Other titles of interest

BISWAS, SAMAHA, AMER and ABU-ZEID
Water Management for Arid Lands in Developing Countries

EL-SHERBINI
Food Security Issues in the Arab Near East

GODBY and OTTERMAN
The Contribution of Space Observations to Global Food Information Systems

SHAINBERG and OSTER
Quality of Irrigation Water

SHALHEVET, MANTELL, BIELORAI and SHIMSHI
Irrigation of Field and Orchard Crops under Semi-Arid Conditions

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE
Problems of the Agricultural Development of Less-favoured Areas in Europe

WIDSTRAND
Water and Society, Conflicts in Development, Part 1—The Social and Ecological Effects of Water Development in Developing Countries

WORTHINGTON
Arid Land Irrigation in Developing Countries: Environmental Problems and Effects

ZAHLAN
Technology Transfer and Change in the Arab World

Journals of interest *

IRRICAB—Current Annotated Bibliography of Irrigation

WATER SUPPLY AND MANAGEMENT

WORLD DEVELOPMENT

**Free Specimen copies available upon request*

Irrigation and Agricultural Development

Based on an International Expert Consultation, Baghdad, Iraq, 24 February - 1 March 1979

Edited by

S. S. JOHL

Professor of Economics
Punjab Agricultural University, India, and Consultant to the Joint ECWA/FAO Agriculture Division, Beirut, Lebanon

1980

Published for the
UNITED NATIONS
by
PERGAMON PRESS
OXFORD · NEW YORK · TORONTO · SYDNEY · PARIS · FRANKFURT

Irrigation Systems Efficiency

S. W. Macksoud and N. Azar

INTRODUCTION

The ever increasing demand on irrigation water for agricultural production and the spiralling costs of irrigation resource development have led to awareness of the efficiency with which available water resources should be used. Irrigation engineers are finding their clients demanding irrigation projects designed for higher efficiencies of water use and insisting on detailed plans to achieve such higher efficiencies. The purpose of this paper is to present concepts and practical recommendations that would help in the design and operation of more efficient irrigation systems.

TERMS USED

There is very little standardization of terms used in describing efficiency of irrigation. This stems from the lack of such standardization describing the status of soil moisture. In order to establish a common ground for understanding, the following definitions are suggested. It is hoped that these and other modified terms and versions would soon be standardized.

Soil Moisture Terms

Field Capacity (FC) is moisture remaining in a soil following wetting and natural drainage until free drainage has practically ceased. The time required for cessation of free drainage varies with soil texture and structure and rate of water use by crops. The Soil Science Society of America defines the field capacity as the "percentage of water remaining in a soil two to three days after the soil has been saturated and after free drainage has practically ceased".

Wilting Point (WP) is the moisture content of the soil after the plant can no longer extract moisture at a sufficient rate for wilted leaves to recover overnight or when placed in a saturated environment.

f) Projects are normally designed on the basis of average values. Individual fields may have specific values differing from the average. Therefore, irrigation techniques must be based on specific characteristics of individual farms and not on project averages.

CONCLUDING REMARKS

Efficiency is the result of need or shortages. Whether it is water, oil or any other commodity, users will accept more efficient practices when they are faced with a shortage. Abundance induces waste and wasteful practices. Fresh water is becoming scarce day by day. The sooner the users realize this, the faster they will improve their use efficiency. The techniques are known. The need is for proper selection of techniques and a persistent follow-up.

REFERENCES

Dar Al-Handasah, Agro and Scoio-economic Study, Jordan Valley Project Report, Beirut, 1969.

Dar Al-Handasah, Jordan Valley Irrigation Project - Stage II, Beirut 1977.

Dar Al-Handasah, Definite Plan Report for the Abyan Delta Project, Beirut, 1972.

Soil Science Society of America, Glossary of Soil Science Terms, Madison, Wisconsin, 1975.

