Reference Crop Evapotranspiration (ETo) calculated by the four methods. For a given year (1980), ETo based on the pan evaporation method was 2 297, 2 154 and 1 963 mm depending on the pan used. The lowest value of 1 963 mm is based on a white-painted, exposed class A pan which is known to have higher reflectivity to solar radiation. The use of standard coloured or aluminium paint is recommended. The average peak monthly rates of reference crop evapotranspiration (ETo) were about 11 mm/day, when based on standard Class B and Class C pan evaporimeters.

Comparing average ETo (1968/78) calculated for Abu-Ghraib by the four methods given in FAO Irrigation and Drainage Paper No. 24, 1977, showed very good agreement except for two months, in May and June. The estimated ETo based on the Penman, Blaney-Criddle and Radiation methods was 2 046 mm per year. ETo estimated from Class A pan was 7% lower. The trend for greater monthly discrepancies in May and June was not obvious in all cases. Examples were shown with discrepancies occurring in July or August. July rates calculated by the four methods ranged from 9.7 to 10.6 mm/day. For Khalis Station, the average ETo for the period 1974/81 by Penman, Blaney-Criddle and Radiation methods was 2 067 mm per year. ETo estimated by the Class A method was 6% lower. July rates calculated by the four methods ranged from 10.2 to 11.3 mm/day. From Wahda Station, the average ETo for the period 1977-81 by Penman, Blaney-Criddle and Radiation methods was 2 184 mm per year. ETo estimated by the pan evaporation method was only 1% lower, but the July rates calculated by the four methods ranged from 9.4 to 11.4 mm/day. Discrepancies of winter values were less critical. It is suggested that the reason(s) for these discrepancies should be studied by checking further the accuracy of the meteorological data used.

First year measurement of potential evapotranspiration with the precision weighing lysimeter at Abu-Ghraib showed average rates of 9 mm/day from mid-July to mid-August 1981. Daily rates of 11 to 14 mm or more were recorded during the same period, in most cases after the grass was irrigated by sprinklers. Daily evaporation rates from Class A pan reached 18 to 20 mm. Yellowing of grass in the lysimeter, due to leaching of fertilizers in the drainage-type lysimeters, reduced markedly the evapotranspiration rates. Winter dormancy of the Bermuda grass also reduced evapotranspiration below ETo estimates by the four methods given in FAO Irrigation and Drainage Paper No. 24, 1977.

On a yearly basis, the estimates of ETo by the original Blaney-Criddle formula and the one given in the FAO paper were 1 843 and 2 041 mm respectively. The difference was 10%. However the original formula underestimated ETo by 35% during the summer period and overestimated it by 45% during the winter period. This represents a serious limitation of the original formula for irrigation planning and design.

During summer the ratios of measured potential evapotranspiration to evaporation from sunken pans (Class B and Class C pans) ranged between 0.9 and 0.95 and for Class A pan the ratio ranged between 0.6 and 0.65. These values agree well with the values recommended as pan coefficients for summer conditions in semi-arid to arid areas in the FAO Irrigation and Drainage Paper. The ratios are highly affected by the percentage of ground cover and the colour of the grass. The ratio decreased to 0.4 and 0.5 when grass started yellowing and became 0.2 to 0.3 in November and December when the grass was dormant. Ratios for the bare wet soil prior or immediately after grass planting (10% ground cover) were 0.5 and 0.65 for Class A and sunken pans (Class B and Class C pans) respectively.

It is important to start recording hourly ETo values from high precision lysimeters and climatic parameters, including solar and net radiation, in order to fully utilize the lysimeter at Abu-Ghraib station, which provides an excellent tool for irrigation research in an important arid region of the world.

From these lysimeter studies the following conclusions could be drawn:

(a) grass mixtures should be used that remain green throughout the year;

(b) adequate supplies of water and nitrogen should be applied to maintain a green actively growing grass cover;

(c) grass height should be maintained at between 8 and 15 cm;

(d) sprinkler irrigation should be applied at night and under low wind velocity conditions;

(e) the work should be continued for another two to three years for testing accuracy of the evapotranspiration estimates by different formulae;

(f) based on the average of 11 years data obtained at Abu-Ghraib (1968-78), potential evapotranspiration calculated by the original Penman equation was 1 499 mm/year; or 76% of the ETo calculated by the modified Penman method given in the FAO Irrigation and Drainage Paper. During the summer period, the original estimated ETo by Penman method was 22% lower than the modified Penman formula;

(g) modification of wind functions in the Penman method, suggested by Al-Nakshabandi and Kijne (1979), needs further work using the grass-covered precision lysimeter of Abu-Ghraib;

(h) standard coloured or aluminium paint should be used for painting the evaporation pan.

2.1.2 Water and fertilizer requirements of corn in Central Iraq under surface irrigation

By international standards, yield of grain corn is very low in Iraq. Most experiments report yields of 2-4 t/ha with irrigation and fertilizer application. Much lower yields are obtained on farmers' fields. The severity of the climate, the soil constraints and the low level of management are the major factors limiting crop yield. The purpose of this work was to demonstrate that yields in the order of 8 t/ha can be obtained in field plots with correct soil, water and crop management. While an integrated approach was used in providing the package of inputs required, the role of fertilizer combined with timely irrigation was highlighted.

The field was chiseled to improve water infiltration, soil aeration, nutrient uptake and root development. Spring planting was avoided to prevent pollination from coinciding with the excessive summer heats. Planting was done in late July with good seeds at the water line of well levelled and well shaped furrows. Frequent wetting of the soil surface was required to control surface crust and soil salinity during the germination and seedling stages. Observations indicated that a 20-50% reduction in yield resulted from poor plant population stands.

A double split-plot design was used to accommodate three irrigation treatments (non-stress, slight stress and stress), three manure levels (zero, 20 and 40 t/ha) and three fertilizer levels:
(120 N + 80 P + 60 K; 160 N + 120 P + 60 K and 200 N + 160 P + 60 K).
Tensiometers and gypsum blocks were used to schedule irrigation and the water use was determined by the standard oven-drying method.

From this work the following conclusions were drawn:

(a) the lowest level of fertilizer used in the experiment, 120 N + 80 P + 60 K/ha, may be considered higher than the commonly used rates in the country. Under good practices of soil, water and crop management 7.3 t/ha of grain corn were obtained with this fertilizer level;

(b) by increasing the fertilizer level to 160 N + 120 P and 60 K or by adding 20 t/ha of manure to the lowest fertilizer level, the yield of grain exceeded 8 t/ha;

(c) higher fertilizer application of 200 N + 160 P + 60 K kg/ha, with or without addition of manure, did not produce any further increase in grain yield, though the fresh weight of the cobs increased;

(d) under stress irrigation, when 90% of the available water was depleted in the effective root zone (60 cm), 7 000 m^3/ha of water were used. Grain yield in the order of 4 t/ha was obtained, irrespective of the fertilizer level or the addition of manure;

(e) for high yields of summer corn in Central Iraq, 9 000 m^3/ha of water was required in 14 to 15 irrigations. Irrigation scheduling at 75 cbars soil moisture tension at 20 cm soil depth proved to be satisfactory. This corresponded to a 6 day irrigation interval from planting till the beginning of grain ripening. A shorter interval may be required during germination, emergence and seedling stages to control soil crust;

(f) fertilizer use efficiency per unit of NPK reached 24-28 kg of grain corn in this experiment, while in most of the previous work in the country it ranged from 8-18 kg of corn per kg NPK;

(g) the water use efficiency in this trial reached 0.90 kg of grain corn per cubic metre of water, while in most previous work it ranged from 0.2-0.4 kg/m^3.

It was concluded that there is a need for increasing the crop coefficient of corn as given by Doorenbos and Pruitt by 25% during the development and mid-season phases. The required increase was found to be much higher during the crop establishment phase occurring in late July and early August to control soil crust and allow good germination and population density. This work demonstrated that 8 t/ha of grain corn or more could be obtained on field plots; the remaining challenge is to realize this on a production scale on state farms using large pilot fields and on farmers' fields. This will entail an integrated approach where all inputs are provided in the optimal amounts.

2.1.3 Irrigation methods

2.1.3.1 Trickle irrigation

In the last five years trickle and drip irrigation has been introduced on some 500 ha in Iraq. This area is likely to more than double in the very near future if solutions to certain problems are found. The project expert supervised a study on the performance of a trickle system used on a reclaimed but resalinized soil in Central Iraq. The system was monitored for three years. Monitoring covered the trickle system itself, plant growth, soil moisture tension and salt distribution in the root zone of a young vineyard. The effect of progressive clogging of the emitters by calcium precipitate on water distribution uniformity, soil salinity built up in the root zone and root development was illustrated. Emitter clogging and vulnerability of the system to pump breakdown are the major constraints of the drip irrigation system, assuming the requisite knowledge of crop water requirements for adequate irrigation scheduling.

Soil salinity ECe in most of the root volume below the emitters was maintained between 2 and 4 mmho/cm while at the soil surface it reached 20-30 mmho/cm at 40 cm from the emitters. ECe of 10 to 15 mmho/cm or more was measured outside the wetted zones and below the soil surface. Equations for the advance of wetting front and for the emitter discharge were derived from field data.

It was concluded that with the surface ditch water used, acid treatment (0.5% HCl) and periodic flushing were essential to maintain high emission uniformity and therefore high application efficiency. Frequent stretching of the precoiled microtube emitters was needed, as well as frequent emitter replacement. With these constraints, and with periodic adjustment of the irrigation duration to apply enough water to the least watered areas, excellent plant growth was obtained.

An application of 1 700 m^3/ha of water in the first year and 3 500 m^3/ha in the third year were considered satisfactory. During the second year, an irrigation application of 5 400 m^3/ha was considered excessive.

For the commonly used Iraqi local grape variety 'DEISS AL-ANZ' and for the performance of the system used, a rule of thumb was determined for irrigating the young vineyard and controlling soil salinity, namely: 3.6 litres/cm^2 stem cross-section area (Area) per cm of evaporation from Class A pan for the first year, 2.7 litres/cm^2 stem cross-section area per cm of evaporation for the second year and 1.3 litres/cm^2 stem cross-section area per cm of evaporation during the third year. An even simpler approach was to apply 5, 7 and 9 litres/cm of stem diameter per cm of evaporation from Class A pan for the first, second and third years respectively. Achieving a good depth and spread of vineyard rooting by adequate wetted patterns is essential for reducing the vulnerability of the system to any pump breakdown or delays in irrigation.

Soil salinity in the root zone was well controlled by the operation of the system and grape growth was excellent.

The project expert, in collaboration with the specialist of the Cyprus Agricultural Research Institute, recommended the introduction of a drip system along with minisprinklers for the irrigation of orchards in Syria. Interesting work on sprinkler and drip systems was also carried out by the University of Jordan, the project counterpart agency, and by the Agricultural Research Institute of Cyprus.

2.1.3.2 Drip irrigation of cardinal grapes (Cyprus)

This experiment was initiated in May 1977 with cordon-trellised Cardinal grapes planted at 2.4 x 2.4 m. Irrigation treatments consisted of four amounts of water applied twice and once a week. Water was applied by drippers, three per plant, installed in an irrigation line along the vine row. Each dripper delivered 6 litres/h at one atmospheric pressure head.

