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ON-FARM IRRIGATION PRACTICES IN MANSOURIYA DISTRICT, EGYPT

by

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On-Farm Irrigation Practices in Mansouria District, Egypt

Mona El Kady, Wayne Clyma and Mahmoud Abu-Zeid

Abstract

A state-of-the-art study of on-farm irrigation practices in the Mansouria District, Egypt was done. Values for the state variables for the water application subsystem were measured for a number of fields and farms on three branch canals for the Mansouria Irrigation District. Results show that farmers irrigate small (0.0008 to 0.014 ha) basins as if they had zero slope. Actually their range in elevation exceeds the maximum allowable for level borders from nearly 2 to 5 times. Thus, unlevel fields are a major limitation to effective water management. Farmers also must manage a flow rate that ranges from near zero to twice the mean flow while irrigating a variable number of small basins of variable size. Farmers are unable to quantitatively apply water to their fields.

Farmer management decisions on how to irrigate have resulted in a water application system that is unlevel and is difficult to apply a given amount of water to. The amount of water applied exceeds the water that can be stored by an estimate 100 percent with resultant fertilizer leaching and a fluctuating water table that both limit crop yields.

The factors which affect crop yield were evaluated but inadequate data did not permit quantification. Preliminary results suggest that increased water application decrease yields suggesting that excess water

increased water application decreased yields or that excess water was applied. No factor except fertilizer had a positive effect on yield out of 10 factors evaluated. Level borders were recommended for improvement of the on-farm system. Evaluations of the new system are presently (1979) being conducted in Egypt.

تطوير طرق الري بالحقل في منطقة المنصوريه بمصر

منى القاضي وين كلايما ،محمود ابوزيد

قد تم عمل الدراسه الحديثه الخاصه بتطبيق وتطوير طرق الري بالحقل في منطقة المنصوريه بمصر . كما تم قياس المتغيرات الخاصه بنظام تطبيق المياه لعدد من الحقول والمزارع على ثلاث ترع فرعيه لمنطقة المنصوريه . وقد اظهرت النتائج ان الفلاحون يروون الاحواض الصغيره والتي تتراوح مساحتها بين ٠٠٠٨و٠ الى ٠١٤و٠ هيكتار كما لو كانت افقيه تماما (الميل = صفر) . وقد لوحظ ان تقدير الفلاحون لمناسيب حقولهم المستويه يزيد من مرتين الى خمس مرات عن الحدود القصوي المسموح بها للاراضي المستويه . وبناء على هذا فان الحقول الغير مستويه تعتبر عائق اساسي في التحكم الفعال في توزيع المياه . ويجب على الفلاحين ان يتحكموا في كمية التصرف والتي تتراوح بين مايقرب من الصفر الى ضعف مقدار التصرف المتوسط - اثناء ري عدد متغير من الاحواض الصغيره ذات الابعاد المختلفه . فقد ثبت ان الفلاحون غير قادرون على تحديد كمية المياه اللازمه لري حقولهم .

ولقد دلت النتائج الخاصه باتخاذ الفلاح القرار في كيفية التحكم في مياه الري بالحقل على عدم التكافؤ في نظام تطبيق المياه وكذلك على صعوبه واضحه في تطبيق كميه معينه منها . وقد اتضح ان كمية المياه الداخله تزيد عن المياه اللازمه للجذور بما يقدر بحوالي ١٠٠ ٪ مما ينتج عنه ازاله المواد التسميديه الموجوده وكذا زياده مضاربه في منسوب الماء اللارضي مما يتسبب عنه تقليل في كمية المحصول الناتج .

وقد تم تقدير العوامل التي تؤثر على انتاجيه المحصول ولكن لم يتم التحديد الكمي بسبب عدم توافر البيانات اللازمه . وقد اظهرت النتائج الاوليه المقترحه بان زياده مياه الري ينتج عنه تقليل في المحصول حيث قد تم بالفعل تطبيق مياه ري زائده عن الحاجه .وقد اتضح ان العوامل العشره التي تم تقديرها ليست لها تاثير ايجابي على المحصول الناتج ماعدا عامل واحد فقط وهو التسميد . وقد ظهرت الحاجه الى مزيد من البيانات وذلك لتحديد العلاقات بين السبب والتاثير الناتج اذا ماحذف عامل او اكثر من العوامل المؤثره في الانتاج مع الاخذ في الاعتبار انه بتطبيق العوامل التقليديه الاخرى اللازمه للانتاج لم ينتج عنه زياده ايجابيه في المحصول الناتج . وقد تمت التوصيه باستعمال الاحواض الافقيه وذلك لتحسين نظام الري بالحقل . كما انه جاري حاليا (١٩٧٩) عمل التقييم اللازم لنظام الري الحديث بمصر .

TABLE OF CONTENTS

	Page
Abstract (Arabic and English)	i
List of Tables	v
List of Figures	vi
Preface	vii
Background	1
State-of-the-Art	6
Water Application Subsystem	6
Procedure	8
System Classification	11
Field Geometry	13
Slope	18
Infiltration Rate	22
Surface Roughness	32
Channel Shape	33
Water Supply Rate	33
Management	37
Water Table Conditions	42
Factors Affecting Crop Yield	49
Summary and Conclusions	51
Recommendations	54
References	56
Conversion Table	57

LIST OF TABLES

Table		Page
1	Slopes of Fields in the Mansuriya District	20
2	Range in Elevation of Bunded Units for Selected Fields	21
3	Amount of Water Applied Per Irrigation for First Irrigation and All Additional Irrigations for Beni Magdul, El-Hammami and Kafret Nasar Canals for Summer Season 1978	28
4	Flow Rate Data Sheet (Summary)	36
5	Irrigation Frequency in El-Mansuriya District	38
6	Seasonal Application of Water to Corn and Squash	43
7	Sample Water Balance for the Corn Field in Figure 7 (amounts in mm)	48
8	Regression Variables for Corn Yield	50
9	Results of 4 3 - Variable Models	52

LIST OF FIGURES

Figure		Page
1	Location Map for Study Areas	3
2	Arrangements of Branch Canal, Mesqa, Head Ditch, Field Ditch and Drains with Measuring Points for Farm Water Supply	5
3	Location Map for Kafret Nassar (K.N.), Beni Magdul (B.M.C.) and El-Hammami (E.H.C.) Branch Canals in Mansuriya District	9
4	Typical Dimensions of Furrows for Various Crops in the Mansuriya District	14
5	Field Geometries of Representative Case Study Fields	16
6	Infiltration Curves Beni Magdul	23
7	Infiltration Curves Beni Magdul	24
8	Infiltration Curves El-Hammami	25
9	Infiltration Curves El-Hammami	26
10	Infiltration Curves El-Hammami	27
11	Effect of Successive Irrigation on Infiltration	30
12	Advance and Recession and Infiltration	30
13	. . . . .	31
14	. . . . .	45
15	Seasonal Consumptive Use (ETa) and Potential Evapotranspiration (ETp) for a Corn Field at Beni Magdul	48

Preface

This report was prepared with the cooperation of the staff of the Eygptian Water Use and Management Project. The assistance of Wadi Fahim, Salah El Ella and Zaki El Fotouh, Engineers Mr. Harold Golus and S. M. Samakia, Agronomists and the Economics and Sociologist teams in planning and conducting the overall study is appreciated. The project is funded by the U.S. Agency for International Development, and the Arab Republic of Egypt. Dr. D. S. Brown is the Mission Director USAID and Mr. Niel Dimick is Project Manager USAID.

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ON-FARM IRRIGATION PRACTICES IN MANSURIYA DISTRICT, EGYPT[1/]

By Mona El Kady, Wayne Clyma and Mahmoud Abu-Zeid[2/]

Background

Irrigation in Egypt began about 6000 years ago. The annual flood, occurring from August to October, led the inhabitants of Egypt to practice both river training and irrigation to improve their existence. Towards this objective, a series of control works such as the Delta Barrage (1840) and Aswan Dam (1902) were built. The works were mainly for irrigation purposes but were also for flood control.

The oldest known method of irrigation practiced in Egypt was basin (flooding) corresponding to the annual flooding of the Nile. Basin irrigation consisted of ponding water on areas flooded by the Nile and growing crops on residual soil moisture after the water receeded. Since the construction of the Delta Barrage, perennial irrigation has been practiced in lower Egypt. After the completion of the High Aswan Dam (1970), the entire cultivated area in Egypt was placed under perennial irrigation.

Before the High Aswan Dam, the cultivated area was decided by the annual storage in Aswan (5 billion m^3/year) and Gabal Aelia (2 billion m^3/year) reservoirs, the base flow of the Nile and some use from

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groundwater. This area averaged about 1.7 million ha (4 million Feddans*) under perennial irrigation and 0.42 million ha (one million Feddans) under basin irrigation of which about 0.25 million ha (0.6 million Feddans) were served by wells in the summer.

After the completion of the High Aswan Dam, 55.5 billion m^3/year was made available for irrigation purposes. This volume allowed the conversion of all basin into perennial irrigation as well as the irrigation of additional area. Perennial irrigation presently encompasses about 2.6 million ha (6.1 million Feddans) of which about 0.4 million ha (1.0 million Feddans) are new lands. The cropping intensity in Egypt in 1978 is very close to 2.0 or an average of two crops per year are grown on each field.

Present perennial irrigation receives water from storage behind the High Aswan Dam through scheduled releases of flow to the Nile (Fig. 1). Barrages divert water to major canals at selected points and deliver water to supply canals administered by Governorates and then Irrigation Districts. The districts range in area from 8 to 24 thousand ha (20 to 100 thousand Feddans). The major canal flow is based on the water requirements of the area served as determined by (1) the crops grown, (2) soil type, (3) the area irrigated, and (4) the expected distribution and farm area water losses. District supply canals (Wolfe, Shahin and Issa, 1979) serve branch and subbranch canals which provide water to private farm supply channels (Mesqas).

Water is supplied to a District on a two or three interval rotation. The length of the interval depends on the crops grown.

*Feddan = 4200 sq. meter = 0.42008 hectare
Underlined words are those used in Egypt and could be unfamiliar for other countries.