APPENDIX 1/

JORDAN VALLEY PROJECT: PRESENT IRRIGATION

Irrigation is an ancient art practised in the Jordan Valley from the oldest of days. However, after having prospered, notably during the Roman occupation, it declined as populations and trade routes shifted. Following the 1948 tragedy, interest in irrigation in the Valley was revived. An Irrigation Department was established and a construction programme was launched aiming at improving diversions from side wadis and their canalizations. This was followed by the East Ghor Canal Project initiated in 1958, which integrated unregulated surface flows of several smaller streams with those of the Yarmouk into a modern irrigation system. Also, following 1948 a rapid growth of irrigation from wells took place.

AREAS AND DISTRIBUTION SYSTEMS

Presently water for irrigation is supplied by diversions from rivers and wadis, from springs, by pumping from individual wells and the Jordan River. The determination of the exact area actually under irrigation is rather difficult. This is because much of the land that is registered as irrigated, either receives water for only a fraction of its area or receives water only occasionally.

River diversions: The available flows of the Yarmouk river are diverted at Adassiya into the East Ghor Canal. This canal with an initial capacity of $20m^3$ per sec., runs approximately along the border of the valley floor or Ghor for a length of about 70 kilometres. It also receives the flow of several wadis along its way in the valley. Laterals perpendicular to its length take off supplying individual farm units. Most of the land presently supplied with water was under irrigation previously. The new project organized water distribution on an equitable basis. It also included regrouping of small holdings and parceling of large estates into economically justified units with a minimum size of 30 donums and a maximum ownership of 200 donums.2/ Measured irrigation flows are delivered following a modified demand system. All water channels are lined. The total area of the East Ghor Canal project is approximately 122 000 donums.

Wadis: The Arab, Ziglad, Jurum, Yabis, Kufrinja, Rajib and Zarqa wadis deliver most of their base flow into the East Ghor Canal. However, diversions are first used to irrigate areas situated above the East Ghor Canal. The total area so irrigated is estimated at 16 000 donums, of which 14 742 donums lie below the gaging stations, and their supply is controlled by the East Ghor Canal Authority (EGCA). The remaining East Bank wadis (Shueib, Kafrein and Hisban) irrigate about 37 000 donums.

1/ Extracts from Chapter 1, of Annex G, in Vol. III of Dar Al-Handasah, Jordan Valley Project, Agro and Socio-Economic Study, 1969, Final Report, Beirut, 1969.

2/ One donum = 0.1 hectare.

The West Bank wadis irrigate an estimated area of 22 000 donums. Much of the land so irrigated is planted with wheat and is deficient in irrigation water supplies.

Springs: There are several springs,mainly on the West Bank, that supply water to adjoining areas. The total area so irrigated is estimated at about 10 000 donums. Of these, about 8 000 donums lie in the West Bank.

Wells: Wells are generally individually owned and serve one farm. However, there are a few wells operated by groups that distribute water to several farm units. The estimated area irrigated by pumping from such wells is 45 000 donums on the East Bank and 13 000 donums on the West Bank. Very few irrigation wells are located north of Zarqa River.

Pumping from Jordan River: Lands lying along both banks of the Jordan River (the Zor) are presently irrigated by pumping water from the river. An estimated area of about 35 000 donums is so irrigated, of which 16 000 donums are presumed to be on the East Bank. A modern concrete lined distribution network to supply water to most of this area from the Yarmouk diversions, taking off from the East Ghor Canal is under construction. This will end the need to pump from the Jordan River whose water quality is expected to deterioriate beyond safe use, once the Khalid Bin Al Walid Dam is completed.

Thus, the total area presently under irrigation is as follows:

East Ghor Canal Project	122 000 donums
From side wadis	75 000 "
From springs	10 000 "
From wells	58 000 "
By pumping from Jordan River	35 000 "
Total area	300 000 "

This may be divided as:

North East Ghor and Zor	138 000 donums
South East Ghor and Zor	100 000 "
West Ghor and Zor	62 000 "

PRESENT IRRIGATION METHODS

The commonly followed irrigation methods range from wild flooding to furrows and basin irrigation. They usually are a reflection of the available water supply and the crop. Cereals are usually flooded with a wild or semi-wild technique, generally utilizing large heads that tend to cover large areas but with inadequate penetration. Vegetables and fruits are commonly irrigated by short furrows or basins. For these crops, water is well controlled and penetration is adequate. However, because of the ungraded land, either short runs or zig-zag runs or runs following natural contours are adopted. This increases labour requirements and diminishes the chance of utilizing machinery for cultural operations.