During the 1977 and 1978 irrigation seasons, the four amounts of water tested were equivalent to 0.2, 0.4, 0.6 and 0.8 times the evaporation from open pan. The results showed that there were no significant differences in yield between irrigation treatments, so from 1979 onwards an unirrigated treatment was included and the four amounts of water tested were modified as following: no water, 0.25, 0.50 and 0.75 times the evaporation from open pan. Irrigations started when the vines were at the flowering stage (late April-early May) and ended just before the first picking (late June-early July).

During the first year of the study irrigating every week gave significantly higher yields than irrigating twice a week. However, this was not observed during the following four years of the study (1978-81).

All the amounts of water tested gave the same yield during the first four irrigation seasons (1977-80), but in 1981 the lowest amount tested gave significantly lower yields compared to the two higher amounts of water. The unirrigated treatment in all seasons gave significantly lower yields. In four out of the five years of the study an amount (depth) of water equivalent to 0.2 to 0.25 times the evaporation from open pan (1 100 m^3/ha) was enough for a good yield. It was concluded that under the conditions of the experiment, with clay soil throughout the profile to 150 cm depth, and maximum evaporation of 7.5 mm/day in July, drip irrigation should be applied once or twice a week.

2.1.3.3 Drip irrigation of greenhouse tomatoes (Cyprus)

During the 1978/79 and 1980/81 growing periods the evapotranspiration of tomato plants grown in unheated greenhouses was measured with plants grown in lysimeters. Seedlings of cv Virosa were planted in early October and transplanted in December at 45 cm interplant spacing in rows 90 cm apart. In 1978/79 the four amounts of water tested were 0.6, 0.8, 1.0 and 1.2 times the reference crop evapotranspiration (ETP) whereas in 1980/81 only three amounts of water were tested and these were 0.6, 1.0 and 1.4 times ETP. Irrigations were applied when ETP cumulated to 6 or 18 mm.

In both seasons the lowest amount of water applied (0.6 x ETP) significantly reduced tomato yield, whereas no differences in yield were found with the higher amounts of water applications.

The frequently irrigated plants (1980/81) gave significantly larger fruits, but the total number of fruits produced was the same under all treatments.

It is recommended that evaporation data from Class A pan should be used as the basic guide for irrigation of greenhouse tomatoes, and for open field crops.

Similar experiments are being carried out in Cyprus on cucumbers and on olives and avocadoes. Some useful results have been obtained, and the work will continue in order to achieve more reliable conclusions.

2.1.3.4 Sprinkler irrigation system

The project encouraged the use of small, low pressure sprinklers for the irrigation of fruit trees at Sahsah in Syria, along with a drip system and surface methods. The equipment was ordered through FAO and delivered on site only in the spring of 1982. It is hoped that the 4 ha field will serve for applied research, training and demonstration in improved irrigation practices. In Iraq a preliminary assessment of different sprinkler irrigation systems, including hand moved, centre pivot, hose pull, grid and self-propelled rainguns, was made by the General Agricultural Organization at Khalis experimental station. Initially good results were obtained with hand moved systems but the subsequent results with all systems were disappointing, mainly because of poor maintenance and shortage of trained staff in addition to technical problems. The project expert visited the various systems at Khalis and found in general poor crop growth.

Applied research on different irrigation methods and water requirements of fruit trees and vegetables is in progress in Cyprus. It includes work on grapes, olives and citrus, tomatoes, potatoes and other vegetables. Methods of irrigation include minisprinklers, drippers and bubblers. Different types and numbers of nozzles and materials and different arrangements are being tried in order to find the most suitable irrigation system for the growers. The effect of rate of water application and the intervals of irrigation on yield, quality and size of fruit as well as the effect on the growth of trees and the accumulation of salt in the soil are being studied. Useful data have been obtained but the experiments will be repeated to obtain more conclusive results.

The valuable work being done in Cyprus can be of great benefit to the Mediterranean countries of the Near East Region such as parts of Jordan, Lebanon, Tunisia, Algeria and Morocco. Some of the results obtained so far are given below.

i. Grapefruit irrigation with minisprinklers

In this experiment three irrigation frequencies were tested. These included irrigation application when the evaporation from Class A pan cumulated to 25, 50 and 100 mm. Irrigation was by one minisprinkler per tree delivering 150 litres/hour to an area of 250 cm radius. The electrical conductivity of irrigation water was 1.4 mmho/cm, having 160 ppm of chlorides.

In 1981 irrigation started on 22 April and concluded on 11 November with the onset of the rainy season. The same amount of water was applied with all three frequencies (7 725 m^3/ha). The total number of irrigations was 52, 27 and 15 corresponding with cumulated evaporation of 25, 50 and 100 mm. The number also included two common irrigations in late April/ early May. Yields were identical under the three treatments (1 011 fruits per tree, weighing 305 kg/tree or 117 t/ha). Considering the age of the trees (grafted in October 1981) these yields are very high.

Tree girth increased more with more frequent irrigation.

Soil salinity observation at the beginning and the end of the irrigation season indicated that salts accumulated in the top 90 cm of the profile only with the most frequent irrigation.

ii. Lemon irrigation experiment, Yeroskipou

This experiment was initiated in spring 1981 to test the effect of two frequencies of irrigation and three amounts of water on the growth and yield of lemon trees grafted in 1973.

All trees were irrigated with minisprinklers delivering 150 litres/hour at 2 atm pressure head, wetting a circle of 250 cm radius. The electric conductivity of irrigation water was 0.7 mmho/cm with 70 ppm of chlorides. Irrigation was initiated on 22 March and was concluded on 6 November. The total amount of water applied was 14.1, 18.3 and 21.9 m^3/tree, equivalent to 0.18, 0.24 and 0.30 of the evaporation from open pan. Trees irrigated with the different amounts of water developed different growth patterns. An application of 14.1 m^3 of water per hectare resulted in trees with more compact and very limited new shoot growth, whereas an application of 21.9 m^3 of water per hectare showed more new shoots. Girth during the period of 8 April to 9 November clearly increased with increasing amounts of water applied. The number of irrigations for the most frequently irrigated trees was 39. Under this treatment trees were irrigated when evaporation from open pan was 50 mm in April-May, 37.5 mm from 9 June onwards and 25 mm from 7 September onwards. Trees under less frequent irrigation schedule received a total of 20 irrigations.

Frequency of irrigation did not influence fruit yield. Only the lowest amount of water applied clearly delayed fruit maturity.

iii. Comparison of drip minisprinkler irrigation in newly planted citrus (Cyprus)

During the 1981 irrigation season 24 irrigations were applied, spaced at every 50 mm of accumulated evaporation from open pan. The first irrigation was applied in early May and the last in early November. Till August common irrigations of 135 litres/tree were applied to all citrus varieties. It was observed that the water requirement of lemons was more so the amount was increased to 200 litres/tree/irrigation compared with 170 litres/tree/irrigation for the other three varieties. The total amount of water applied was 3.7 m^3/tree for Valencias, Navels and grapefruit, and 4.1 m^3/tree for lemons.

The general appearance of lemon trees (new growth and the colour of leaves) and the trunk increase of lemon and grapefruit trees were affected by the treatments. The same volume of water applied on a smaller area resulted in better tree growth. Four drippers/tree were superior to 6 drippers/tree. This can be attributed to (i) the higher efficiency of water application by drippers and (ii) a limited weed growth with the trickle method. It is evident that more water has to be applied when a larger soil area is wetted, as with the use of minisprinklers.

Where conditions are similar to those of the experiment, such as the rather heavy soil in Cyprus, it is recommended that the drip system be used instead of minisprinklers. It is also recommended that the water be applied within a smaller area instead of wetting a larger area.

2.1.3.5 Basin irrigation of date palms

An irrigation experiment using basin irrigation was conducted in the date palm grove of the Zafaraniah Horticulture Station near Baghdad, in collaboration with the FAO Regional Project for Palm and Date Research and the Horticulture Department, Ministry of Agriculture. The basin irrigation at different levels ranged from severe water stress through intermediate moisture condition to no stress in the top metre of the soil. The date palm orchard was on levee soil with a water table ranging between 3.70 and 3.90 m; the capillary rise affects the root zone below 1.0 m.

Some of the first season (1980) results and conclusions are as following:

(a) Class A pan evaporation and reference crop evapotranspiration ETo were 3 200 and 2 140 mm respectively. The crop coefficient (Kc) should account for the date palm water use from all the effective root zone. It should include the estimated contribution from the water table. The monthly Kc values ranged from 0.75 to 1.00 with a seasonal average of 0.853. Evapotranspiration of date palm = 0.853 reference crop evapotranspiration. The total net water use was 18 250 m^3/ha/year divided as follows:
   - 1 200-1 300 m^3/ha from irrigation
   - 750-1 250 m^3/ha from rain
   - 450-550 m^3/ha from water table.

(b) For three varieties out of four, the increase in seasonal leaf elongation averaged 30% in the non-stress treatment of 10 irrigations/year as compared to the stress treatment of 4 irrigations/year. In the intermediate treatment with 7 irrigations/ year the increase ranged from 3 to 14%.

(c) Fruit weight increased by 21% in the medium stress and 47% in the non-stress over the stress treatment; varietal differences in response to improved irrigation scheduling were shown as well as trends to increased total yield. Large deviations of yield within treatments were observed as a result of the past history of the trees. Since soil water conditions in 1980 will affect the number of fruit bunches in 1981, the experiment will continue for another two years in order to verify and complete these preliminary results.

2.1.3.6 Improved surface irrigation methods

The project expert wrote an outline for the establishment of a demonstration/training field using various surface irrigation methods for Wahda experimental station, with borders 10 m wide, 200 m long, with 0.1, 0.2 and 0.3% slopes, and furrows of different slopes and basins of different sizes. The project requested that the supply ditch be concrete lined with appropriate water structures (Neyrpic type gates) allowing controlled stream flow from 10 to 60 litres/s.

While the efficiency of surface irrigation methods is usually very low in the Region, reports from Phoenix, Arizona show that under similar climatic and soil conditions water distribution efficiency exceeding 90% can be achieved by absolute level basin irrigation. The project employed a consultant to advise on the design and implementation of such level basins. Laser controlled levelling equipment was obtained, and the consultant visited the sites and made his recommendations, which were also presented in a seminar.

It is recognized that the basic problem with the adoption of improved surface irrigation in the Region is the need for yearly land levelling and an appropriate organization and/or equipment service to do the work. Government agencies usually reclaim the land, do the grading once and hand over the graded fields to farmers or state farms. After a single cropping season the land needs regrading, but there are no organizations available for this task. As a result the irrigators revert to traditional irrigation by breaking down the sizes of the initially graded fields to control water in small basins. It is therefore recommended that governments establish agencies to do the relevelling or help in the creation of cooperative organizations for this task, otherwise the initial investment will be lost.