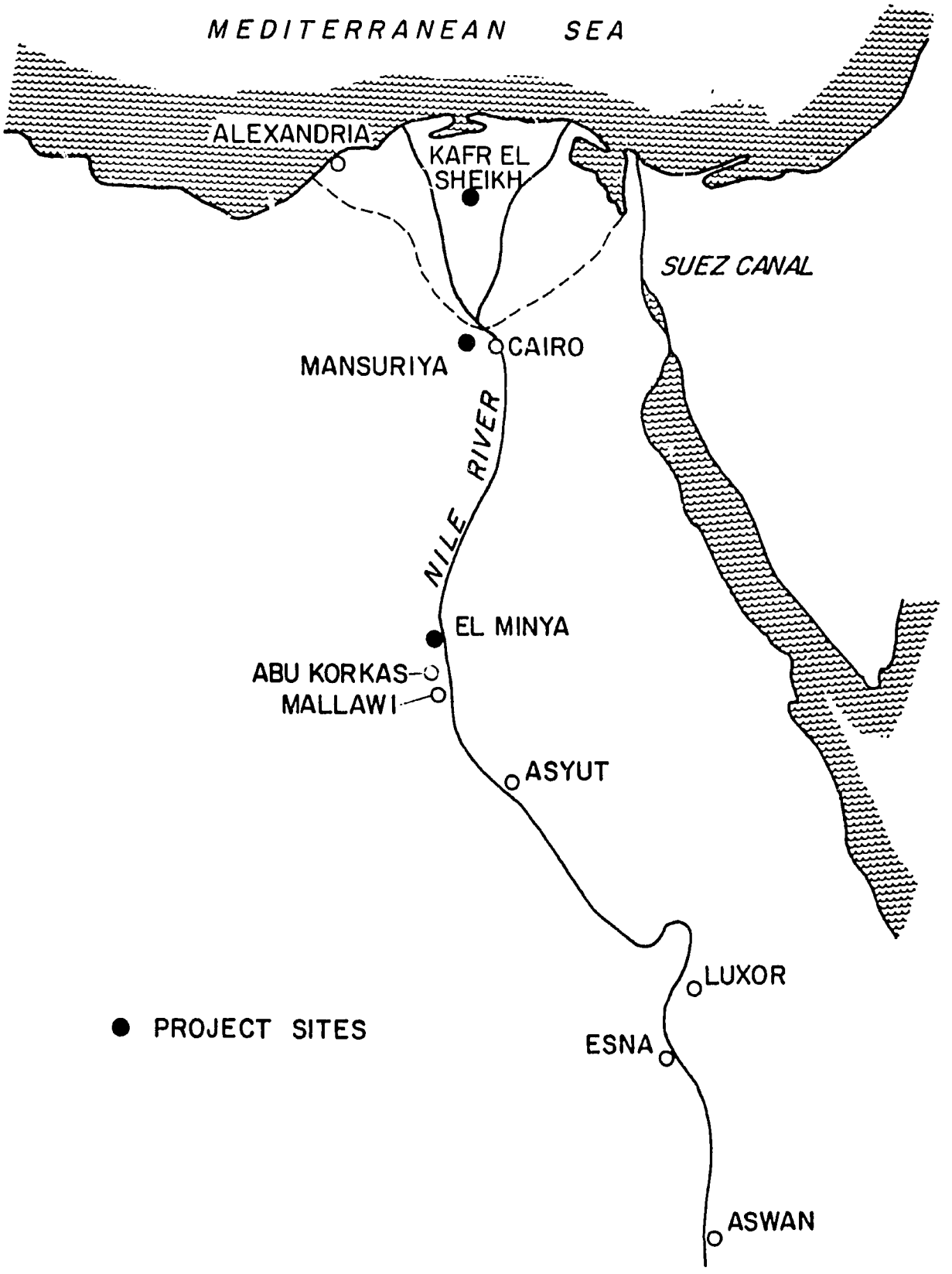


Figure 1. Location Map for Study Areas.

Intervals are typically 4 and 7 days. On the three interval rotation, for example, the upper, middle and lower reaches of the canal receive water for an interval in turn. For the four day and three interval rotation, a branch canal would receive water for four days and then for eight days would receive no water (Wolfe, Shahin and Issa, 1979).

Regulation of the flow to a branch canal is related to the available flow in the district supply canal; however, water is supplied based primarily on the water surface elevation on the downstream side of the inlet gate. Usually there is no determination or allocation of a specific flow rate at any point within the district. Thus, the more water a group of farmers use on a branch canal, the lower the water surface elevation and the more water supplied to that branch canal.

On a branch canal as shown in Figure 2, water is conveyed to farmers through an outlet which supplies a private channel (Mesqa) that serves individual farms. An outlet may serve only one or several farm supply points. One farmer or a small group of farmers may take water at one supply point. Flow through the outlet that serves each Meska is regulated hydraulically by the size of the outlet and by assuming that the supply rate to the branch canal results in a specific downstream water surface elevation. The top of the pipe outlet is located 25 cm below the design water surface elevation. This elevation is located up to 50 cm below the surface of the surrounding land. Actually, because of variations in supply and use rates, local topography and the installation by farmers of additional unauthorized outlets, flow rates through each Mesqa outlet vary widely.

Typically each farmer or group of farmers must lift the water from the supply channel to the field. Lifting is usually accomplished by the

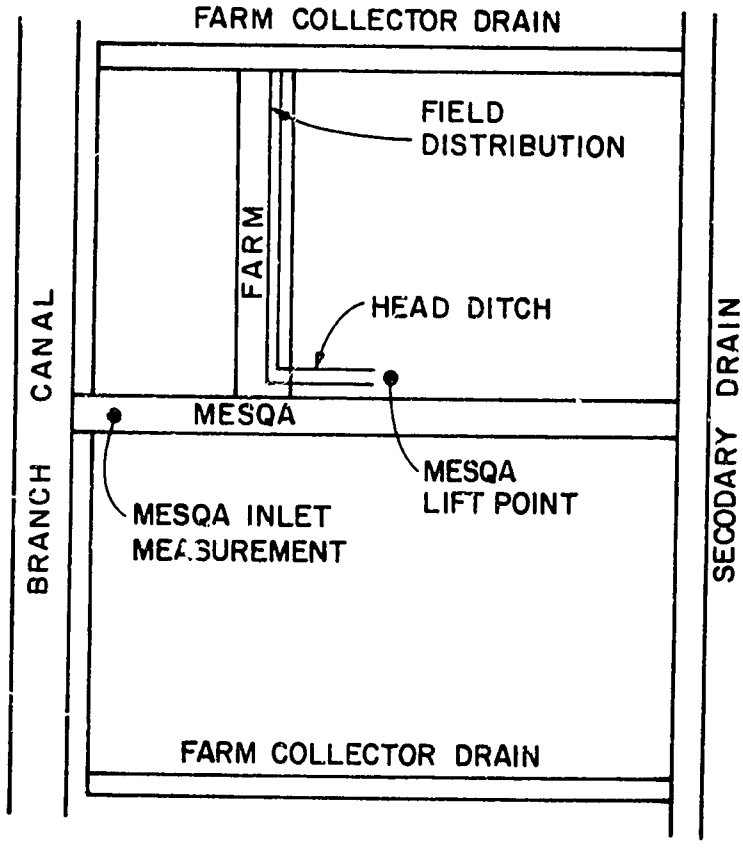


Figure 2. Arrangements of Branch Canal, Mesqa, Head Ditch, Field Ditch and Drains with Measuring Points for Fram Water Supply.

Shadouf*, Tambour**, or Saqia*** using animal or human power. Sometimes electrical or diesel powered pumps are used. The informal rotation or simultaneous use systems result in lifts widely varying from the official maximum lift of 50 cm. The official government policy is to supply water below the ground surface thus requiring farmers to lift water. The stated purpose of this practice is to discourage excessive use of water by the farmers.

*Shadouf - Consists of a bucket on a pole with a counter balance and a man lifting the water supply.
**Tambour - Archimedes screw powered by human labor.
***Saqia - water wheel usually operated by animal power (bullock, donkey or camel).

Primary, secondary and farm collector drains serve most irrigated areas in Egypt. Substantial numbers of surface field drains also have been installed. Many drains are not well maintained and as a result may not be effective.

State-of-the-Art Approach

Art according to the American Heritage Dictionary (1976) is "A system of principles and methods employed in the performance of a set of activities: the art of building." The state-of-the-art of on-farm irrigation practices will reveal the principles and methods employed by the farmers in their practice of irrigation. Clyma and Ali (1977) used the same procedure to define priority problems and suggest proposed solutions for on-farm irrigation systems in Pakistan. Clyma, Kemper and Ashraf (1977) also applied the approach to define practices and problems for the water delivery system in Pakistan. This report will describe the system, the procedure for data collection and uses state variables for water application to describe and define farmer irrigation practices to identify priority problems in the Mansuriya district.

Water Application Subsystem

The water application subsystem is part of the on-farm irrigation system. The on-farm irrigation system consists of the following four subsystems:

1. Water Delivery
2. Water Application
3. Water Use
4. Water Removal

The water application subsystem serves the following functions:

1. Supplies designed amounts of water to a field.
2. Distributes desired amount of water with the designed uniformity.
3. Meets crop tolerances for seed germination and emergence, inundation, salinity control, aereation, temperature, crusting and other special requirements.
4. Meets minimum and maximum amounts criteria for crop production.
5. Satisfies erosion control standards.
6. Provides necessary surface drainage.
7. Is economically appropriate and socially acceptable to the management abilities of the farmer.

The processes of water application to a field can be described by the following state variables:

1. Field geometry (length and width)
2. Slope
3. Infiltration rate
4. Surface roughness
5. Channel shape
6. Water supply rate
7. Management

The boundary and initial conditions of the system must also be specified to completely describe the state of the system.

Water application system management is accomplished by the farmer by operating the system to meet functional objectives (usually unstated). In the process he answers the following three basic management questions:

1. How do I irrigate?
2. When do I irrigate?
3. How much water do I apply?

Qualitative and quantitative descriptions of the variables which define the water application process and of how a farmer arrives at answers to these management questions are used to describe the state-of-the-art of water application. In this section, the state variables will be discussed. First, however, the data collection procedure will be described.

Procedure - The Egypt Water Use and Management Project (1979) has selected three areas for improvement in Egypt of which the Mansuriya District is the first such area (see location map in Figure 1).

Representative sites on two branch canals (Beni Magdul and El Hammami) were selected for the study (Figure 3). The selection of these sites was based on engineering, agronomic and socio-economic criteria. These criteria were mainly:

1. Location with respect to source of irrigation water.
2. Irrigation systems and methods (gravity and the different types of lift).
3. Soil types.
4. Ownership and other social aspects.
5. Crops.
6. Shape and leveling of fields.
7. Continuous flow and rotational delivery.