Only three or four farms have so far utilized sprinklers. Of these, the Arab Development Farm in Jericho is a Boys Town operated for educational and welfare purposes. This farm has utilized sprinklers continuously and in an expanding manner since 1956. On a few other farms the use has been sporadic and usually for trial periods.

WATER USE AND FIELD APPLICATION EFFICIENCY

The usual irrigation interval is one week. However, depending upon crops, availability of water and personal experience this interval may range from one or two days to several weeks. Fruit and vegetables are usually irrigated weekly, except when nursing young plants, when water may be applied every other day. Alfalfa and corn may have longer intervals of two or three weeks, while wheat and barley may be irrigated only once or twice a year. No soil moisture determinations are made and irrigation intervals are fixed by custom and experience.

No published data exists on the actual amount of water utilized for various crops in the project area. The records of the East Ghor Canal Water Delivery Offices show volumes and dates of water diversions to separate farm units. Units that were ascertained to have been planted with only one crop were selected. For various units, the data were extracted as in Table 1. The data indicate a wide range for most crops which could be due to different soils, application efficiencies and cultural preferences. However, it provides an assessment of the volumes of water the various farmers are using. Rough comparisons with a few farms irrigated by wells indicated reasonable similarities. One exception was a comparison with water applications by sprinklers, which were found generally much lower than those in Table 1.

A second attempt at determining amounts of water actually utilized for irrigation in the valley was made on the basis of total cultivated and irrigated areas. Again the records of the East Ghor Canal Authority were consulted. From the monthly reports of various field agents, the areas under crops for each section and during each month were determined. Table 2 presents the summary results. The figures include only water losses incurred on the farm, because only net volumes delivered to farmers were used in the calculations.

No actual field data have been published on rates of use or field application efficiencies. Thus, a field study was undertaken during the field stage of operations to determine a few typical field application efficiencies and rates of water use by crops under surface irrigation. The method adopted for this combined study consisted of making soil moisture determination before and after each irrigation and measuring the volume of water applied to a measured area of the field. Furthermore, the field capacity and bulk density of the soil were determined.

Considering the period during which the work had to be done, and due to the late rains of 1966/67, only three crops were studied - bananas, citrus and sweet peppers. Three fields were chosen and field capacity and bulk density of the soil at depths of 15, 30, 60 and 90 cm. were determined by standard methods. A textural analysis of the soil was made. Using an auger, soil samples at the indicated depths were

TABLE 1 Actual Rates of Irrigation Applications to Various Crops, Jordan Valley, 1965 - 1967

(Cubic metres per donum, millimetres)

Crop	Typical seasonal applications (m^3 per donum	Range of average daily rates (mm)	Remarks
Potatoes	358	3.0 - 7.4	Jan - Apr
"	220	1.4 - 5.3	Oct - Jan
Tomatoes	970	6.2 - 14.5	Apr - Jun
"	1249,920	3.5 - 7.7	Nov - Jun
Wheat	70,122,280	-	-
Sesame	122	1.3 - 10.4	-
Alfalfa	805	2.4 - 19.5	-
"	770	2.0 - 28.4	-
Citrus	921,722	1.8 - 7.1	Mature trees
"	240,540,660,870	-	Young trees
"	1690,1170,926,705	-	In Zor regions
Corn	276,240	1.6 - 4.2	July - Oct
"	563,447	3.5 - 5.2	Jun - Sep
Sweet peppers	867	3.0 - 5.4	Sep - Jun
Onions	388	2.4 - 6.0	Dec - May
Cauliflower	507,435	2.7 - 8.1	Aug - Dec
"	550,457	4.3 - 11.5	Jun - Dec
Bananas	4000,2500,3500	10.7 - 18.0	-

TABLE 2 Actual Farmer Diversions in the East Ghor Canal Project 1966 Average Application Rates