2.1.3.7 Conveyance of irrigation water

In Kuwait, Bahrain and Qatar surface irrigation is very wasteful of precious water. Surveys were conducted to assess the losses sustained in this way, and demonstrations were organized to show the advantages of modern irrigation methods in saving of water and labour and in increasing yields.

It was found that total avoidable losses of up to 25% (the equivalent of 35 million m^3/annum) occur through the use of unlined canals, in conveyance and in overirrigation. Conveyance losses are high in spite of relatively short distances. It was also found that in addition to saving precious water farmers can obtain direct benefits, equal to BD 250/ha/annum, as follows:

(i) Saving in pumping cost: BD 50/ha/annum

(ii) Saving in labour for irrigation: BD 30/ha/annum

(iii) Reduction in weed control cost: BD 20/ha/annum

(iv) Increased production and profit: BD 120/ha/annum

It was concluded that the water conveyance should be in pipes in order to eliminate these losses. The total length of the distribution network should range from 100 to a maximum length of 280 m. Different conveyance materials were considered and PVC pipes with galvanized iron fittings and risers were recommended for use in sandy and permeable soils. Legislation is recommended to compel farmers to convey water by pipes, with or without government subsidy. Education via the mass media should be used to convince the farmers of the benefit of conveyance of water by pipes.

2.1.3.8 Efficient use of water

All the work done by the project aimed at more efficient use of irrigation water and more production and profit to farmers per unit of water and land. The research aspects covered determination of water requirements of crops, leaching requirements of soils, suitable intercropping patterns, optimal plant populations per unit area, and of methods for the modification of microclimates by mulching and/or windbreaks.

By reducing the distance between rows of tomatoes from 3 to 1.5 m the yield increased from 20 to 40 t/ha and the income increased from BD 2 000 to 4 000/ha. Proper scheduling of irrigation saved 30% of the irrigation water. The water applied reduced from 71 cm total depth to 50 cm.

Intercropping of radish with tomatoes increased overall production with the same water quantity, resulting in BD 4 600/ha, more income as compared to the pure cropping of tomato.

Investigations revealed that 20-40% water can be economized in the northern part of Qatar with good yields and maintenance of soil fertility even with the present surface irrigation, simply by proper irrigation scheduling without any investment in sophisticated equipment. In addition to water economy, 40-200% higher yields over the state average were obtained in different crops in field trials. For example 45 t/ha bulb onion were harvested, compared to 15-18 t/ha obtained by farmers, without additional inputs over the usual cultural practices. In addition there was saving in resources. In Qatar it was also found that growing cabbage, cauliflower and onions on the flat instead of on ridges produced better yields and maintained a better salt balance in the soil.

The sand dunes of south Qatar are the potential area for expanding agriculture, although the available water is highly saline (EC 5 000 micromho/cm). In field experiments in Wadi Alarieg it was possible to produce 15-20 t/ha green forage (over 200 t/ha/year) with 600 mm depth of water. It is expected that savings of up to 60-90% can be made with sprinklers (farmers apply 1 200 mm per year in surface irrigation). The national average for fodder production on better soils is 80 t/ha/year only.

Rhodes grass was introduced in Qatar for the first time. It gave excellent results in coarse sandy soil irrigated with saline water (3 500 ppm) under very hot conditions. The grass was cut every 22 days, and had an average green weight of 30-35 t/ha. In comparison, tall fescue gave 11-12 t/ha. Alkali Socation and displachne gave 8-10 t/ha. Alfalfa under similar conditions was cut every 26 days and gave 20 t/ha per cutting.

Mulching with white plastic, black plastic and date palm fronds helped to reduce evaporation from the soil and made it possible to use drip irrigation on the heavy, calcareous soils of Qatar without the danger of salinization of the root zone, although salty water containing 2 000-2 500 ppm was used for irrigation.

Modification of the microclimate by the use of windbreaks in Qatar and Bahrain also reduced evaporation from the soil and thus reduced salt accumulation in the root zone.

It was concluded that the efficiency of water use can be improved by simple, inexpensive methods such as increasing plant populations, reducing the distance between plants within the row and between rows, proper scheduling of irrigation and applying only the amounts needed. Another way to raise water and land use efficiency is the intercropping of a short period crop with a long period crop, such as onions with tomatoes and okra with cucumbers.

2.1.4 Water quality studies

The scarcity of good quality water makes it necessary to use water of poor quality pumped from underground and partially treated sewage water; studies were therefore made on the response of different crops to water of different qualities from different sources.

2.1.4.1 Effect of partially treated sewage water on salinity and potato yields

Partially treated sewage water is available in Kuwait and will soon be available in Qatar and Bahrain; this study was made in Kuwait to take advantage of the availability of such water and other facilities.

Five rates of water applications were made which included 70, 105, 140 and 170% of the calculated values. First year results showed an increase in yield from 12.3 t/ha from the lowest rate to 16.6 t/ha with no leaching treatment to the highest leaching rate. This was despite the fact that the crop was sown on 10 January 1980 due to late arrival of seeds from the Netherlands, and that a severe aphid attack occurred during the third week of March.

The yield of potatoes in the 1980/81 season showed an increase from 27.9 t/ha under no leaching to 32.4 t/ha under 175% leaching application. The second year crop suffered from disruption of the regular irrigation schedule owing to damage to the main supply pipe, which was out of action for 20 days during March. Supply of irrigation water by tanker was not satisfactory.

The following tentative conclusions can be drawn from the results of the two seasons' data:

(a) Partially treated sewage water with salinity up to 2 300 ppm can be used successfully for raising potato crops on sandy to loamy sand soils without shallow impervious layers.

(b) Under no leaching treatment the average soil profile salinity increased at all depths except at 0-15 cm and 15-30 cm, where it decreased slightly during 1979/80. The overall average salinity of the whole profile showed an increase of 5.9% during 1979/80 and 12.5% during 1980/81.

(c) Soil salinity decreased up to 60 cm depth under 70 and 105% leaching applications, but salt accumulation occurred at 60-90 and 90-120 cm depths. The overall average soil profile salinity decreased by 8-9% during 1979/80 and 6-18% during 1980/81.

(d) Under 140 and 175% leaching treatments, the average soil salinity showed a marked decrease at all depths. The overall average soil profile salinity decreased by 22.23% with 140% leaching application and by 29-37% with 175% leaching application during the 1979/80 and 1980/81 seasons.

Partially treated sewage water may be used for the production of potatoes under good water management. However, the leaching requirements must be taken into consideration and more than the calculated value of water should be applied to avoid soil salinization.

2.1.4.2 Water quality, leaching requirements, salt distribution and salt tolerance of tomato in Kuwait

Irrigation water of 700, 3 000 and 6 000 ppm salinity was used to study salt distribution and salt tolerance of tomato on a virgin sandy to loamy sand soil. Calculated quantities of water of different salinities were applied to assess crop consumptive use, without leaching and with leaching of 33.3, 66.6, 100 and 133.3% of the calculated leaching requirements.

The tentative conclusions drawn are given below:

(a) Irrigation with fresh water (700 ppm) made little or no change in soil salinity before and after harvest under different leaching treatments. Soil salinity ranged from 2.0 to 3.5 mmho/cm.

Irrigating with water of 3 000 ppm salinity, the average soil salinity increased under all leaching treatments. However, the increase in soil salinity under 133.3% was minimal and under no leaching treatment maximum. Average soil salinity at harvest ranged from 3.5-4.8 mmho/cm. At sowing, the average soil salinity range was 2.5-3.5 mmho/cm.

(b) Irrigation with water of 6 000 ppm salinity raised the electrical conductivity of the soil under all treatments. Again increase in soil salinity under 133.3% leaching was the minimum and under no leaching treatment the maximum. Soil salinity at harvest ranged from 4.0 to 5.0 mmho/cm whereas soil salinity at sowing ranged from 2.5-3.5 mmho/cm.

These studies should be pursued to obtain adequate data to enable irrigation engineers and agronomists to issue farmers with bulletins giving recommendations on the amount of water to be applied to crops and the proper water management practices to be followed. The provision of higher leaching applications is essential as the salinity of the water increases.

2.1.4.3 Salt tolerance of different grasses using highly saline groundwater

Salt tolerance of Tall Fusca Alta, Tall Fusca Goars, Tall Wheat, Seitch,Orchard, and Alkali Scation was studied on a non-saline sandy soil using 6 000 ppm salinity groundwater in Kuwait.

The germination percentage of Tall Fusca Alta, Tall Fusca Goars and Seitch was 90 to 100%, Orchard and Tall Wheat grass about 50% and Alkali Scation about 20%. Alkali Scation died but started tillering again in March 1981. The first cutting was made on 13 April 1981, and yields were Tall Fusca Alta 14.4, Tall Fusca Goars 15.0, Tall Wheat 15.4 and Orchard 13.3 t/ha. Alkali Scation and Seitch grasses did not give any yield. Five cuttings were obtained during the period from July to November. The total yields of various grasses recorded by the end of November were 18.6, 36.2, 29.3, 6.8 and 50.6 t/ha for Alkali Scation, Tall Fusca Alta, Tall Fusca Goars, Seitch and Tall Wheat grasses, respectively.

It was hoped to find a suitable salt tolerant fodder grass to be used in the Arabian Gulf States to augment alfalfa, which is at present the most important if not the only fodder crop. However, it is clear from the results of this study that none of the grasses tried can compete with alfalfa as a fodder.

2.1.4.4 Monitoring of salt movement in the soil under sprinkler irrigation using partially treated sewage water

Three 36 m^2 sites were selected in an alfalfa field to monitor salinity changes under sprinkler irrigation with 2 300 ppm salinity sewage water in a virgin non-saline sandy soil. The first site was at the highest elevation, the second on the slope and the third at the lowest spot in the field.

From April 1980 to April 1982 alfalfa yields of 23.9, 24.2 and 24.6 kg/m^2 were obtained from the highest, the middle and the lowest spots respectively. The average electrical conductivity of the soil profile at the highest spot first increased from 0.96 mmho/cm in October 1979 to 4.18 mmho/cm in July 1980 but decreased to 1.11 mmho/cm in March 1981 (after rains). Thereafter it again increased to 1.74 mmho/cm in June 1981. In the middle spot, the electrical conductivity first increased from 0.77 to 3.3 mmho/cm, but dropped to 1.38 in March and subsequently increased to 1.48 in June 1981. Similarly, at the lowest spot the electrical conductivity of soil increased from 0.69 to 2.70 mmho/cm initially, decreased to 1.55 in March and increased to 2.11 in June 1981.

It was concluded from this study that differences in yield and changes in salinity were negligible between sites with the exception of salinity increase at the upper spot during the first summer, which may indicate that the water runs off to the lower spots. More water may be applied to the upper spots where the slope is steeper, but it should be given at a lower rate to allow it to percolate into the soil instead of running down to the lower spots.

2.1.5 Soil salinity control

2.1.5.1 Effect of mulching on salinity of different soil types

On calcareous heavy soils, such as those prevailing in north Qatar, irrigation with saline water (2 000-3 500 ppm or more) coupled with poor water management causes notable salinity hazards that greatly influence crop production and often lead to complete crop failure. Although drip irrigation could result in considerable water saving, its use in Qatar has been almost discontinued as under the prevailing soil and water conditions it speeded up soil salinization. The effect of mulching to reduce evaporation and salinization under drip irrigation was therefore investigated by the project.