All fields on a selected site were monitored at every irrigation. In addition, socio-economic, crop production and soils data were

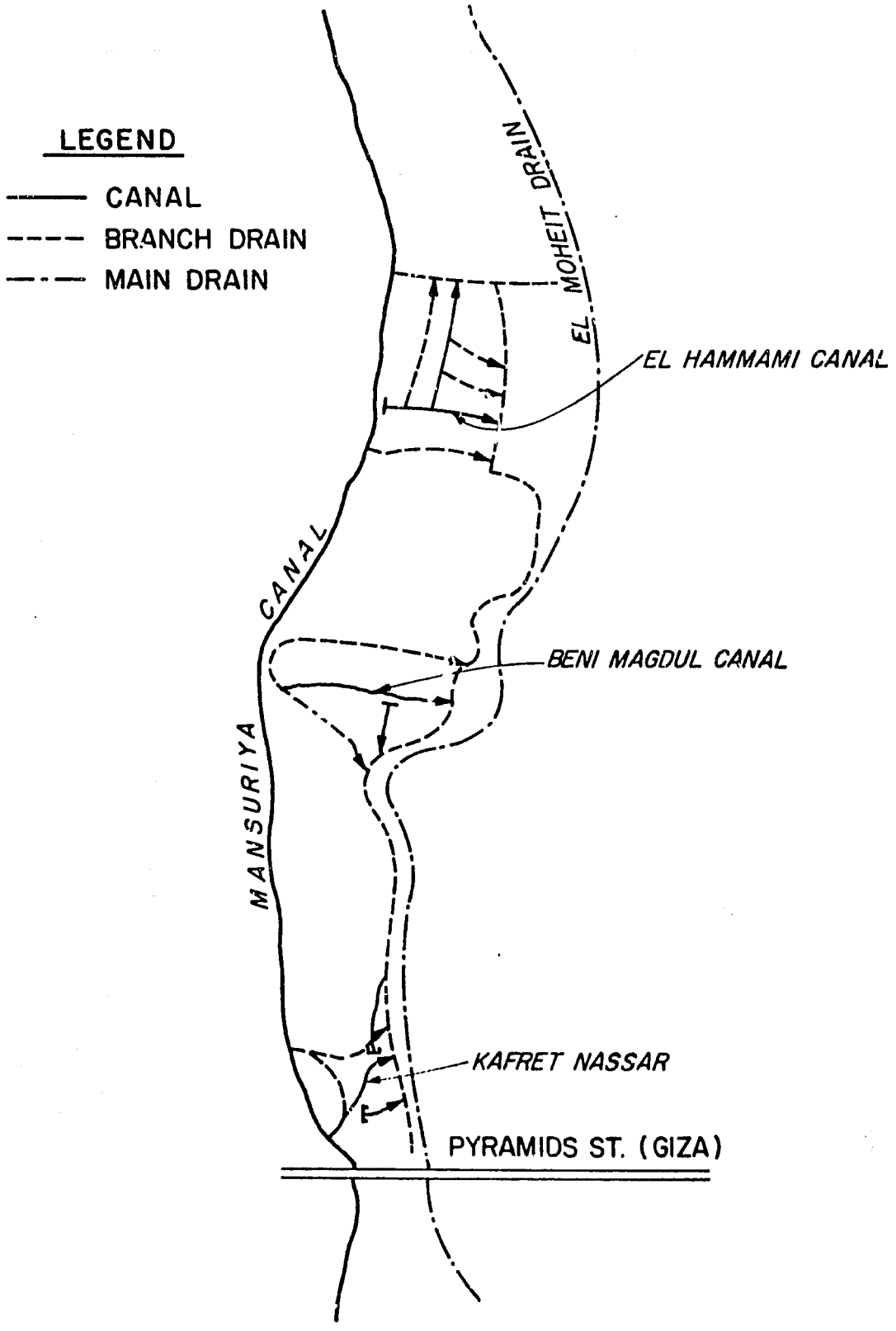


Figure 3. Location map for Kafret Nassar (K.N.), Beni Magdul (B.M.C.) and El Hammami (E.H.C.) branch canals in Mansuriya District.

collected on selected sites by other members of the interdisciplinary team (Clyma, Lowdermilk and Corey, 1977).

On each site the following data were collected:

1. Water Delivery Data (see Figure 2)
   - Flow rate with time downstream of the inlet of the Mesqa
   - Flow rate near the site where water is lifted
   - Flow rate just out of the Saqia
   - Flow rate at the inlet of the field
2. Water Application Data
   - Field and bunded unit* dimensions
   - Time for filling the bunded units
   - Beginning and ending time of each irrigation
   - Elevations of selected fields and bunded units
3. Water Use Data
   - Soil moisture measured gravimetrically before and after each irrigation, initially at one location and subsequently at four locations in each field
   - Quantity of water used in irrigation
   - EC measurements for irrigation, groundwater and drainage water
   - Some data in selected fields on soil moisture tension at 15, 30, 45 cm depth
   - Crop evapotranspiration estimations using the Jensen-Haise (1973) method**

*Bunded unit - This describes the smallest irrigation unit with a ridge or bund completely enclosing an area and cropped flat or on ridges internal to the boundary.

**Evapotranspiration estimation for El Mansuriya district, Egypt, using different equations and field data are under preparation by M. El Kady, F. Shahin, M. Abu-Zeid.

4. Water Removal Data

   - How much runoff occurred and where it went
   - Groundwater levels at several locations around the boundary and internal to a field on a daily basis.

5. Farmer Practice Information

   - Land preparation data: tools used, field geometry, leveling, fallow time between two successive crops
   - Planting data: date of planting, the farmer's planting practices, seeds (how much, kind, time), fertilizers (kind, amount, time)
   - Growing data: practices each time of irrigation, disease, weeds and insect control
   - Harvesting and yield data.

System Classification - The class and type of irrigation system used by farmers must be determined before evaluating the appropriateness of each state variable for farmer practice. In the Mansuriya district only surface irrigation is practiced (as opposed to sprinkler or trickle). Two classes of irrigation are common, level and graded. Either system class may distribute water by two types, basin or furrows. Standard critiera for evaluating an irrigation system vary with the class and type of system.

The principles by which each class and type of system operate are different and the method of management should reflect these principles. Level irrigation systems (zero grade) require the addition of a specific quantity of water to a field such that the time water covers near and distant areas of the field do not result in significant differences in total infiltration. While water is ponded on a field, infiltration and

the distribution of water with length (or width) is approximately proportional to the elevation variation within the field (high spots and low spots). Thus, level irrigation systems require precision leveling if good distribution of water is to result.

Graded irrigation systems require the careful balancing of advance and recession times with the appropriate flow rate to apply the desired application depth. Degree of precision in leveling is not as stringent, but the management knowledge and experience of the farmer must be combined with an appropriate design. Otherwise, underirrigated or overirrigated sections in the field will result and appreciable runoff will occur. Greater skill and knowledge and more careful management by the farmer is required for good water management with graded irrigation systems.

Farmers in the Mansuriya district appear to assume their fields have zero grade. They introduce water into a bunded unit until the area is covered and allow the water to stand and infiltrate into the soil. This practice is followed in both the sandy soil of El Hammami and the clay loam soil of Beni Magdul. They also irrigate bunded units with slopes that are opposite to the direction of irrigation indicating that they do not use the field grade in accomplishing the distribution of water. A more detailed analysis of how farmers use slope and field geometry to apply water will be given in subsequent sections.

In one particular area on the Beni Magdul canal, farmers on one particular Mesqa appear to use a graded system of irrigation. The length of the field is from Mesqa to drain and farmers appear to use a criteria of inflow time and ponding on the lower end of the field to apply water. No other areas have been identified in the District which appear to use the graded system.

Farmers in the Mansuriya District use both basin and furrow types of systems. Furrows are used for most summer crops including corn, vegetables, and peanuts. Major exceptions are citrus and rice. Winter crops grown in basins are berseem and wheat. Most other winter crops are grown with furrows, especially the vegetables. Criteria for appropriate slope (especially deviations and flow rate) are different for furrows as compared to basins. These differences will be discussed under the appropriate state variable.

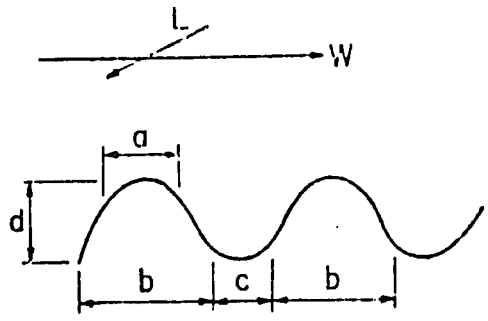
Field Geometry - The length and width of a unit enclosed by a ridge is the irrigation or bunded unit for a farm. When a farmer establishes this unit, he establishes many characteristics of his irrigation system. The relationship between flow rate and area irrigated is established by this unit. A farmer usually does not know nor manage an explicit flow rate. The deviations from mean elevation are determined by the boundaries of the bunded unit since a farmer usually establishes these boundaries after leveling. The sequence and number of units simultaneously irrigated usually become fixed by the selection of the size of the bunded units.

In the Mansuriya district, farmers use bunded units that range in size from approximately 2 x 4 m to 8 x 18 m and areas that range from 0.0008 to 0.014 ha (0.002 to 0.03 Feddans). In general, furrows and ridges do not have exact spacings nor dimensions since they generally are formed by hand. Two types of furrows are prevalent with the following spacings:

1. Narrow furrows with spacings between furrows ranging from 20 to 40 cm, usually used for crops such as corn with one row of plants per ridge.

2. Wide furrows with spacings between furrows ranging from 60 to 80 cm, usually used for vegetables and sometimes having two rows of plants per bed.

The ridge height between furrows usually ranges between 12 and 15 cm. Figure 4 shows typical dimensions of furrow systems for various crops. The ranges for the different dimensions were taken from measurements of farmers' fields. Ridges which define each irrigation unit are usually not much, if any, higher than the interior ridges which form furrows. The boundary ridges are frequently overtopped by irrigation water. This may cause some damage to crops in nearby bunded units when irrigation water is not needed.