(mm/d for all sections)

Month	For total irrigable area	For area actually cropped
January	15	19
February	16	20
March	47	59
April	63	89
May	86	182
June	93	280
July	91	287
August	102	207
September	102	182
October	75	168
November	81	155
December	23	30

taken just before irrigation from three locations in each field. The soil was placed in precalibrated airtight cans and weighed. Samples were then placed in an oven at 105°C until they reached a constant weight. The dry-weight was determined and the soil moisture expressed on a dry-weight basis. Soil samples were again taken 36 hours after irrigation, and their moisture content determined. These operations were repeated before and after every irrigation until interrupted by the June hostilities. The intention was to carry through with these studies, although officially the field stage study period would have ended.

From the soil moisture determinations before each irrigation the average moisture content of every soil layer was determined. This was subtracted from the average field capacity of that layer and the result multiplied by the bulk density and the actual depth of the layer. This gave moisture deficiency. When added for all layers sampled and compared to the depth of irrigation water applied, a measure of field application efficiency was obtained. The volume of water applied was measured in cubic metres by the fixed head orifice controlling flow into the field which, when divided by the area of the field in square metres, gave the depth of application.

The rate of water use covering the period between any two irrigations was fixed by determining the difference in soil moisture content per depth layer during this interval. Thus, the average moisture content prior to irrigation was subtracted from the average moisture content as determined 36 hours after irrigation. The balance, multiplied by the bulk density and soil depth per layer gave moisture depletion which, when divided by the number of days between two readings, gave the daily rate of use. Table 3 gives the summary of this work. From this it was assumed that 55 per cent might be considered as an average application efficiency for the area. This is in line with other areas where ownership is small, water scarce and land usually not graded to optimal uniform slopes.

A study on sprinklers was carried out on the Arab Development Farm at Jericho. Catch pans were placed on a three metre square grid in various fields being sprinkled. The catch in every can was measured at two-hour intervals. This coincided with the time at which the lateral was moved to the next position. Sprinklers were spaced at 9 m and the laterals at 15 m. The overlap was such that cans received water only from two adjacent lines; thus the effective radius of reach was 15 metres. The four-hour catch is given in Table 4 and the calculated uniformity coefficient, using the Christiansen equation was 79 per cent. The loss by drift was established through relating the total discharge from the sprinkler head during a given period (2 hours) and the catch registered within the area it dominated. This assumed that sprays not recorded within two lateral spacings were lost. Actually part of this loss might contribute to reduced transpiration over the area where this drift was actually evaporated. Notwithstanding this, the average calculated efficiency was 70 per cent. This was better than the surface methods, but considerably below reported efficiencies for better sprinkler systems.

EFFICIENCY OF CONVEYANCE AND DISTRIBUTION

A measure of the attained level of efficiency in distribution, incorporating conveyance losses incurred in the process, was obtained from the records of the East Ghor Canal water deliveries. Table 5 gives a summary of monthly volumes of water diverted into conveyance system and those delivered to various farms. The calculated loss ranges from 0.2 to 28.6 per cent with an average of 13.7 per cent. With a system of delivery on demand and on water storage facilities, a higher efficiency is not to be expected. However, considering the high percentage of so-called controlled waste water not utilized and willfully discharged by the wasteways, which is a cushion for absorbing considerable administrative inefficiencies, the true loss figure is much higher than is indicated by the table.

TABLE 3 Water Use and Field Application Efficiency in the Jordan Valley during the period of 4 May - 5 June 1967

Crop	Sweet Peppers	Bananas	Citrus
Area	29 689 m^2	30 549 m^2	20 000 m^2
Location:			
- EGCA basin	20	19	20
- Plot number	36	25	45
Soil texture: (per cent)			
- Clay	40	46	38
- Silt	31	33	30
- Sand	29	21	32
Bulk density (average)	1.30	1.25	1.35
Field capacity at:(per cent)			
- 15 cm depth	26.0	-	-
- 30 cm depth	23.7	30.8	25.2
- 60 cm depth	21.7	26.5	23.1
- 90 cm depth	-	30.5	19.1
Application efficiency	4/5/67:45	4/5/67:30	13/5/67:52
at indicated dates	11/5/67:69	21/5/67:52	-
(per cent)	16/5/67:62	28/5/67:50	-
	27/5/67:ins	-	-
Period/average water use	4-11/5/67:4.3	14-21/5:6.3	13-19/5:4.9
(mm per day)	11-16/5/67:4.6	21-28/5:6.8	-
	16-27/5/67:5-0	-	-