In four consecutive seasons the effects of various locally available mulching materials (black plastic, white plastic and date fronds) were studied. All mulching materials successfully controlled salinity under the drip system to a reasonable level, even with the use of brackish water with up to 2 000-2 500 ppm, such as that used in Rodiat al Faras experimental farm in Qatar.

The black plastic in general gave the best performance and highest yield in winter time (31% increase over unmulched soil). Moreover, it proved to be more resistant than the white plastic, which was easily torn in high temperatures. It also prevented weed growth. However, the black plastic affected the small seedlings in their early stage of growth and the number of dead seedlings sometimes increased with high temperatures. In spring white plastic gave satisfactory results.

The same investigation was conducted on sandy soil in Bahrain. The use of a plastic mulch resulted in appreciable yield increases in both winter and spring. White plastic gave the best results in winter and black plastic in spring.

This study showed, through the intensive soil sampling carried out to monitor salt distribution, that the drip irrigation system could be used in Qatar with success. Measures should be taken to control salinity by using plastic mulches and applying periodical leaching by operating the drip system continuously for a relative long period.

In general, the effect of mulches in controlling soil salinity and increasing yield was more evident on calcareous sandy soils than on calcareous heavy soils when both were irrigated with almost similar quality irrigation water. In most cases the plastic mulch gave better results than the date fronds.

It is therefore recommended that the drip irrigation system be used in Qatar on the calcareous soils even when using saline soils, providing that it is combined with effective mulching material such as black plastic sheets.

The cost of the plastic mulches should be set against the yield increase and salinity control, the possibility of using the drip system, which leads to a saving in irrigation water, and the savings in hand labour and in water pumping costs that result.

2.1.5.2 Effect of change of micro-climate on salinity control of different soil types

Under the prevailing climatic conditions in Qatar and Bahrain a change in the micro-climate by growing windbreaks, either permanent or temporary, can play an important role in crop production. In Qatar, sesbania was planted as a temporary windbreak at different spacings (7.5 m, 11.25 m and 15.0 m) and vegetable crops were grown under surface irrigation. In Bahrain date fronds and plastic nets were used as windbreaks, using the same spacing as for sesbania, and vegetables were grown under drip irrigation.

The results obtained showed that the major effect of windbreaks is on yield increase, with a slight effect on salinity. Windbreaks were more effective in controlling salinity in sandy soil than in heavy soil.

The closer spacing used for sesbania in this study caused some problems with ploughing and other mechanical operations. When sesbania was used as a temporary windbreak it was noted that the height of the trees reached 3-4 m after one year, so the spacing between the windbreak rows can be increased to 25-50 m.

2.1.5.3 Effect of leaching on salinity control on different soil types

This study on leaching requirements used three different empirical equations and leaching methods on shallow calcareous heavy texture soil in north Qatar, irrigated with brackish water (EC 32 mmho/cm). Two trials were carried out, one under surface irrigation on alfalfa, the second under drip irrigation on tomatoes. The same investigation was carried out on calcareous sandy soil in Bahrain under drip irrigation on grapes and pomegranate trees. The purpose of the study was to find the most suitable equation or leaching requirement fraction that could be used to give the best salinity control and the highest yield under the prevailing climatic, soil and water conditions in both Qatar and Bahrain.

The calculated leaching requirements according to the three equations were 27, 40, and 67% of the consumptive use. Two methods for leaching were used: continuous, by giving small doses of excess water with every irrigation, and intermittent, by giving a large dose once a month. Alfalfa was planted and 20 cuttings were obtained over a period of about two years.

Although the highest total yield of alfalfa and the best salinity control were obtained with the consumptive use plus 67% leaching treatment, the highest yield per unit of water and also reasonable salinity control were obtained with the consumptive use plus 27% leaching treatment under continuous leaching.

Increased irrigation water resulted in increased total yield of tomatoes, but in lower yields per unit of water. The use of mulches under the various water regimes has resulted in increasing both the total yield and yield per unit of water. The black plastic was usually more effective in increasing yield than the straw mulch. With no mulch, all leaching requirement treatments and also the consumptive use treatment with no leaching requirements added have successfully lowered the electrical conductivity (EC) of the soil profile in the area located under the drippers to a reasonable level of about 6.3 mmho. With the black mulch the EC was further decreased to about 4.5-6.0 mmho, with the lower EC value being under the consumptive use treatment and increasing with increase in leaching requirement doses added. With the straw mulch similar results were obtained as with black plastic, but with slightly higher EC values. Hence the black plastic was usually more effective in increasing yield and decreasing the soil salt content.

The experiment conducted on sandy soil in Bahrain on grapes and pomegranate trees showed that adding excess water for leaching requirement has resulted in vegetative growth increase, but not in better salinity control over the consumptive use treat-ent with no excess water for leaching. In fact the high irrigation application treatment (consumptive use plus 60% for leaching) resulted in some salt increase.

It was concluded that the calculated consumptive use for grapes and pomegranate trees, using the Blaney-Criddle equation, could in fact be higher than the needs of the plants, and include an excess of water that results in salt leaching. The suitability of the leaching requirement equation for drip irrigation under both trials on calcareous heavy soil in Qatar and sandy soil in Bahrain could not therefore be properly tested. It is recommended that studies be made to evaluate by field trials the actual consumptive use of the major crops, as such information was lacking at the time of this study in both countries. Unless the correct information on consumptive use is available, the leaching requirement concept cannot be used.

2.1.6 Drainage

The lack of natural drainage in most of the countries of the Region is one of the most important problems for irrigated agriculture, and artificial drainage is essential if irrigated crops are to succeed. Unfortunately the recruitment problems delayed the project's work on drainage, but some useful activities were carried out in a relatively short time, as shown below.

2.1.6.1 Monitoring the performance of drainage systems

This work was conducted in central Iraq in two irrigation projects, the Kusaiba project west of the Tigris River 20 km south of Suwaira town, and the Al-Wahda project east of the Tigris River 40 km south of Baghdad, where the soils contain more clay than the soils of Kusaiba. The salient features are given below:

(a) The groundwater level at Kusaiba is influenced by the fluctuation of the water level in the Tigris River. If there is no irrigation, the groundwater level follows exactly the same regime as the water level in the river.

(b) During the flood season water flows from the river to the unconfined aquifer in contact with the stream, while it flows from the aquifer back to the river when the level of the river is low during the period of August to November.

(c) Crops with high water requirements cause the water table to rise to a depth of 0.5 m from the soil surface. Drains were able to control the water table by a drawdown rate four times faster than areas without drains.

(d) Fallow causes increase in the salt content of the soil, and resalinization is faster where crops receive less water applications.

(e) Ploughing after harvesting proved to reduce resalinization of the top soil layer.

(f) The severe resalinization of the continuously uncultivated lands indicates a high rate of capillary water rise towards the soil surface from the groundwater, which is at a depth of 2.5-3.0 m.

It was concluded that fields should be provided with interceptor drains to alleviate the bad effect of seepage from canals, and should be ploughed after harvest to reduce the hazard of resalinization, especially when they are left fallow.

2.1.6.2 Drainage activities in various countries

i. In Iraq

The drainage expert contributed to the finalization of the work started by the FAO/UNDP Pilot Project in Soil Improvement and Management (IRQ/73/015). He helped to finalize the designs of irrigation works, and advised on the execution of the irrigation and drainage networks and on establishing an experimental station at Kusaiba where it was planned to carry out part of the research activities of the project. He participated in a study on spacing of drains in the Dalmj Experiment Station, which belonged to the Scientific Research Council and which was established originally to carry out research work on drain spacing, envelope materials and the use of different pipe types.

ii. In Bahrain

Drainage is badly needed in half the agricultural area in Bahrain. The drainage expert visited Bahrain twice, reviewed the situation, carried out some detailed investigations and prepared designs for a pilot drainage project.

iii. In Kuwait, Qatar and Jordan

The drainage expert visited Kuwait and Qatar twice and Jordan once. His activities in these three countries were limited to consultancy services.

2.1.6.3 Future needs

The development of reliable drainage in all member countries of the project should take priority in future work. The programme initiated in Iraq should be extended to other countries. A workshop to discuss and agree on unified methodology should be held in the Region.

Construction techniques should aim to reduce the need for elaborate maintenance and to simplify and increase the efficiency of operation. The use of covered collector drains is recommended.

Research is required to identify an alternative to expensive natural granular material for enveloping for pipe drains.

The study of the drainage of sloping land subject to artesian water in Bahrain is very important. The new pilot field should be kept under continuous monitoring to evaluate the system used.

Fields should be ploughed immediately after harvest in order to reduce the capillary pull from the groundwater table and the hazard of resalinization.

2.2 BETTER MANAGEMENT OF SANDY SOILS

The sand dunes in Southern Qatar could contribute to agricultural expansion through the production of fodder crops for sheep, since there is some fairly good quality groundwater in the area. Three different experiments were conducted to find suitable ways for amelioration of the sand dune soils: by the addition of organic matter, by the addition of loamy soil and by the addition of loamy soil and organic matter combinations.

2.2.1 Addition of organic matter and its effect on alfalfa yield

Two rates of chicken manure, 15 and 30 t/ha, and city refuse compost, 25 and 50 t/ha, were used and two methods of addition were followed:

- mixing with the top 10-15 cm of the soil;
- placing the organic matter as a layer 30 cm below the soil surface in order to slow the rate of decomposition of the added materials and prolong their effect. The soil organic matter content was checked by analysis immediately after addition, 6 months and 12 months after planting.

The results obtained showed clearly the importance of using organic matter as a means of improving sand dune soils in south Qatar. This is reflected by the appreciable increase in alfalfa yield. The highest yield obtained from 10 cuttings (in less than a year) was from the treatment involving 30 t/ha chicken manure placed in the sub-surface; this produced 173 t/ha compared to 121 t/ha from the control, or a 43% increase. Such an increase would have a considerable effect on the farmer's net income, as the actual price of green alfalfa ranges from QR 600-1 000/t (US$ 165-274). Both organic materials gave satisfactory results.

The use of organic matter, as expected, has increased the water holding capacity of the soil. The increase was more evident with the city refuse than with chicken manure. Differences in yield obtained from the different levels of fertilizers were not appreciable.

Soil analysis results of organic matter content at three different periods showed that the decomposition rate of city compost is somewhat slower than that of chicken manure. This finding is reflected in the yield of the first five cuttings, which was higher from plots fertilized with chicken manure, while the yield of the second five cuttings was slightly higher from the plots fertilized with city compost. This leads to the suggestion to use chicken manure for short growing period crops and city compost for perennial and long growing period crops.

2.2.2 Addition of loamy soil and its effect on yield of some grain crops

The sandy soils in south Qatar are almost devoid of plant nutrients and have very low water and nutrient holding capacity. Although it was clearly demonstrated that the use of organic matter appreciably increased the yield of alfalfa (up to 43% for some treatments), it was clear that relatively large amounts of organic matter should be added almost yearly, especially if they decompose rapidly, such as the chicken manure, thus rendering this technique costly in the long run. The addition of loam soil was therefore investigated as one of the ways to improve the physical and chemical characteristics of these sandy soils.