Crop	Top Width	Base Width	Channel Width	Ridge Height	Basin Length	Basin Width
	a cms	b cms	c cms	d cms	L ms	W ms
Squash	70- 85	85-100	18-25	15-20	8-20	3- 8
Tomatoes	60- 90	70-100	20-40	12-18	8-20	3- 8
Cabbage	10- 20	38- 40	30-42	12-22	8-20	3- 8
Eggplant	10- 20	35- 40	18-25	10-20	8-20	3- 8
Watermelon	140-200	200-250	20-25	20-25	15-30	10-20
Corn	12- 20	35- 40	15-25	10-15	5-15	3-12

Figure 4. Typical Dimensions of Furrows for Various Crops in the Mansuriya District.

While a farmer knows very well that he should not overtop the furrow ridge nor inundate his plants, he frequently must do so in order to cover the high areas in a given basin.

The head ditch as shown in Figure 2 transports water from the lift to the boundary of the field. This channel is always at the same location with respect to the field. However, internal field channels vary in location from one crop to the next. This is primarily because the farmer perceives that locating the ditch in the same place may make that land less productive. The result is more delivery losses through the field ditches because of the higher infiltration rates after plowing. The internal field channels use 8 to 14 percent of the field area.

Several field geometries and irrigation sequences will now be described. Typical arrangements of bunded units and their dimensions, field ditches, head ditches, lift, Mesqa and sequence by which the units are irrigated are shown in Figure 5 (a) through 5 (f) from actual case fields. There are many minor variations of these arrangements but these represent typical field layouts.

The major points to observe are the following:

1. The size and size variation of the bunded units even within one field.
2. The area used by head ditches and field ditches and the distance water must travel.
3. The variation in the direction water travels in the delivery channels and within each bunded unit during an irrigation.
4. The range in number of bunded units simultaneous irrigated even within the same field.

One case study farmer (Figure 5 (a)) began his irrigation from the end farthest from the supply by irrigating two basins together (S_1).

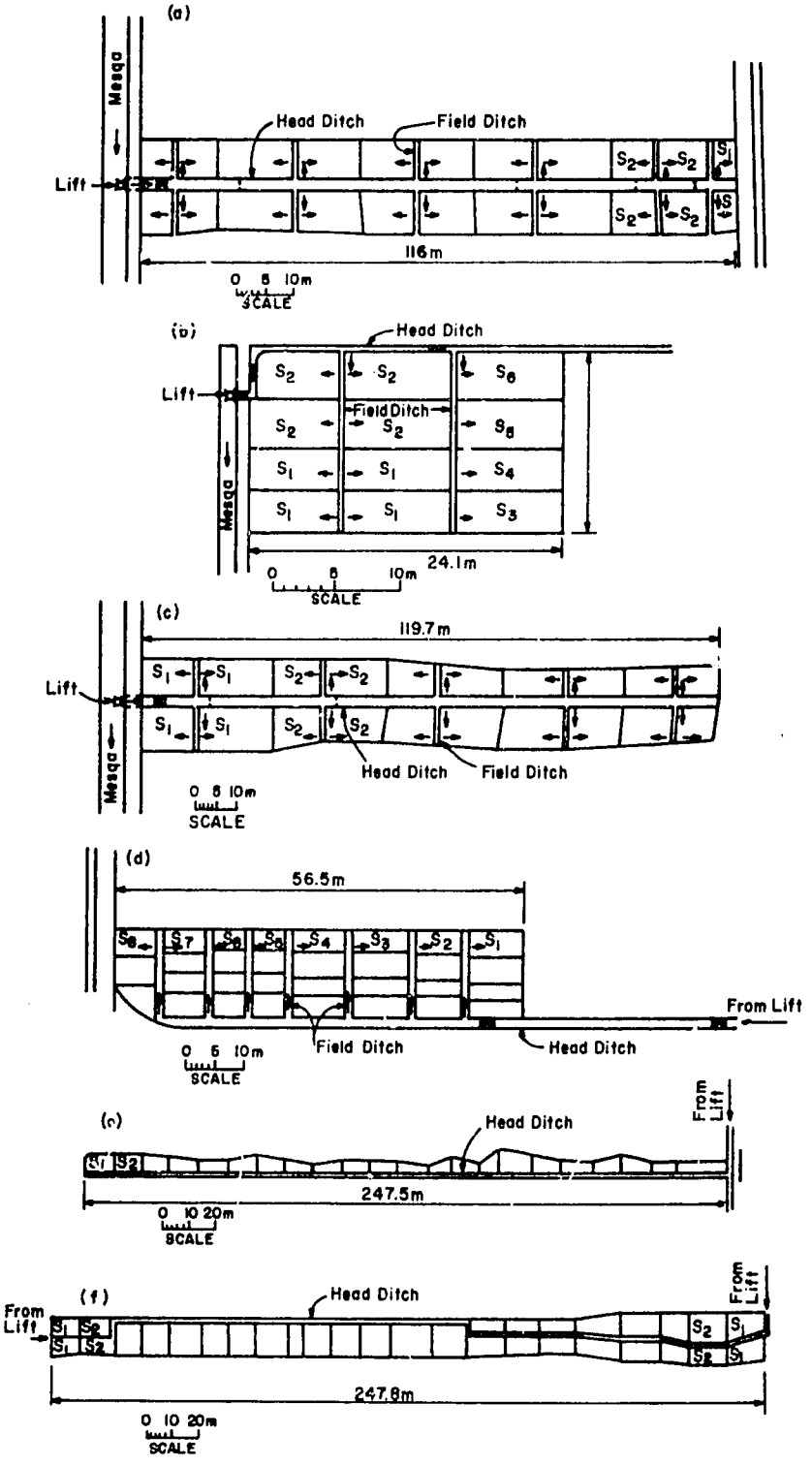


Figure 5. Field geometries of representative case study fields.

In the next sequence, S_2, four basins are irrigated and four are irrigated simultaneously for the rest of the field.

A second case study farmer (Figure 5 (b)) has a head ditch located at the side of his field. Some of the field ditches are used to supply basins on both sides of the ditch. Others serve only one side of the ditch. The farmer first simultaneously irrigates the four basins designated S_1 and then the four basins designated S_2. Then basins S_3, S_4, S_5 and S_6 are irrigated in sequence, one at a time.

A third farmer (Figure 5 (c)) irrigates four basins together beginning from the end nearest the water source. Four are irrigated each time in sequence until the field is completed. Note the variations in dimensions of each basin even though four are always irrigated together.

Figure 5 (d) shows a permanent head ditch along one side of a fourth farmer's field with an interior field channel between each basin. In every instance but the last, basins only on one side (the upstream side from the head ditch direction of flow) of the field channel are irrigated. They are irrigated in sequence S_1, S_2, S_3 ... and S_6 as indicated in Figure 5 (d). Only the last channel is used to irrigate two basins (S_7 and S_8) simultaneously, one on each side of the field ditch.

Figure 5 (e) illustrates a fifth farmer's field that is very long and narrow with a head ditch on one side and irrigation that begins from the far end. One basin is irrigated, then another, until the field is complete. Another farmer owns the adjacent area and has another head ditch to serve his field. The result is an extensive network of head

ditches and within field distribution systems which consume land and increase the delivery losses from the lift to the field.

The field in Figure 5 (f) is irrigated with flows from both ends, most often at the same time. Two basins, one on either side of the head ditch, are irrigated at each end. In the middle only one basin at a time is irrigated. Farmers in an area between the two Mesqas irrigate most of the fields in this manner. The reader should note the small size of each basin and the widely varying sequence of irrigation in a field.

In summary, analysis of field geometry suggests that the size and shape of the fields in Mansouria district are mainly a result of the unlevelness of the land and the traditional methods used in leveling, sowing, plowing and cultivation. The rate of the flow and the availability of water are not major factors for the farmer in designing his field. This is demonstrated by the fact that the size of bunded units do not change when a Tambour is used instead of a Saqia although the flow is reduced by at least half (Table 4)). Studies (Clyma and Ali, 1977) have shown that the size of a bunded unit that farmers used in Pakistan was substantially related to the flow rate available. Some limited data did suggest that where the surface topography was very rough, farmers used much smaller bunded units. The variation of elevation within a bunded unit will be discussed under slope.

Slope - The slope and degree of levelness of a field is an important characteristic of irrigation systems if good water management is to be practiced. In graded irrigation systems, slope is combined with flow rate and infiltration rate to distribute the desired amount of water to a field. Slope variation is permitted but deviations are carefully

incorporated into the design to prevent uneven distribution of water and to minimize excess runoff. Since graded systems are not common in Egypt, further analysis of graded systems will not be presented.

Level (zero grade) irrigation systems require precision leveling. The deviations from design elevation within a bunded unit may not exceed ± 0.05 ft (± 1.5 cm) as an acceptable standard (USDA, 1974). No difference between level basins or furrows are suggested as many fields change from furrows to flat planted each season. In no instance is a reverse gradient (in the direction of irrigation) permissible. Slopes of fields and variation of elevations within a bunded unit in Mansuriya District will now be reviewed.

Table 1 gives the field length, the fall of the field from the end nearest the Mesqa to the end nearest the drain, the maximum difference in elevation measured in the field, and the slope computed as the fall divided by the field length. A fall between Mesqa and drain of approximately 10 cm commonly occurs in the Mansouria District. Farmers do not appear to use this slope to distribute water within the basin since water is introduced into basins from both directions.

More detailed data on bunded units, and as a result fields, are presented in Table 2. The basic elevation data consisted of 15 to 30 elevations in each bunded unit from three or four bunded units along the length of a field. The field elevations are computed from all units measured while the bunded unit elevations are restricted to that unit. Field elevations ranged from 9 to 20 cm between maximum and minimum. This is a significant elevation differences between basins.

The individual bunded unit elevations ranged from 5 to 20 cm in elevation. All exceeded the critiera for a level basin given as 3 cm.

Table 1. Slopes of Fields in the Mansuriya District.