TABLE 4 Sample Uniformity Coefficient Calculation, Sprinkler Irrigation of the Arab Development Farm at Jericho. Jordan Valley, 1967

Can number (n)	Catch in cc/44 hrs	Deviation from average (Y)
1	70	3
2	40	27
3	53	14
4	70	3
5	70	3
6	46	21
7	44	23
8	66	1
9	77	10
10	68	1
11	79	12
12	81	14
13	47	20
14	85	18
15	95	28
16	100	33
17	73	6
18	50	17
19	60	7
20	77	10
21	70	3
22	51	16
23	40	27
24	90	23
Total (Σ)	1 602	340
Average (m)	67	

$$\text{Uniformity coefficient} = 100\left(1 - \frac{\Sigma Y}{nm}\right)$$

$$= 100\left(1 - \frac{340}{1\ 602}\right)$$

$$= 100\ (1 - 0.21)$$

$$= 100 \times 0.79$$

= 79 per cent.

TABLE 5 Efficiency of Conveyance and Delivery at East Ghor Canal, 1966

(Million cubic metres, per cent)

Month	Inflows		Deliveries to farmers	Controlled waste	Losses
	Yarmouk	Side wadis			
	(Rounded to million cubic metres)				(per cent)
Jan	9.4	0.1	1.9	7.6	0.2
Feb	9.2	0.4	2.1	5.6	18.0
Mar	12.1	0.4	6.1	6.3	1.2
Apr	11.4	1.7	8.1	4.8	0.6
May	11.9	2.5	9.8	0.5	28.6
June	11.1	2.7	10.2	1.6	14.3
July	11.3	2.3	9.8	1.5	17.5
Aug	12.1	2.3	11.1	0.7	17.2
Sept	13.5	2.6	12.0	1.0	19.0
Oct	11.6	2.7	9.2	3.1	14.5
Nov	12.0	1.7	10.1	2.4	9.2
Dec	8.2	2.7	2.8	5.5	24.1
Total	133.8	22.1	93.2	39.1	

Agricultural Development and Optimal Water Use in a Labour-Scarce Environment

(The Case of the Kourris Delta in Cyprus)

Apostolos Condos

INTRODUCTION

This paper discusses the main features of an agricultural development problem and its proposed solution in a setting of initially "wrong" proportions in resource endowment, rectified by appropriate farm and infrastructure investments (Cappi, Condos and Ottaviani, 1977). Although the Kourris Delta development prospects may be atypical on account of favourable markets for its products, quality of its soil, water resources and climate, the case is of interest because it shows how to make up for "wrong" initial resource endowment and relax the most binding constraint by appropriate choice of farm technology (FAO, 1978).

The Project Objectives

The project aims at developing a cultivable area of 7 500 donums 1/ in the four villages of Kolossi, Eremi, Episkopi and Akrotiri. The proposed development would be based on the expansion of both perennial and annual irrigated crops. The main objectives are to (a) increase the returns to farm resources, (b) earn foreign exchange, (c) induct a proper use of local ground water resources and (d) provide gainful employment for Greek Cypriot refugees. The basic means for the attainment of these objectives are the introduction of (i) high value crops for export, (ii) modern on-farm irrigation systems to surmount severe labour and water constraints and (iii) necessary irrigation infrastructure and facilities.

The Project Setting

The 7 500 donums project area is located on the south coast of Cyprus, a few kilometres west of Limassol, on the alluvial fan of the Kourris River which drains a part of the Troodos range to the north. The area is therefore relatively flat, ranging in elevation from sea level to about 25 metres. As the climate is typically

1/ 1 donum = 0.134 hectare