Three levels of loam addition to the sand dune soil were studied, 200, 400 and 800 m^3/ha of loam. The loam was mixed with the surface 15-20 cm. Barley was grown during the winter season 1979/80 and was followed by sorghum during the summer 1980.

The effect of loam addition on soil moisture characteristics, soil texture and salt content of the sand dune soil was also investigated, and the following results were obtained:

(a) An increase in fine particles (clay and silt), mainly in the 0-10 cm depth and to a lesser extent in the 10-20 cm depth before planting of barley. Fine particle fraction increased from 2 to 7% and 16% in the 0-10 cm layer with addition of 200, 400 and 800 m^3/ha of loam respectively. Some movement of the fine soil particles occurred as a result of irrigation from the 0-10 cm depth to the 10-20 cm depth. This change in soil texture and content of fine particles was clearly reflected in the moisture holding capacity of the surface soil. Available moisture increased from 1.1% in the control to 2.2% and 2.8% with the addition of 200, 400 and 800 m^3/ha respectively. However this change in soil texture was also reflected in the salt content of the surface layer, as the EC of the 0-10 cm layer increased from 2.4 mmho/cm in the control plot to 5.8, 6.0 and 7.1 mmho in the 200, 400 and 800 m^3/ha treatments. After planting of barley and irrigation, some leaching of the salts occurred, but the salinity of the surface layer in the treatment plots remained higher than in the control; this did not affect yield, especially as barley is a salt tolerant crop, and the soil salinity remained within the acceptable range.

(b) Loam addition resulted in an increase of barley grain yield of 16, 20 and 25% and of straw weight of 5, 13 and 12% with 200, 400 and 800 m^3/ha respectively.

(c) The yield of sorghum which followed the barley was severely affected by the high temperature prevailing during the summer months. Sorghum was planted about one month and a half after the suitable time of planting. This delay affected grain pollination and resulted in many sterile seeds. However, loam addition to sand dune soil resulted in an appreciable increase in grain yield over the control. Increases of 114, 90 and 88% were obtained with the addition of 200, 400 and 800 m^3/ha respectively. The increase in green forage was not as great, but followed a direct trend with increase of loam addition: 12, 16 and 19% increases were obtained for the same treatments.

2.2.3 Addition of loam and organic matter and its effect on the yield of some field crops

It was important to compare the effect of both loam and organic matter addition to the same crops, taking into consideration the previous results obtained and the different levels of loam and organic matter addition recommended.

The addition of loam, 400 m^3/ha; organic matter, 20 t/ha chicken manure; and a mixture of both, 200 m^3/ha loam plus 10 t/ha chicken manure, was investigated and compared with the control, which received chemical fertilizers at the same rate as the other treated plots. Wheat was grown during the winter season 1980/81 and was followed by sorghum during the summer season 1981.

Addition of loam (400 m^3/ha) caused an increase of the fine particles mainly in the surface layer (0-10 cm) from 4% clay plus silt in the control to 10%. A smaller increase occurred in the 10-20 cm layer, from 4% clay plus silt to 7%. Chicken manure addition had very little effect on the fine particle content, as the rate of addition was small, 20 t/ha. The effect of organic matter addition was more notable in the water holding capacity of the soil. The available moisture in the 0-20 cm layer increased by 83% with the addition of 200 m^3/ha loam plus 10 t/ha chicken manure.

The electrical conductivity of the surface layer (0-10 cm) was somewhat affected with loam addition. It increased from 3.3 to 4.9 mmho/cm with the addition of 400 m^3/ha of loam. Loam addition caused an increase of the water, nutrient and salt holding capacity of the soil, but the latter increase did not have a harmful effect on seed germination.

The organic matter content of the soil more than doubled in the surface layer with the addition of chicken manure, increasing from 0.2% in the control to 0.6% with 20 t/ha and 0.6% with 10 t/ha plus loam. The residual organic matter from the winter application and the fine root residue seem to have contributed to this relatively high content of organic matter. The loam mixed with chicken manure seems to reduce the decomposition rate of the latter and reduces its movement to a deeper layer with the frequent (daily) irrigation schedule.

An appreciable increase was obtained for both the grain and straw yield of wheat. An increase of grain yield of 38, 58 and 67% was obtained over the control (2.75 t/ha) for the loam, chicken manure and loam plus chicken manure treatments respectively. The increase obtained for straw yield over the control (8.65 t/ha) for the same treatment was 20, 50 and 39% respectively.

2.2.4 Conclusions

Under the prevailing climate and soil conditions in south Qatar, that is well aerated sandy soils and very high temperature during most of the year, there is only limited advantage in applying organic fertilizer to the sub-surface soil as a thin layer at a depth of 30 cm. The expense and labour involved are not justified by the results obtained during the first year, and the mixing of organic fertilizer with the surface soil is therefore recommended.

However, when using either chicken manure or city compost it is advisable to irrigate the soil generously twice or three times before planting to leach the excess salts added to the soil through the use of the organic fertilizer, and to reduce the effect of the heat of organic matter decomposition on the seeds. It also seems advisable to use chicken manure for short growing period crops and city compost for perennial and long growing period crops.

These studies lead to the conclusion that, when the effects of loam, organic matter and their mixtures are compared under the same climatic and soil conditions in south Qatar on the same crops, the use of a mixture of loam plus chicken manure in relatively small amounts (200 m^3/ha plus 10 t/ha) is preferable. The mixture of the two soil amelioration materials has a good effect on yields of wheat and fodder sorghum grown on sand dune soil. Besides being more practical from the availability and cost points of view, this mixture combines the physical and chemical advantages of loam and organic manure (see Field Documents Nos. 14, 15 and 16).

The addition of loam should be made once only while organic matter should be added every year.

2.3 SAND DUNE FIXATION

Sand dunes cause problems in many countries of the Region. In Iraq true sand dunes in the Baiji area represented an important hazard on the Baghdad-Mossul highway before they were stabilized, and pseudo sand dunes constitute problems in central and southern Iraq. They clog drainage and irrigation networks and block the east-west roads connecting cities and communities in the Tigris and Euphrates river basins. In Saudi Arabia sand drifts block desert roads. The same situation exists in the United Arab Emirates and in parts of Kuwait, Libya, North and South Yemen. Sand drift is a big problem around Sana'a. Thus the importance of sand dune fixation in the Region cannot be overemphasized.

The sand dune fixation expert assessed the areas affected by sand dunes in six provinces of Iraq: Wasit, Qadisia, Al-Muthanna, Theequar, Babil and Salah Eddeon provinces. He made an evaluation of perennial plants and grasses in the vicinities of the main drain at Fajer and the Sand Dune Fixation Experiment Station at Baiji, and two sites were chosen for the establishment of arboretums, one at Baiji and the other at Al Fajer. Seed was brought from abroad and planted in nurseries. The growth was satisfactory.

Some areas were prepared for experiments on sand dune fixation by the use of synthetic materials. Dunebond and agromul effects on dune fixation are being studied.

The expert also made visits to the Yemen Arab Republic and Kuwait.

Work in this field is in the early stages, and the only conclusion that can be reached is that more attention should be given to sand dune fixation in many countries of the Region.

2.4 FARMING UNDER LOW RAINFALL CONDITIONS

In some countries of the Region over 95% of the cultivated lands are totally dependent on rainfall (Algeria 96%, Jordan 92%, Lebanon 71%, Libya 95%, Morocco 93%, Saudi Arabia 80%, Somalia 83%, Syria 91%, Tunisia 96%, Iraq 50%). Yields of crops in these areas are very low. Wheat yield, for example, is less than 1 t/ha. These low yields are often due, however, to other production factors besides shortage of moisture. Low fertility, weeds, diseases and insects are all causes of low yield.

The project's expert stationed in Amman, Jordan, reviewed work on rainfed agriculture both in the Region and outside and initiated experimental work in Jordan and Syria. It was hoped that the College of Agriculture and Forestry in Mossul would undertake the experimental programme, but unfortunately this was not possible.

2.4.1 Review of literature

The review of the literature on rainfed agriculture was completed. It contains 300 references and gives information on the results of research related to rainfed agriculture carried out within and outside the Region.

2.4.2 Trials on conservation of soil and moisture

Two years data on conservation of soil moisture by three spring tillage operations in order to control weeds and produce soil mulching did not provide conclusive results. This experiment was repeated in spring 1982, but the project was terminated before the results of this season were reported.

The effect of tillage up and down the slope as compared to tillage across the slope, no tillage, and no tillage plus straw mulching on loss of soil and soil moisture storage was studied at Marrow Station in Jordan. In autumn 1981 barrels were installed at the lower ends of the plots to collect eroded soils, but due to the shallow soil profile no moisture data was collected from depths below 30 cm. Herbicides were used to control weeds. No conclusions can be drawn on the basis of two years' results. This kind of work should be continued for longer in order to convince the farmers of its value.

Cultivation of land for conservation of moisture in dryland farming areas is a common practice, but the best timing for the cultivation is not known. The expert conducted an experiment for this purpose. Three spring cultivations were made at different times. The preliminary results showed that in wet years cultivations in March, April and May gave much better soil moisture storage than delaying the cultivation until April or May as farmers usually do. This experiment was carried out for two seasons and at two stations (Rabba and Ramtha in Jordan). It should be repeated for at least two more seasons.

Based on data obtained through a questionnaire on tillage carried out by farmers in rainfed areas of Syria, the expert prepared a research programme on tillage for such areas, which can also be applied in other countries of the Region. The expert visited Syria and made an agreement with the Head of the Land Department to implement two of the six experiments proposed.

2.4.3 Resistance of wheat varieties to nematodes and smuts

The expert cooperated with one of the College of Agriculture staff of the University of Jordan in evaluating the resistance of the ten wheat varieties most commonly used by Jordanian farmers to wheat nematodes and covered smuts.

2.4.4 Selection of drought resistant crops

Sixty-eight species and varieties of forage crops were planted on 7 November 1981 at Moshagger station, Jordan to test their resistance to drought. It was planned to test the best entries in succeeding seasons. This should be done by the counterpart staff.

Fifteen varieties of drought resistant sorghums were obtained by the expert, and were studied by him in a yield trial at Moshagger station in spring 1982. The project was terminated before the results of this study were analysed and reported.

2.4.5 Crop rotation

The expert designed an experiment to compare ten two-year rotations, in order to study their effects on soil conditions and soil moisture storage and their economic effects. The treatments included planting barley and barley/legume mixtures for green forage, which has not been studied in the area. It was planned to study medics. It is recommended that this planned work be implemented by the national staff.

2.4.6 Other research activities in dryland farming

The expert planted an experiment at Ramtha station to study the effect of deep seeding of wheat on emergence. The study included five wheat varieties, three depths replicated three times. It was expected that the results of this experiment would lead to recommendations to farmers to adjust their rate of seeding.