Canal	Site	Field	Field Length (m)	Fall (cm)	Max. Dif.	Slope
B.M.	1	1	147.2	2	9	0.0001
	2	1	26.80	4	4	0.0015
		3	64.60	9	11	0.0014
		4	118.00	8	10	0.0007
		5	119.75	10	10.5	0.0008
	3	1	145.10	9	9	0.0006
	4	1	163.0	13	14	0.0008
	5	1	58.30	0	9	0
		2	58.30	9.5	9.5	0.0016
	6	1	227.5	20	21	0.0009
E.H.	1	1,2,3	204.30	18	18	0.0009
	4	1	62	8	13	0.0013
	8	1	72.10	8.5	17.5	0.0012
		2	68.30	6.5	7.5	0.001

Only 10 percent were less than double the required range and 80 percent were more than double the required range. The minimum range of the other 10 percent was 5 cm. Furrow bunded units also exceeded the range in elevation criteria. In addition, 20 percent of the furrows had a reverse slope which is unacceptable.

These data suggest that unlevel fields are usual in Mansouria since all fields exceeded the levelness criteria. Furthermore, serious unlevelness exists since the criteria are usually exceeded by several magnitudes. Lack of precision leveled fields is a consistent and major problem for the Mansuriya district. Proper leveling is a prerequisite for application of the proper amount of water as well as for deriving the benefits of good water management and proper inputs for increased crop production (Johnson, Khan and Hussain, 1978).

Studies by Ali, Clyma and Early (1975) of level systems in Pakistan have shown that deviation from level of only 3 cm significantly affect farmer's irrigation practices. First, to cover a high area on a level

Table 2. Range in Elevation of Bunded Units for Selected Fields.

Location	Field Variation: Mean Field Elevation (m)	Field Variation: Range (cm)	Unit to Unit: Max.	Unit to Unit: Min.	Unit to Unit: Standard Deviation
		Level Basin without Furrows - Field Variation			
B.M. Site 2, Field 2	16.59	.9	16.64	16.55	0.02
Field 4	16.58	20	16.67	16.47	0.07
Field 5	16.58	21	16.69	16.48	0.07
B.M. Site 6	16.40	13	16.46	16.33	0.03
B.M. Site 7	16.64	13	16.71	16.58	0.03
B.M. Site 1	16.70	17.5	16.795	16.62	0.05
B.M. Site 4	16.49	20	16.60	16.40	0.07
B.M. Site 5	16.43	12.5	16.485	16.36	0.03
		Level Basin Without Furrows - Bunded Unit Variation			
B.M. Site 3	16.43	10	16.48	16.38	0.03
	16.43	10.5	16.485	16.38	0.026
	16.43	12.5	16.485	16.36	0.026
B.M. Site 2	16.59	9	16.54	16.55	0.019
Field (?)	16.59	6	16.61	16.55	0.014
B.M. Site 2	16.59	8	16.62	16.54	0.0199
Field (4)	16.59	8	16.62	16.59	0.0199
	16.60	6	16.61	16.55	0.0166
	16.60	10	16.67	16.57	0.029
	16.59	5	16.62	16.57	0.017
	16.57	7	16.60	16.53	0.013
	16.56	7	16.60	16.53	0.033
	16.52	9	16.56	16.47	0.026
B.H. Site 2	16.61	9	16.66	16.57	0.022
Field (5)	16.61	8	16.66	16.58	0.019
B.M. Site 6	16.40	5	16.43	16.37	0.021
	16.42	10	16.46	16.36	0.024
	16.41	7	16.44	16.37	0.015
	16.37	9	16.42	16.33	0.02
B.M. Site 7	16.63	5	16.65	16.60	0.014
	16.62	6	16.64	16.58	0.015
	16.67	8	16.71	16.63	0.016
B.M. Site (1)	16.75	9.5	16.795	16.70	0.03
	16.72	8	16.76	16.68	0.025
	16.71	8	16.75	16.67	0.026
	16.69	10	16.72	16.62	0.030
	16.68	5	16.70	16.65	0.018
	16.68	10	16.74	16.64	0.021
E.H. Site (8)	17.04	20	17.15	16.95	0.07
	16.93	11	17.00	16.89	0.029

Level Basin with Furrows - Bunded Unit Variation

	Ridge	Furrow	R	F	R	F	R	F	R	F
E.H. Site 6	17.70	17.62	8	7	17.73	17.65	17.65	17.58	0.026	0.022
E.H. Site 6	17.72	17.63	4	5	17.75	17.65	17.71	17.60	0.016	0.016
E.H. Site 8(X)	16.96	16.86	9	6	17.01	16.88	16.92	16.82	0.026	0.017
-- --	16.92	16.78	8	23	16.95	16.93	16.87	16.70	0.023	0.071
-- --	17.66	17.54	10	8	17.705	17.575	17.61	17.51	0.0226	0.0196

field requires additional water. Farmers must cover the high area or salinization of the area will eliminate the growing crop or severe stress from inadequate water will drastically reduce crop yield. Second, since water is ponded on a level field, the distribution of water will be approximately proportional to the difference in elevation resulting in excess water in low areas and inadequate water in high areas.

Infiltration Rate - Data on mid-season infiltration rates (Figures 6 to 10) show that on Beni Magdul area the clay loam soil is characterized by a terminal intake rate of less than 0.2 mm/min (1.2 cm/hr). In El Hammami where a sandy or a sandy loam predominates, terminal intake rates of 1 to 2 mm/min (6-12 cm/hr) were measured.

An evaluation of design criteria suggests that successful level and graded irrigation systems can be designed and managed for soils with infiltration rates exceeding 7.5 cm/hr such as exists at Beni Magdul and El Hammami.

Table 3 suggests that the farmers apply some heavy irrigations early in the season. Perhaps these irrigations are needed to leach salt from the soil surface during the time when plant seedings are most sensitive. However, previous studies (Clyma and Ali, 1977) suggest that these heavy applications are the accidental result of high infiltration rates after tillage and before or just after planting.

The difference between the median amount of near 60 to 80 mm (Table 3) for most irrigations and the median for early irrigation must be attributed to initial intake rate.

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*Developed by M. Semaika and Harold Golus using a double ring infiltrometer.

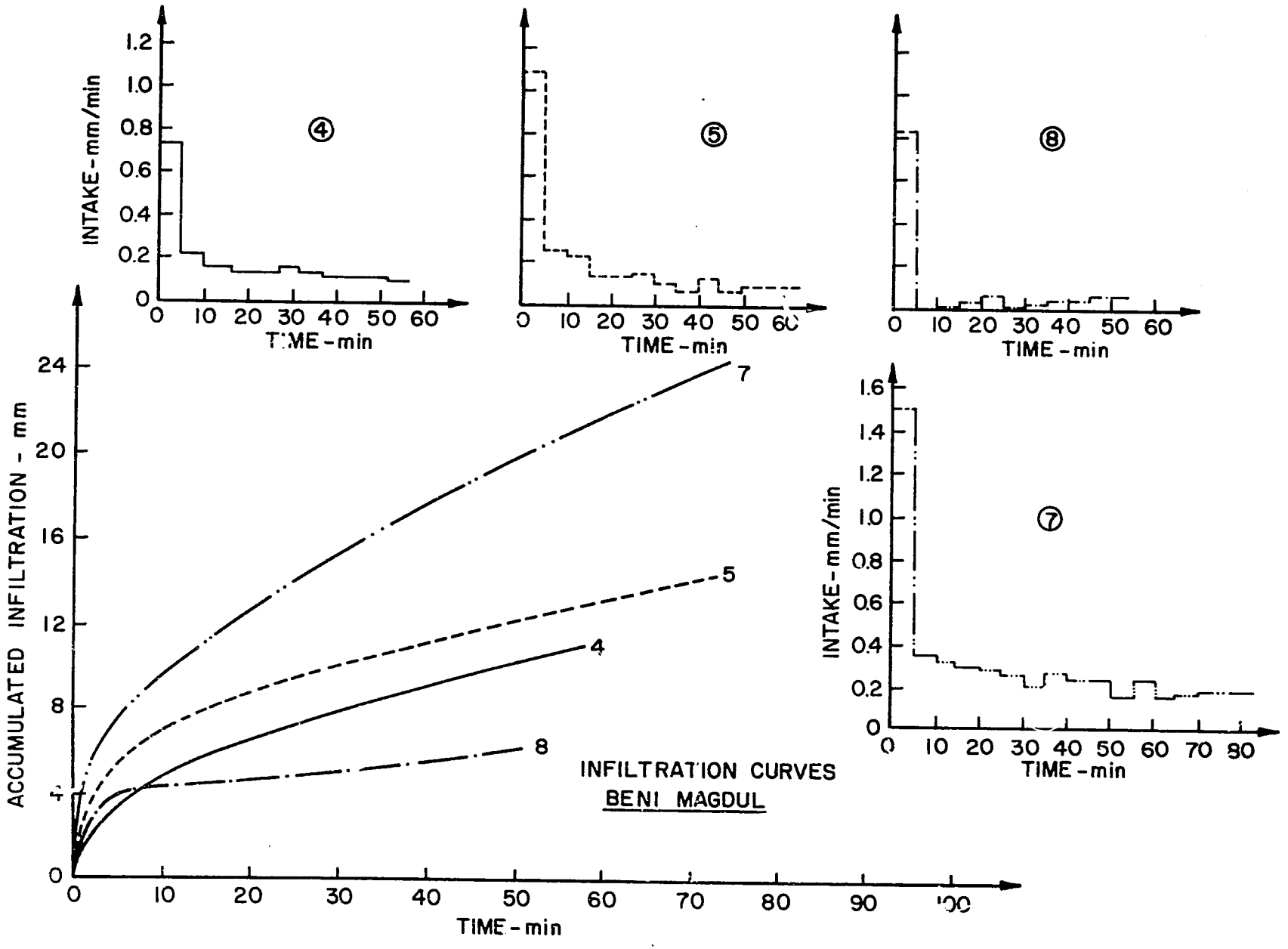
INTAKE-mm/min
TIME-min
④
⑤
⑧
⑦
ACCUMULATED INFILTRATION - mm
TIME-min
7
5
4
8
INFILTRATION CURVES
BENI MAGDUL