Four experiments were also planted to test the effect of newly introduced chemicals that are expected to improve soil fertility.

The expert designed an experiment to study the effects of minimum and no tillage in spring and autumn as compared to farmers' methods of tillage. The experiment was approved, but its implementation awaited the allocation of land at Moshagger experiment station.

The expert also designed an experiment to control primary noxious weeds in the Maabada area. Its implementation awaits the provision of a badly infested field.

2.4.7 Conclusions

In most cases the experiments were run only three years but data were collected for only one or two years due to drought and consequent crop failure, therefore no conclusions can be drawn. Longer duration studies are needed to collect reliable data. However, preliminary results from work on cultivation for moisture conservation showed that in wet years cultivation in March, April and May gives much better soil moisture than delaying the cultivation till April or May.

2.5 TRAINING

One of the objectives of the project was the upgrading and strengthening of national staff in participating countries, which was accomplished through long- and short-term fellowships (see Appendix 2). The project allocated for training and fellowships some 13.5% of the total original budget 1/ but only part of that amount was spent, since although many fellowships were offered only eight were utilized. The main reasons for this were that most nominees did not have the requisite qualifications for admission to graduate schools, and that the oil exporting countries had their own fellowship programmes.

Training was also provided through formal national or regional training courses and through inservice collaboration with the FAO experts.

2.5.1 Regional training course on Development of Land and Water Resources

This course was held in Cairo at the Egyptian International Agriculture Training Centre from 18 November 1978 to 17 February 1979. Eighteen trainees from 11 countries participated in the course.

2.5.2 Regional training course on Agrometeorology

A regional training course on Agrometeorology and Water Use was held in Baghdad in cooperation with the United Nations Regional Meteorological Training Centre and the Iraqi national staff of the Centre. The course was held from 1 to 28 February 1981. It was attended by 16 trainees from Iraq, Tunisia, Somalia, Jordan and Sudan.

2.5.3 Regional training course on Improved Irrigation Methods

This course was held in Amman, Jordan from 14 March to 3 April 1981. The main lecturer was a consultant, Mr Wynn R. Walker from the University of Arizona, Tucson, Arizona, USA. Twenty-two trainees attended from 13 countries. Theoretical lectures were given and practical training sessions were held. Demonstration field trips were made to the Jordan valley irrigation projects.

1/ Of the original planned budget of US$ 5.25 million, US$ 710 000 were allocated for fellowships and training.

2.5.4 Regional training course on Salt Affected Soils and Their Reclamation

This Regional course was held in Baghdad from 3 to 19 May 1981. A total of 30 trainees attended, from Bahrain, Jordan, Iraq, Oman, Saudi Arabia and Tunisia, and 19 lecturers contributed to the course.

2.5.5 National training course in Agrometeorology

Two courses were conducted in Baghdad in cooperation with the experts of the UNWMO Regional Meteorological Training Centre and the national staff of the Centre. The first course was held from 17 to 29 November 1979 and attended by 10 participants from Iraq's agricultural sector. The second course was organized in the same way. It lasted from 8 to 27 March 1980 and was attended by 12 participants from Iraq's agricultural sector.

2.5.6 National training course on Proper Construction of Covered Drain Outlets

A national training course was conducted on the Kusaiba Project by the drainage expert on the proper construction of covered drain outlets to prevent collapse. The course lasted for one week and was attended by 10 participants.

2.5.7 National training course on Salt Affected Soils

This course was held in Musrata, Libya from 17 to 28 October 1981. It was arranged by the FAO Land and Water Development Division and was attended by 16 trainees. The project contributed two lecturers, Dr Haider, Irrigation (Water Quality) Expert and Mr Abdel Dayem, Drainage Expert.

2.5.8 Sub-regional training course on Salt Affected Soils

This course was held in Riyadh, Saudi Arabia, from 7 to 18 November 1981. The course was arranged by the FAO Land and Water Development Division in cooperation with the Ministry of Agriculture and Water. The project contributed one lecturer, the Regional Drainage Expert, and sponsored eight agricultural engineers from Kuwait, Qatar, Bahrain, PDRY and Iraq. Seventeen agricultural engineers attended this course.

2.5.9 Training on the job with the regional project experts

A total of 76 people received on the job training in association with the experts in research work and use of equipment. This number includes civil engineers, soil scientists and agronomists with B.Sc. degrees, and some with M.Sc. degrees, in addition to the senior counterparts associated with the experts. About one-fifth of the trainees were institute graduates. The countries benefiting from this type of training and the number of trainees were Bahrain 5, Kuwait 6, Jordan 5, Lebanon 3, Qatar 10, Syria 6 and Iraq 33.

2.5.10 Conclusions

Although a considerable number of counterpart staff were trained, more need to be trained in nearly all the countries, especially at the middle level between the college graduate and the unskilled labourer.

2.6 CONSULTANT SERVICES

2.6.1 Shared Water Resources Study for the Arabian Gulf States and the Arabian Peninsula

This study was made in response to a request from the Secretariat General of the Council of Arab Ministers of Agriculture of the Arabian Gulf States and Arabian Peninsula. Its objectives were to survey and evaluate available data on groundwater resources, with emphasis on areas where sharing occurs or is expected to occur, to identify gaps in available knowledge and to identify the studies needed to ensure better utilization of available water and equitable sharing by neighbouring states.

The study covered an area of 1 700 000 km^2; the boundaries were defined by:

- the lower Cretaceous outcrop horizon in the central peninsula region;
- the Jordanian and Syrian borders in the northwest;
- the Euphrates river in Iraq;
- the Gulf Coast in the east, but including Bahrain;
- the Oman mountains;
- the Arabian southern coast.

It concluded that further investigations were required in Kuwait, Bahrain and the UAE, and proposals were prepared for these with their estimated costs.

It was also concluded that recharge to the main basin is a difficult figure to quantify; however, based on a reasonably accurate figure for regional basin underflow, an average recharge of 6.9 mm/annum would be required to balance the aquifer system over its total intake beds.

Sources of recharge are the infiltration of rainfall and wadi flow (the latter source is almost all taken up in the Wasia-Biyadh outcrop). Another source of recharge to the upper and middle aquifers is leakage to the middle aquifer's intake beds and another is the consistent and homogeneous diffuse upward leakage from the lower aquifer. To account for leakage losses to the intake beds of the middle aquifer, it was estimated that the lower aquifer would have to receive 17 mm of effective recharge to balance its system.

For coastal states it was concluded that the sabkhah discharge line was a most significant horizon. While the sabkhahs remain active hydraulic features, they maintain a constant hydraulic head on the aquifer and a constant hydraulic gradient to the Gulf. Thus, with a constant transmissivity a consistent or 'metered' underflow passes the sabkhahs; this underflow or 'tail' water does not benefit from increases in recharge in the basin's intake beds, as increases in water level or piezometric head are discharged at the sabkhah discharge line. Therefore in the Gulf Coast states the 'basin' commences at the sabkhah discharge line, with recharge to the system being that 'metered' amount of water allowed to bypass the sabkhahs. As a consequence, it can be concluded that developments upstream of the sabkhah line do not affect the lower basin sector as long as the sabkhahs remain active.

Aquifer System B was recognized previously as the tongue of good quality water supposed to underflow and replenish Bahrain's aquifers. Somewhat patchy, but nevertheless conclusive evidence exists for the Bahrain lens aquifer in geophysical results, in the chemical and isotopic results, in drilling and geophysical logging.

It was found that there is no direct sharing of water from the System B aquifer and no direct sharing of the aquifer. Indirect effects could possibly occur via excess pumping of the Umm er Radhuma section of the middle aquifer, and the introduction of an unstable interface between the overlying good quality waters and the underlying saline waters. Aquifer effects produced by Bahrain on coastal Saudi Arabia, or vice versa, will have only a minimum piezometric response since observation boreholes will react in sympathy with the unconfined System B aquifer. It was concluded that urgent attention should be paid to Bahrain's situation since present conditions show the lens aquifer to be in a severe state of stress.

With regard to the sharing of resources, it was shown that there was far less sharing than was originally thought. The main area where the concept of sharing a common resource is important is in the coastal zone down gradient from the sabkhah discharge line, but remote from any System B aquifer influence. Kuwait is the country in the most vulnerable position, particularly with regard to pumping across the border in Iraq.

Though outside the terms of reference of this study, problems of overpumped and overstressed aquifers were identified in the United Arab Emirates between the neighbouring states. The safe withdrawal limits from these aquifers need to be established by a sustained data gathering exercise leading to an accurate mathematical model for the aquifer.

The study made three major recommendations. The first of these concerned the importance of making an integrated, detailed and accurate assessment of the water resources in three major areas. This can only be done through the sustained gathering and analysis of relevant hydrogeological and meteorological data over long periods. Three projects were accordingly proposed, with a life span of 10 to 14 years each. Each project will involve the establishment and operation of an area data gathering scheme feeding into a data archive, to be used for hydrogeological model development and periodic data analysis.

The second recommendation proposed the establishment of a Select Committee of specialists to supervise the interpretation of data in the light of certain specific objectives. This Committee would also supervise the interpretation of data arising from the first recommendation.

The third recommendation relates to the reconstruction of the hydrogeological history of the basin, covering conditions in the pluvial periods and particularly the availability of recharge then, the onset of aridity, the decline in basin water levels, inland sea transgressions and their effects on the present-day groundwater situation, the origin and development of the sabkhahs and their role in the basin discharge scheme.

2.6.2 Vertical versus horizontal drainage of the Euphrates Valley in Syria

This study concluded that under the existing conditions of the Euphrates Valley in Syria horizontal drainage was more feasible than vertical drainage, which poses a problem in the disposal of drainage water, since it is too saline to be used for irrigation even with mixing. Maintenance of pumps and high costs of fuel are other reasons in favour of a horizontal covered drainage system. It was therefore recommended that covered field drains be used instead of vertical drainage.

2.6.3 Agroecological zoning

This study, a joint venture by FAO and ICARDA, covered a visit to the Sudan and the Yemen Arab Republic for three weeks to collect agronomic data for the regional study on rainfed agriculture with particular emphasis on agroecological zones.

2.6.4 Rehabilitation of date palm gardens in UAE

Two project experts participated in a mission for the survey and rehabilitation of date palm gardens in UAE from 21 September to 1 October 1980. This mission was another example of the cooperation between the project and the Regional Palm and Date Research Centre Project.

2.6.5 Joint venture projects for food and feed production

The project participated in an FAO Mission to the Gulf States and the Arabian Peninsula to identify joint venture projects for food and feed production. Several projects were identified in several countries but so far none has been implemented.

2.6.6 Soil survey of Abdali area in Kuwait

A consultant was recruited to make a soil survey in Kuwait for irrigation and development. It is recommended that full use be made of the study before further development of the area.

2.6.7 Evaluation of Wadi Jizan agricultural development

The regional irrigation expert participated in an FAO mission for the evaluation of the Wadi Jizan Agricultural Development Project, Phase II. The Government of Saudi Arabia implemented the second phase of the project as recommended.

2.6.8 Water quality and plant tolerance to salinity

The irrigation expert (water quality) visited Jordan at the request of the Government, to advise on water quality and plant tolerance to salinity.

2.6.9 Drainage problems in Bahrain, Qatar and Kuwait

The project's drainage expert visited Bahrain, Qatar and Kuwait to advise on drainage conditions and the setting up of an organization to deal with the problem. The expert returned to these countries in November 1981 to provide further advice.

2.6.10 Planning economic use of water resources for crop production in Yemen Arab Republic

The project's irrigation expert visited YAR to assist in planning the economic use of water resources for crop production. His study should be used as a basis for further location development studies.

2.6.11 Participation in national research committees

The Project Director and the regional expert stationed in Baghdad were members of the Scientific Research Committee of the State Organization for Land Reclamation and the National Research Council Committees. They contributed to the new programmes, and sought to orientate each research station towards a given line of research. Each regional expert was a member of the research committee in the country where he was stationed.

2.6.12 Review of the work of field stations, Saudi Arabia

Three regional experts visited Saudi Arabia as requested by the Ministry of Agriculture and Water for 14 days in February 1980 to review the work at the field stations of Al-Hassa, Wadi Jizan and Dawasir projects.

2.6.13 Academic activities aiming at upgrading national skills

Experts of the project contributed to the upgrading of personnel and institutions in the Region through various activities, such as participating in the evaluation of M.Sc. and Ph.D. theses and in the final examinations of candidates. They were also called on by institutes in the Region to review papers before publication.

2.7 SEMINAR

The project participated in the organization of a seminar on rainfed agriculture with the Regional Commission for Land and Water Use and the Overseas Development Administration of the UK, which provided four lecturers. The Ministry of Agriculture of the Hashemite Kingdom of Jordan acted as host. The project recruited a consultant who gave two lectures on methods of water harvesting and range improvement. The seminar was attended by delegates from Cyprus, Jordan, Iraq, Lebanon, Pakistan, Syria, Saudi Arabia, ACSAD, ECWA, and the Palestine Liberation Organization.

3. RECOMMENDATIONS

3.1 IRRIGATION

Irrigation schemes cannot be successfully planned without an adequate knowledge of the water requirements of the crops to be grown. It is therefore essential that all countries continue the work started by the project for the identification of crop water requirements and of soil leaching properties. Allied studies should comprise suitable plant spacing and intercropping techniques. The two precision weighing lysimeters, at Tel Amara, Lebanon and at Abu-Ghraib Experiment Station, Iraq, can provide direct measurements of potential evapotranspiration which in turn can be used for checking and calibrating the formulae used in calculating the water requirements of different crops. Full use should be made of these two lysimeters for the benefit of the whole Region.

It must, however, be borne in mind that increased crop production can only be achieved through an integrated approach that provides all the necessary inputs, such as high quality seeds, adequate amounts of fertilizer and plant protection materials, and correct cultivation techniques, and not through the provision of irrigation water in isolation from the other needs. The identification of the correct package of inputs will require continuing research in the various countries.

3.1.1 Irrigation methods

There is a need to collect information on the various types of irrigation equipment available on the market, in order that the most suitable types may be chosen for the specific conditions of the areas to be irrigated. The information should be collected and classified by groups that are independent of commercial sources and should be freely available to the governments of the Region. Once equipment is purchased, thorough training in its operation and maintenance must be provided to all potential users.

Drip irrigation should be used on saline soils for growing grapes and trees where desalinization of the soil is not feasible. Adequate knowledge of the water requirements of the crop throughout the season, proper maintenance and efficient operation are essential. Drip irrigation is also suitable for irrigating trees and vegetable crops with relatively saline water if the soils are highly permeable.

Sprinkler irrigation is recommended where the land is too steep or too shallow to be levelled for surface irrigation, and where the soil is too sandy for efficient water conveyance. Since high winds distort the distribution pattern of sprinkler water, causing uneven growth, sprinkling should be carried out at low wind velocities, i.e. usually early in the morning, late in the evening and at night. In the summer sprinkler irrigation should be avoided at mid-day as evaporation losses are high and scorching of the leaves may occur.

It is recommended that the Government of Iraq should proceed with the implementation of the design prepared by the project consultant for absolute level basin irrigation. When combined with covered collector drains this method of irrigation is expected to aid in eliminating the flow of irrigation water into the drainage network, reducing the collapsing of drains and the growth of the reeds that clog them. This new irrigation system should first be instituted in pilot fields; once it has proved successful it should be applied to all projects, in order to reduce the need for maintenance of the drainage network and eliminate the resalinization of reclaimed land caused by clogged drains and a rising water table in the fields. It is further recommended that the Government should accept responsibility for maintaining the level of the basins in order to ensure efficient water distribution, since the farmers do not have the means to do this.

3.1.2 Conveyance of irrigation water

Surface conveyance of irrigation water is wasteful whenever the soils are sandy or highly permeable, but much water can be saved by conveyance in lined canals or pipes. The project recommends the use of PVC pipes. This will not only save water but will reduce the labour needed for surface irrigation and the weeding of canals. It will also reduce the rise in the water table caused by excess water seepage from the drainage ditches.

3.1.3 Water quality

The scarcity of good quality water makes it necessary to use water of poor quality pumped from underground and partially treated sewage water for irrigation purposes. Leaching requirements must be taken into consideration when irrigating with saline water, in order to prevent salinization of the soil, and with high salinity water higher rates of irrigation should be applied. When saline water only is available, relatively salt tolerant crops, preferably winter crops, should be grown in order to conserve the limited water as long as possible. The growing of summer salt sensitive crops should be avoided. Health aspects are important when using partially treated sewage water, which should not be applied to vegetable crops that are eaten uncooked.

3.2 AMELIORATION OF SAND DUNE SOILS

It is recommended that agricultural expansion into sand dune areas should be pursued wherever possible, in line with the project studies in south Qatar. It has been shown that treatments with city refuse, chicken manure and loamy soil in various mixtures improves both water and nutrient holding capacity. It is recommended that in conditions similar to those prevailing in south Qatar 200 m^3 of loam plus 10 t/ha chicken manure be applied, the loam only once and the chicken manure every season.

3.3 DRAINAGE

The lack of natural drainage in most of the countries of the Region is one of the most important problems for irrigated agriculture. It is therefore recommended that the development and testing of reliable drainage design factors be given priority in future work in all countries. The programme initiated in Iraq by the project should be continued and the other countries should institute similar studies, using a unified methodology which should be agreed upon at a regional workshop. The studies should concentrate on identifying construction techniques that reduce the need for elaborate maintenance and simplify operation, such as covered collector drains. Research is also required to find an alternative for the expensive natural granular material now used as enveloping for pipe drains.

It is recommended that fields be provided with interceptor drains to alleviate the effect of seepage from canals, and that they be ploughed after harvest to reduce the hazard of resalinization, especially when they are left fallow.

The study on the drainage of sloping lands subject to artesian water in Bahrain is very important. It is recommended therefore that the new pilot field be kept under continuous monitoring to evaluate the system used.

3.4 FARMING UNDER LOW RAINFALL CONDITIONS

Further research is required throughout the Region on how to improve yields in dryland farming. Some aspects deal with conservation of moisture and its better utilization. Field trials were initiated on conservation of soil and moisture including work on methods, frequency and timing of tillage, to assess their effect on moisture retention and yield, but no final conclusions could be drawn during the project. The work should be continued until conclusive results are obtained.

Work was also initiated on the selection of drought resistant crops and on crop rotation, and this work should also be continued.

3.5 SAND DUNE FIXATION

Work on sand dune fixation is continuing in Iraq, and should be pursued until concrete results are achieved. Further international assistance may be required in this field.

3.6 TRAINING

The need for training will continue for some time, and it is recommended that the countries of the Region continue to seek external aid to improve the skills and knowledge of their staff. Where possible students should be placed in colleges or universities where the climatic conditions are similar to those of their countries. Efforts should be made to ensure that they work in the subjects they have specialized in when they return to their home countries.

Seminars are also an excellent training device, since they bring professional people together to exchange and discuss ideas and become aware of the latest developments in their fields. It is recommended that seminars on specific scientific topics be held periodically.

3.7 SHARED WATER RESOURCES IN THE GULF STATES AND THE ARABIAN PENINSULA

Three major recommendations have emanated from the project's study of this subject. The first concerns the proposal to initiate a long-term data gathering and analysis programme in the following three areas: A, between Iraq, Kuwait and Saudi Arabia; B, between Kuwait, Saudi Arabia and Qatar; and C, between UAE, Oman and Saudi Arabia. The data should be used for the development of a hydrogeological model designed to provide assessments of the potential water resources under various utilization regimes.

The second recommendation is for the establishment of a select committee of specialists who would have the task of directing the data collection and interpretation programme, including the reinterpretation of earlier national studies in the light of any new information that may have become available.

The third recommendation concerns the establishment of various projects with the specific goal of reconstructing the hydrogeological history of the basin. Such projects might include:

- a study of palaeoclimates in the Quaternary and their effects on the environment of the Arabian Peninsula and the Gulf area;
- a study of the occurrence and dating of humid periods, or times of maximum recharge, and of very arid periods, or times of minimum recharge and maximum evaporation;
- a study of ancient river systems, including estimates of their discharges from meander belts and patterns;
- archeological studies of ancestral spring zones and along ancient river courses (of which satellite imagery shows many);
- geomorphological studies related to sea-level changes, ancient coastlines and tectonic movements;
- a study of the remnant hydrochemical effects of sea-level changes;
- investigation of the relationship between sabkhahs and sea-level changes, including palaeontological studies of sabkhah zones.

A useful complement to these investigations would be the collection and abstracting of the large volume of scientific papers that have been published on the hydrology of the Arabian Peninsula, and it is recommended that funds be sought for the implementation of such an undertaking.