Figure 6

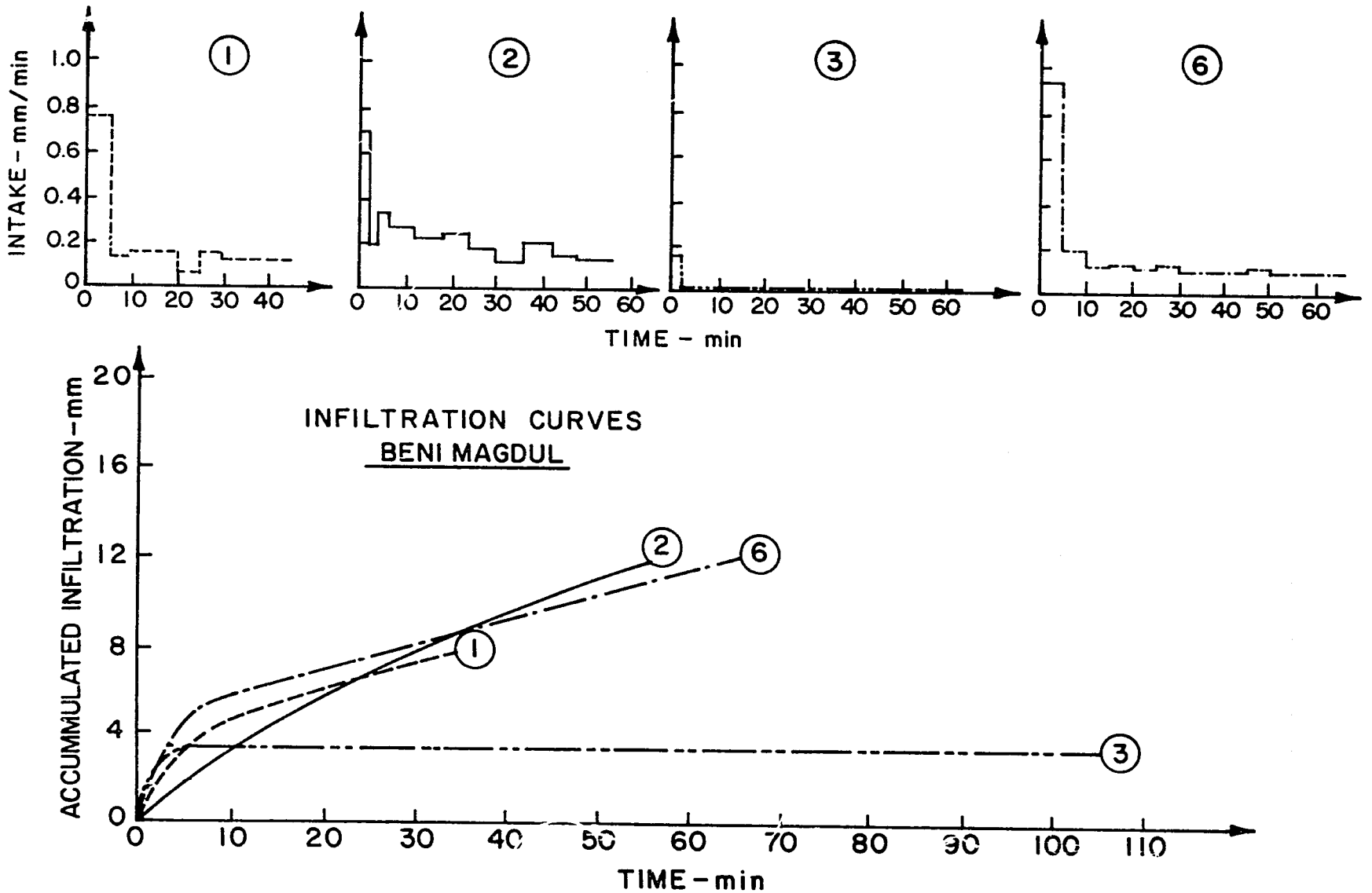
INTAKE - mm/min
1.0
0.8
0.6
0.4
0.2
0
0 10 20 30 40
0 10 20 30 40 50 60
0 10 20 30 40 50 60
0 10 20 30 40 50 60
TIME - min
INFILTRATION CURVES
BENI MAGDUL
ACCUMMULATED INFILTRATION - mm
20
16
12
8
4
0
0 10 20 30 40 50 60 70 80 90 100 110
TIME - min

Figure 7

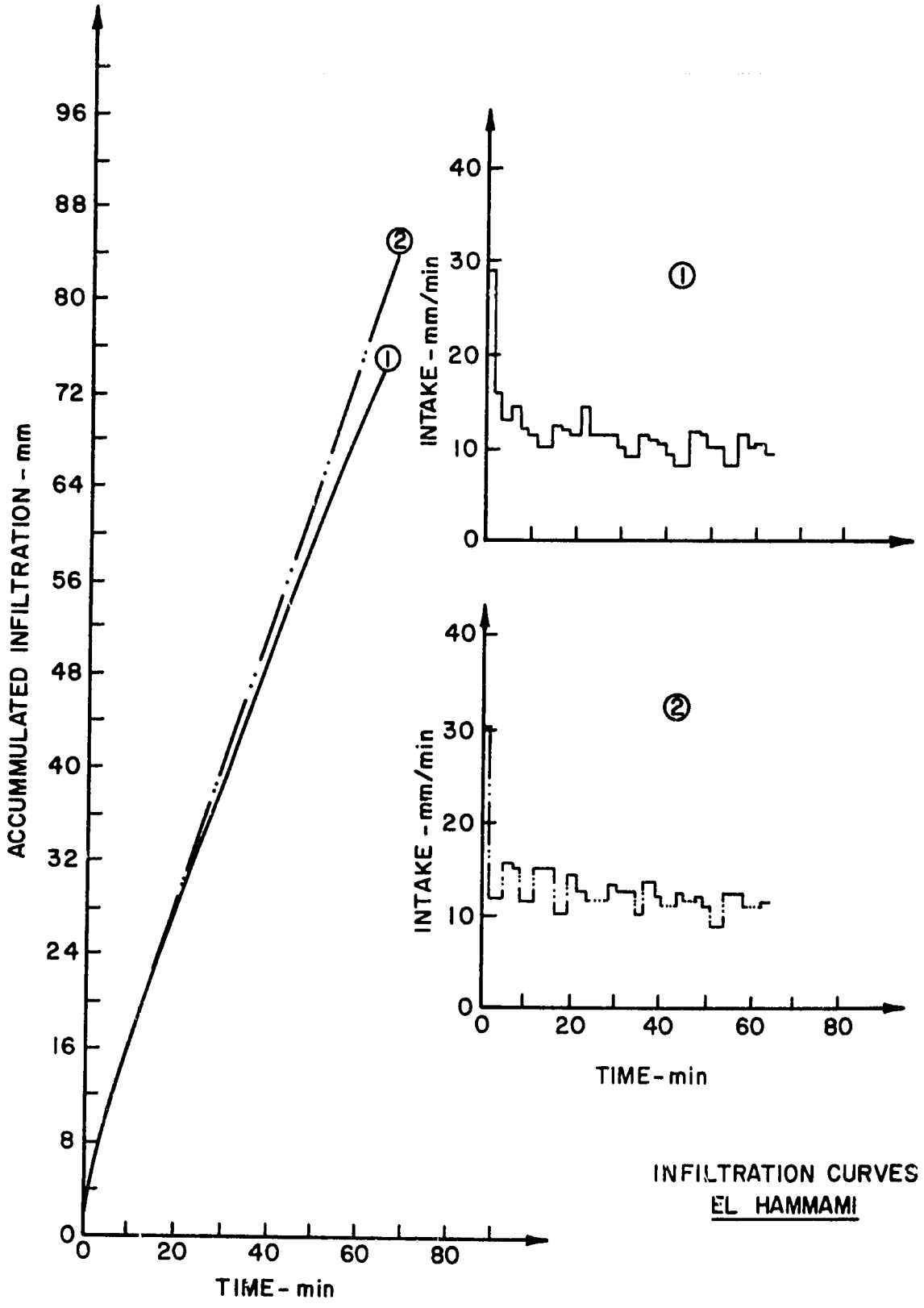
ACCUMMULATED INFILTRATION - mm
96
88
80
72
64
56
48
40
32
24
16
8
0
0
20
40
60
80
TIME - min
②
①
INTAKE - mm/min
40
30
20
10
0
①
INTAKE - mm/min
40
30
20
10
0
②
0
20
40
60
80
TIME - min
INFILTRATION CURVES
EL HAMMAMI

Figure 8

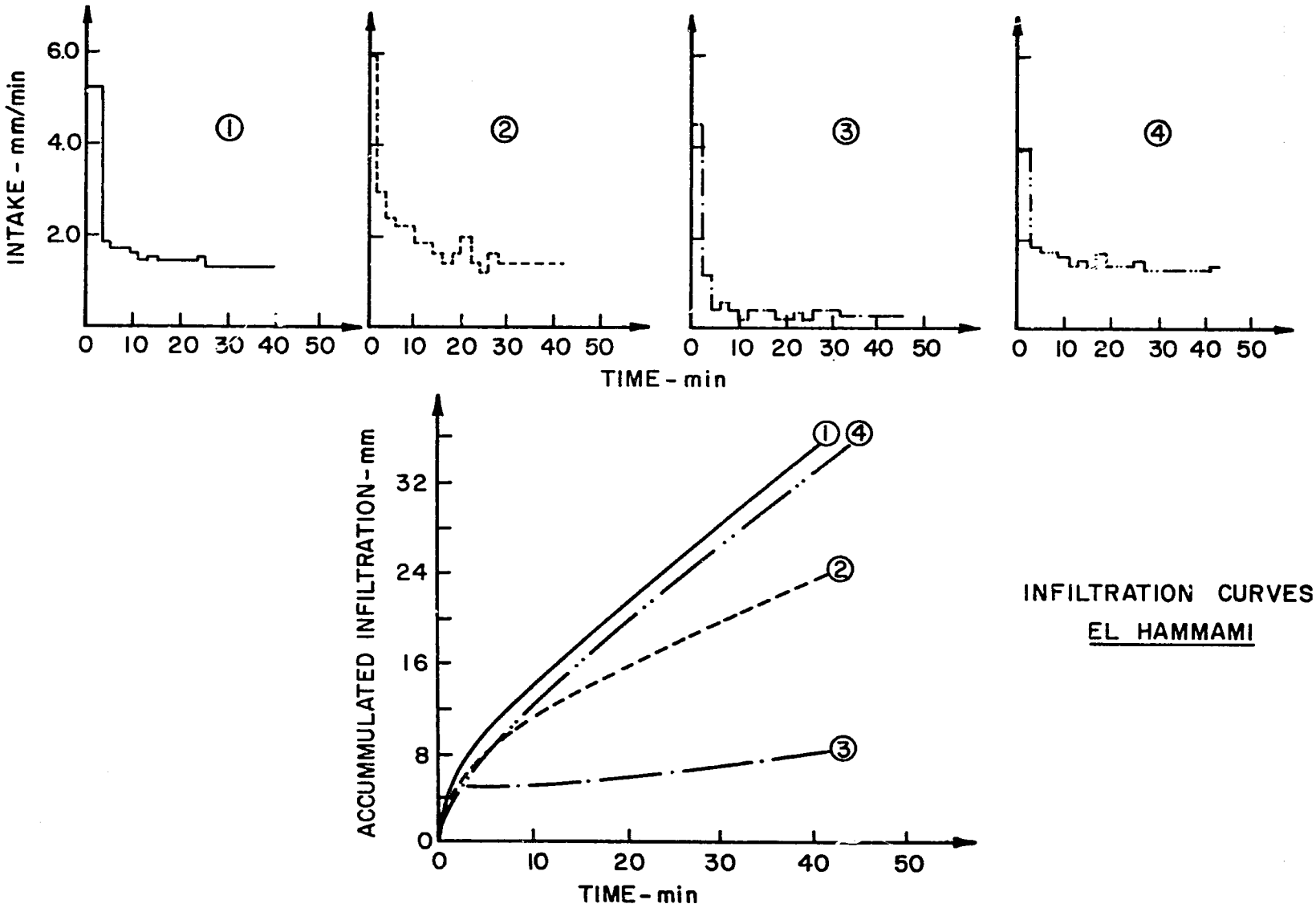
INTAKE - mm/min
6.0
4.0
2.0
0 10 20 30 40 50
TIME - min
ACCUMMULATED INFILTRATION - mm
32
24
16
8
0
INFILTRATION CURVES
EL HAMMAMI