Appendix 1

PROJECT STAFF

1. International

Name	Title	Duty Station	Started	Concluded
Dhari Al-Hardan	Project Director	Baghdad, Iraq	19 May 1977	30 June 1982
Dwite Michener	Drainage Expert	Baghdad, Iraq	1 July 1978	31 Dec. 1978
N.G. Dastane	Irrigation Expert	Doha, Qatar	28 Aug. 1978	30 Dec. 1981
Sadi A. Tamimi	Rainfed Agriculture Expert	Amman, Jordan	1 Sept.1978	30 Dec. 1981
Samir Naghmoush	Soil Reclamation and Improvement Expert	Doha, Qatar	1 Oct. 1978	30 Dec. 1981
Tony Abou-Khaled	Irrigation Expert	Baghdad, Iraq	24 Mar. 1979	30 June 1982
Ghulam Haider	Irrigation Expert (Water Quality)	Kuwait	6 Apr. 1979	31 March 1982
Mohammed Safwat Abdel-Dayem	Drainage Expert	Baghdad, Iraq	1 July 1980	30 Dec. 1981
Mohammed Bin Bashir Daghfous	Soil Conservation Expert (Sand Dune Fixation)	Baghdad, Iraq	19 Jan. 1981	30 Dec. 1982

2. National

Name	Title
BAHRAIN	
Ahmed, Jaafar Habib	Deputy Director, Department of Agriculture
Ayub, Mohammad	Irrigation Engineer, Directorate of Agriculture
CYPRUS	
Metochis, Christos	Olives Expert, Agriculture Research Institute

Name	Title
CYPRUS (Cont'd)	
Papadoupoulos, I.N.	Soils Expert, Agriculture Research Institute
Stylianou, Yerolemos	Irrigation Expert, Agriculture Research Institure
IRAQ	
Abdel Rahman, K.R.	Drainage Engineer, SOLR
Al Kawaz, Ghazi M.	Head, Water Resources Division, Scientific Research Foundation
Al Shammari, Abdel Karim	Head, Fertilizer Research Unit, SOLR, Ministry of Irrigation
Dawood, Abdul Hakim M.	Soil Conservation, SOLR, Ministry of Irrigation
Hassani, Qasim Al	Physicist, SOLR, Ministry of Irrigation
Ismail, Mudhaffer A.	Drainage Engineer, SOLR
Kiwark, H.N.	Irrigation Practices, SOLR, Ministry of Irrigation
Lafta, Ibrahim Z.	Irrigation Science, SOLR
Mohammed, Kamil Majeid	Soil Science, SOLR, Ministry of Irrigation
Mudhloom, Noor	Soil Conservation, SOLR, Ministry of Irrigation
Nooh, Muhamed J.	Drainage Engineer, SOLR
Suleiman, Amer D.	Director, Reclamation and Irrigation Research Centre, SOLR
QATAR	
Alfaihani, M.	Head, Water Resources Section, Ministry of Industry and Agriculture
Al Kawari, Ajlan A.	Irrigation Researcher, Agriculture and Water Resources
Baidak, Abdel M.	Irrigation Researcher, Dept. of Agriculture and Water Research
Barghout, G.	Irrigation Researcher, Dept. of Agriculture and Water Research
Hashim, M.A.	Irrigation and Drainage Specialist, Dept. of Agriculture and Water Research
Latifur Rahman, M.	Assistant Hydrologist, Dept. of Agriculture and Water Research

Name	Title
KUWAIT	
El Bably, Abdul Raoof	Agricultural Engineer, Dept. of Agriculture
Hefnawi, Mustafa S.M.	Agricultural Engineer, Dept. of Agriculture
JORDAN	
El Sharif, Wael Adel Hamdi	Water Science, College of Agriculture, University of Jordan
Haddadine, Naji	Head, Soils Department Scientific Research Institute, Ministry of Agriculture
Hawatmeh, Nader Ghattas	Irrigation Science, College of Agriculture, University of Jordan
Iweis, Samir Shafiq	Laboratory Technician, Soil Department, Ministry of Agriculture
Mirza, Ahmed Balad	Soil Conservation, Soil Department, Ministry of Agriculture
Qasem, Jalal Mustafa	Irrigation Science, College of Agriculture, University of Jordan
Yousef, Abdalla Subhi Abdalla	Irrigation Practices, College of Agriculture, University of Jordan

Appendix 2

FELLOWSHIPS

Name and Country	Subject	Location	Duration	Position on return
Jaffar Habib Ahmed,, Bahrain	M.Sc. Soil Survey	Nottingham University, UK	20 months	Deputy Director, Agriculture Department, Bahrain
N. Haddadine, Jordan	International Course on Land Drainage			Head of Soils Department, Scientific Research Institute, Ministry of Agriculture, Jordan
Ioannis Nicou Papadopoulus, Cyprus	Ph.D. Soil Science (Plant Nutrition)	University of California, Davis, USA	36 months	
Samir Shafiq Iweis, Jordan	Laboratory equipment course	Advanced Technical Services Co., Cyprus	One month	
Ahmed Bulad Mirza, Jordan	M.Sc. Soil Conservation	University of Ankara, Turkey	21 months	
Kamil Majeed Mohammed, Iraq	M.Sc. Soil Science	Ghent University, Belgium	27 months	Sand dune fixation officer, Iraq
Hamberson Narsis Kiwark, Iraq	Irrigation Sciences	Awaiting decision on admission to Colorado State University, USA	24 months	

Appendix 3

EQUIPMENT

The project supplied vehicles to Afghanistan, Bahrain, Cyprus, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, Yemen Arab Republic. In addition, the following major items of equipment were supplied to the countries where project work was undertaken:

Resistivity meter
Camera, Hasselblad
Hydroprobes
Analytical balances, Mettler
Glass still, Fisher
Plot combine, Hege 125 B
Compressor, Soiltest
Conductivity meter, Philips
Seed drill, Oyord
Printing electronic integrator
Multirange recorder
Sodeco printer for integrator
Moisture meter, Solo
Land leveller
Laser levelling and survey system
Infrared thermometer
Net radiometer
Analogue integrator
Electronic recorder
Wind recorder
Precision weighing lysimeter
Photocopying machine, Canon
Generator/meter unit
Soil testing equipment

Appendix 4

FIELD DOCUMENTS ISSUED BY THE PROJECT

No.	Author	Date	Title
1	M.S. Abdel-Dayem and K.R. Abdel-Rahman	June 1981	Computation and Evaluation of Drain Spacing Under Iraqi Conditions.
2	Abdel Dayem, M.S., A.I. Mudhaffar, K.R.A. Rahman and M.J. Nooh	December 1981	Monitoring the performance of drainage systems.
3	A. Abou-Khaled and K. Kawaz	January 1981	A Case Study of Corn Yield as Affected by Water and Soil Management Under Arid Conditions.
4	A. Abou-Khaled and A.S. Suleiman	May 1981	Irrigation Methods in Relation to Salinity.
5	A. Abou-Khaled, S.A. Chaudry and S. Abdel-Salam	November 1981	Preliminary Results of an Irrigation Experiment on Date Palms in Central Iraq.
6	A. Abou-Khaled Amer D. Suleiman and Ibrahim Z. Lafta	April 1982	Irrigation Requirement of grapes under Drip Irrigation in arid conditions and performance of the system in Iraq.
7	A. Abou-Khaled and Qassim Al-Hassani	June 1982	Evaporation and potential evapotranspiration under the arid conditions in Central Iraq.
8	Dhari Al-Hardan	April 1981	Interim Report.
9	Al-Shammari, A.K. C.M. Al-Kawaz and A. Abou-Khaled	1980	Water and Soil Management with emphasis on Irrigation and Fertilizer Requirements for Higher Yields of Corn Grain in Central Iraq.
10	Mohammed Daghfous	February 1982	Manuel pour la lutte contre les vents de sable et fixation des dunes à l'usage des techniciens.
11	N.G. Dastane and M. Ayoub	August 1979	Water Management for Crop Production in the State of Bahrain, review and suggestions.
12	N.G. Dastane, M. Al-Fihani and Adel M. Baidak	March 1980	Water Management Practices for Crop Production in the State of Qatar. Results of Investigations 1978/79.

No.	Author	Date	Title
13	N.G. Dastane and M. Al-Fihani	May 1980	Increasing Water Use Efficiency in Qatar Agriculture. Review and Suggestions.
14	N.G. Dastane, Mahmoud A. Hashim and Ajlan A. Al-Kawari	September 1981	Improved Irrigation Practices for Important Vegetable Crops in the State of Qatar.
15	N.G. Dastane, Mahmoud A. Hashim and G. Barghout	September 1981	New Vistas for Economising Irrigation Water with Sprinkler System for Crop Production in South Qatar.
16	N.G. Dastane and Mohammad Ayub	January 1982	Revitalizing Bahraini Farming with improved water management and higher crop density.
17	Wael Adel Hamdi El-Sharif	December 1980	M.Sc. Thesis on Water Requirement and Scheduling Irrigation for Sweet Corn Under Sprinkler Irrigation in the Jordan Valley.
18	G. Haider	October 1980	Review of Soil and Water Management Research, Identification of Present Agriculture Problems and Suggestions.
19	G. Haider	January 1981	Irrigation Water Quality Criteria and Management.
20	G. Haider	January 1981	Use of groundwater for irrigated agriculture in Jordan - problems and suggestions.
21	G. Haider	February 1981	Leaching Requirements for Irrigated Agriculture.
22	G. Haider	November 1981	Review of present research activities on some research stations in Iraq and proposed plan of work.
23	G. Haider and Mustafa Hefnawi	November 1981	Study on Leaching Requirement, Salt Distribution and Yield of Potato Crop Irrigated with Partially Treated Saline Sewage Water.
24	G. Haider	December 1981	Effect of Cutting Intervals on Yield of Alfalfa.
25	G. Haider and M.S.F. Hefnawi	January 1982	Study on Water Use Patterns at Wafra Farms and Relationship Between Soil Salinity and Crop Yields.

No.	Author	Date	Title
26	G. Haider	January 1982	Study on Irrigation Water Quality Criteria, Leaching Requirements, Salt Movement in Soil and Salt Tolerance of Tomato Under Kuwait Conditions.
27	G. Haider M.S.M. Hefnawi and A.R. El Bably	March 1982	Study on Irrigation Water Quality Criteria, Leaching Requirements, Salt Movement in Soil and Salt Tolerance of Tomato Crop Under Kuwait Conditions.
28	Nader Ghattas Hawatmeh	February 1980	M.Sc. Thesis on Wetting Fronts Under A Trickle Source in Some Soils of the Jordan Valley.
29	J.H. Johnson J.L. Astier J.J. Groot C.M. Groot (Mrs) and K.H. Benjamin	1979	Survey and Evaluation of Available Data on Shared Water Resources in the Gulf States and the Arabian Peninsula.
30	M. Latifur Rahman and N.G. Dastane	September 1981	Improving Farm Survey on Appraisal of Extraction and Salinity of Well Waters in Qatar.
31	S.Naghmoush	September 1981	Amelioration of Sandy Soils in Qatar. Part A - Effect of Organic Matter Addition on Yield of Alfalfa Growth on Sandy Soils.
32	S. Naghmoush	September 1981	Amelioration of Sandy Soils in Qatar. Part B - Effect of Loam Addition on Yield on Some Grain Crops.
33	S. Naghmoush	October 1981	Amelioration of Sandy Soils in Qatar. Part C - Effect of Organic Matter and Loam Application on Yield of Some Field Crops.
34	S.R. Naghmoush	May 1982	Soil Salinity Control - Part A - Effect of Mulching on Salinity Control on Different Soil Types.
35	S.R. Naghmoush	June 1982	Soil Salinity Control - Part B - Effect of Change of Micro-climate on Salinity Control on Different Soil Types.
36	S.R. Naghmoush	June 1982	Soil Salinity Control - Part C - Effect of Leaching Requirements on Salinity Control on Different Soil Types.

No.	Author	Date	Title
37	Jalal Mustafa Hussein Qasem	May 1980	M.Sc. Thesis on Scheduling Irrigation for Tomato Under Drip Irrigation.
38	S.A. Tamimi	March 1981	A Brief Review of Research on Rainfed Agriculture.
39	Abdalla Subhi Abdalla Yousef	December 1980	M.Sc. Thesis on Evaluating the Effect of Wind Velocity Spacing and Operating Pressure on Water Distribution from Sprinklers in the Jordan Valley.