Figure 9

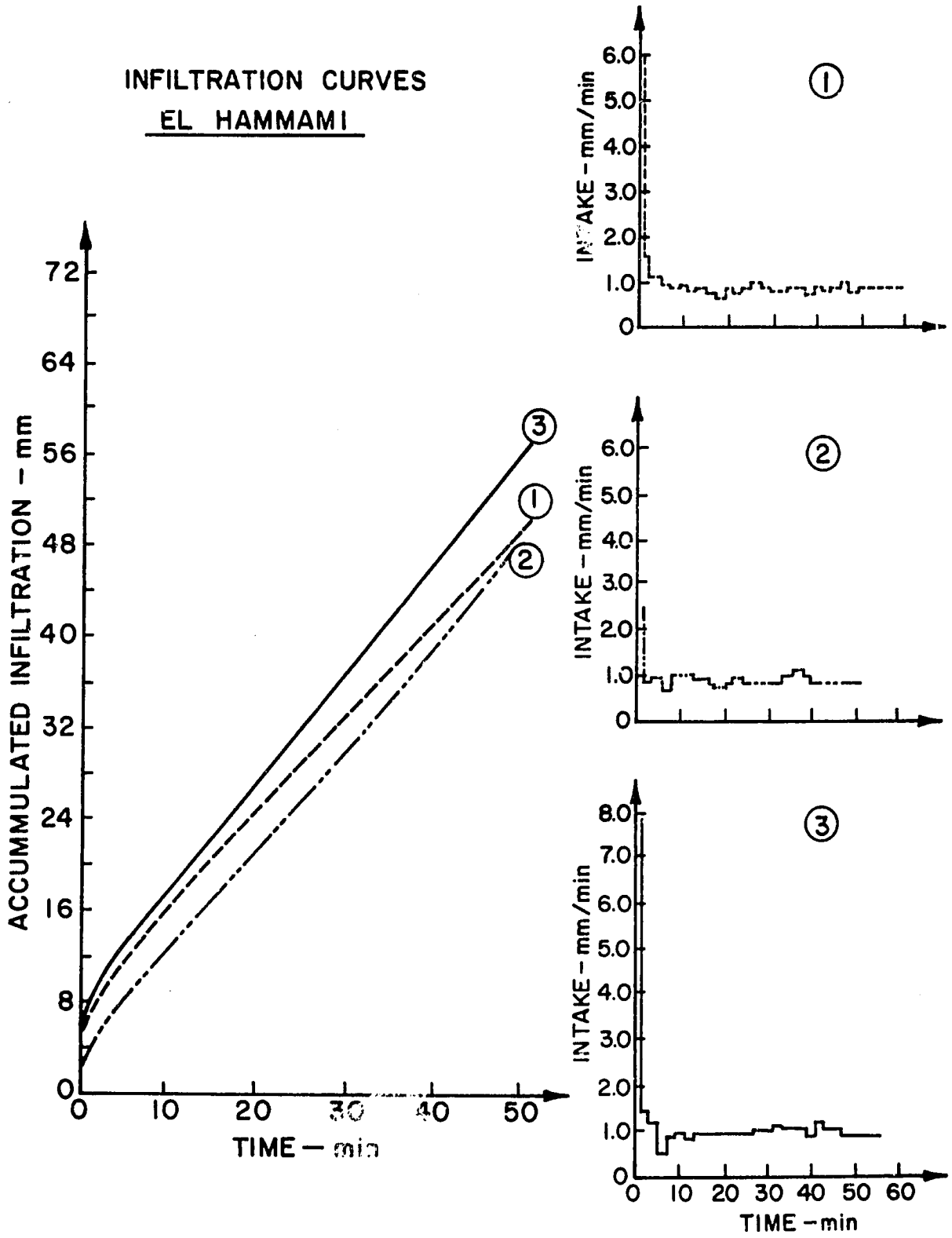
INFILTRATION CURVES
EL HAMMAMI
ACCUMMULATED INFILTRATION - mm
TIME — min
INTAKE - mm/min
TIME - min
1
2
3

Figure 10

Table 3. Amount of Water Applied Per Irrigation for First Irrigation and All additional Irrigations for Beni Magdul, El Hammami and Kafret Nassar Canals for Summer Season, 1978.

Applied Water (mm)	First Irrigation			All Additional			All Canals	
	BM	EH	KN	BM	EH	KN	All Irrig.	
	Percent			Percent			No.	Percent
0 ≤ 20				1	7		8	3
20 ≤ 40		8		4	26		32	13
40 ≤ 60	8	8		11	25	33	43	17
60 ≤ 80		8	40	37	24	42	70	28
80 ≤ 100	8	17		27	6	17	39	16
100 ≤ 120	8			10	4		15	6
120 ≤ 140	8		20	6	1		9	4
140 ≤ 160	22.5	26		2	3		11	4
160 ≤ 180	22.5	8	20	3	3	8	12	5
180 ≤ 200	15	17			1		5	2
> 200	8	8	20	1			4	2
Total (Pct.)	100	100	100	102	100	100		100
Total (No.)	13	12	5	104	102	12	248	

Infiltraion rates affect the distribution of water in a field. The time difference between when water first covers an area and when it recedes from an area is called the "opportunity time" for infiltration. On high infiltration rate soils, small differences in opportunity time result in large differences in amount of water infiltrated and poor distribution of water results. The average amount of water applied to a field may equal consumptive use estimates. When most of the water infiltrates in only one part of the field, major overirrigation and underirrigation still occurs. As discussed under slope for level (zero grade) systems, differences in elevation produce differences in

opportunity time and result in low irrigation efficiencies because of poor distribution.

High priority should be given to the collection of replicated infiltration rate data during farmer planned irrigation applications on selected farms and crops. Also, data should be collected on soil moisture and water table status to establish the effect of these variables on infiltration rate. The measurements should be repeated for successive irrigations from pre-irrigation to the end of the season or until substantial changes in the infiltration rate curve do not occur. Major soil types, cropping patterns, ground water conditions and farmer cultural practices should be represented.

Figures 11 through 13 will be used to illustrate some of the major effects of infiltration rates on irrigation practices.

A characteristic variation in infiltration with successive irrigations is illustrated in Figure 11. The differences can be more or less than that illustrated for particular soils. These differences have been observed based on infiltration data from Texas, Colorado, Arizona and Pakistan. Similar curves are expected for the soils of Egypt.

Figure 12 gives the advance and recession curves, which define the opportunity time or time available for water to infiltrate, for three different fields. An important point is that if all the variables affecting water application except flow rate are constant, then different flow rates for the three fields are necessary to obtain the same advance and recession curves. The bottom part of Figure 12 gives the depth of water infiltrated as a function of distance from the inflow point.

The effect of a high area in a field on water distribution is illustrated in Figure 13. The elevation of the high area might be 3 cm

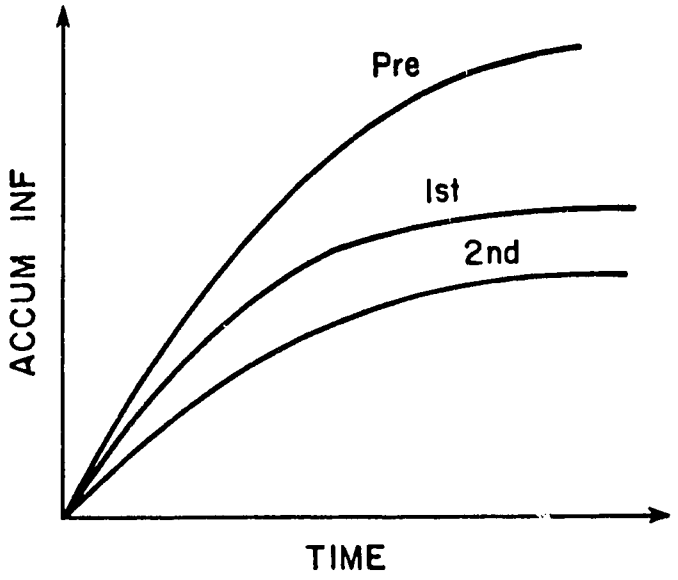

Figure 11. Effect of successive irrigations on infiltration.

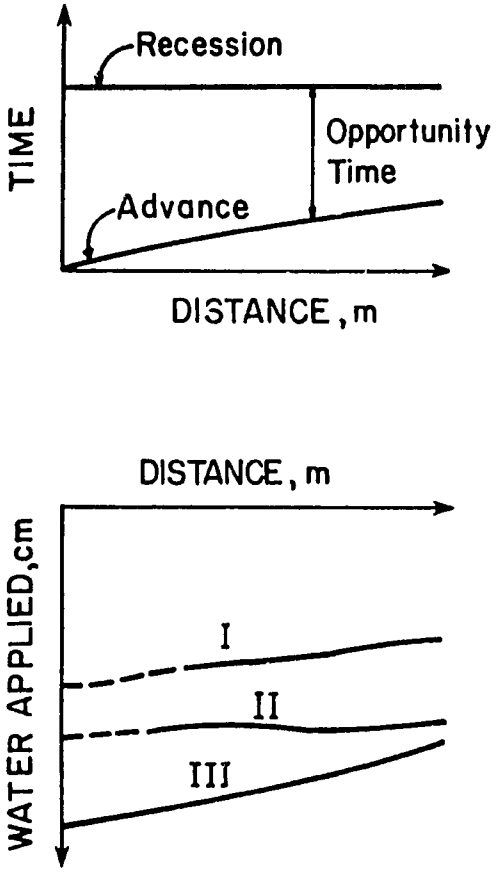

Figure 12. Advance and recession, and infiltration.

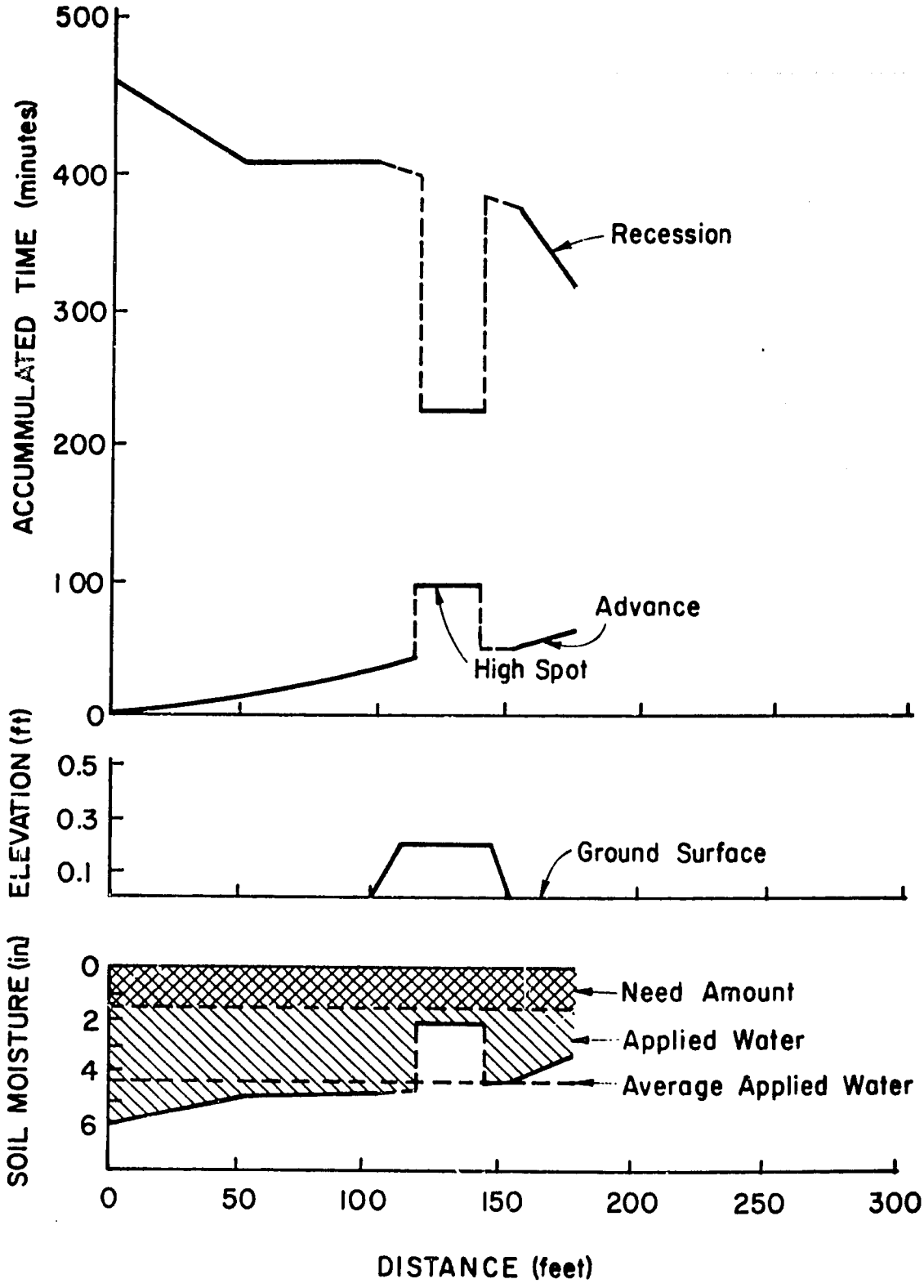
500
400
300
200
100
0
ACCUMMULATED TIME (minutes)
Recession
Advance
High Spot
0.5
0.3
0.1
ELEVATION (ft)
Ground Surface
0
2
4
6
SOIL MOISTURE (in)
Need Amount
Applied Water
Average Applied Water
0
50
100
150
200
250
300
DISTANCE (feet)

Figure 13.

above the surrounding area. The location of the high area, whether the field has zero grade and the flow rate into the field also have an effect. The requirement that different flow rates be used to achieve the same advance and recession curves still applies.

Another frequent problem is that these high areas become salinized, reducing crop yields or killing all plants. The salinization further reduces infiltration rates and the problem is accentuated.

As suggested previously, high infiltration rates after tillage are expected to be a major factor in the excess applications during pre-irrigation. Infiltration rates and the shape of the infiltration curve will accenturate or moderate the effects of variable flow rates, negative slopes, and high and low areas in a field on the distribution of water. In El Hammami, the rate and shape of the infiltration rate curve provides insight into the adequacy of water distribution in farmers' fields because of the sandy soil.

With short lengths of run, an appropriate grade and the correct flow rate, soils with high infiltration rates can be successfully surface irrigated.

Surface Roughness - Surface roughness is variable throughout the season. In some areas surface clods formed during tillage may complicate water distribution and require a higher flow rate for the greater depth of flow necessary to cover the clods. Vegetation density especially in sugarcane and fodder crops, increases as the season progresses. The result is that the amount of water required to cover a field as well as the depth of flow are increased. On such crops the amount of water applied per irrigation may initially decrease after the pre-irrigation but then began to increase as vegetation density

increases during the season. For many crops and fields, roughness is not a significant variable.

Channel Shape - A number of fields and crops are broadcast in small basins. Distribution of water to these fields is not materially affected by channel shape. A majority of the summer crops (except rice) and numerous winter crops (except berseem and wheat) are grown on ridges and irrigated by furrows. Furrows in the Mansouria District have a variety of dimensions but some typical spacings and profiles are shown in Figure 4. Farmers also appear to regulate the flow rate and depth of water applied to attempt to insure that most crops, especially vegetables, are not inundated during irrigation. This factor more than any other appears to influence the number of basins filled simultaneously and the time of filling according to farmers. Some fields appear to be drained if excess water is applied or the ponding time becomes excessive. No data are currently available on the effect of channel shape on infiltration rate, water distribution or salt movement.

Water Supply Rate - A farmer irrigates a field of a given geometry, slope, infiltration rate, surface roughness and channel shape. There is an appropriate flow for the given conditions that should be used for effective, quantitative water management. In some instances the value of an above variable on the values of a combination of variables result in an uppr limit on the level of water management that a farmer can achieve. For example, an unlevel field limits the efficiency of an irrigation regardless of the flow rate used during the irrigation. An unlevel field combined with a high infiltration rate further reduces the efficiency of an irrigation for a given flow rate. If an inappropriate flow rate is used, the maximum achievable efficiency for an irrigation

is further reduced from the above examples. Flow rate may be considered to be the final variable by which farmers can make management decisions that result in good water management.

Quantitative approaches to water application to a field require that the flow rate and time of irrigation of a field be known. The conventional approach is to measure the flow rate. If the water delivery system supplies a constant, known flow rate, then the measurement of the time of water application can be used to quantitatively apply water to a field. The constant flow rate must be within a range if an efficient irrigation is to be achieved. The flow rate must also meet adequacy criteria to limit erosion, for an appropriate flow depth and for proper distribution along the length of the field.

Proper distribution of water within a bunded unit requires the flow rate to be sufficiently high such that the difference between opportunity times for each end of the basin will not result in substantial differences in total water infiltrated. With the very small bunded units, flow rates appear to be adequate for proper distribution within each bunded unit. Flow depth appears to be adequate for each bunded unit whether the crop is on ridges or flat. The depth of flow sometimes overtops ridges but this is probably related to high areas and reverse slopes with too large a flow rate. Inadequate ridge heights are provided in some instances for the ponded depth resulting in overtopping. The extremely short lengths of run largely prevent erosion from being a problem.

A constant flow rate can be substituted for a metered flow as mentioned earlier. Since farmers do not know or measure the flow rate in Mansuriya District, an evaluation of the constancy of the available

flow rate provides some measure of their ability to manage water qualitatively.

The water supply rate to fields depends on the method used for lifting water. Table 4 indicates the range in flow rates for each study farm as a function of the method of lifting water. A Tambour supplies water at between 5 and 18 l/s while the Saqia flow ranges between 3 and 61 l/s. Another effect is also illustrated in Table 4. The flow for both methods tends to range from near zero to at least 50 percent more than the mean. Since the flow rate varies so widely, it is exceedingly difficult for a farmer to apply a uniform amount of water to each small basin in a field.

The farmer irrigating a variable number of basins of widely varying size with an unmeasured and highly variable flow rate is unlikely to achieve efficient application of water even if all other conditions are ideal. Since the farmer uses criteria other than flow rate to irrigate a basin, the geometry of his irrigation units makes good water management difficult if not impossible.

Two additional factors affect the rate at which water is supplied to a field. Water is supposedly supplied to the farmer at the necessary rate at an elevation. There is no internal regulation by farmers on a Mesqa of the time of use (formally or informally). Mesqa outlets also have been enlarged without authorization. Therefore, simultaneous and heavy use of the water at the upper reaches of the Mesqas lowers the water level below the authorized level. The result is a higher lift for a given flow rate. Since the power required to lift a given flow rate is directly proportional to the lift, the lowered water level increases the effort required for a constant flow rate. Humans, when using the

Table 4. Flow Rate Data Sheet (Summary).

Area	Farm No.	Field No.	Crop 1978	Type of Lift	Flow Rate lit/sec. Max.	Min.	Av.
K.N.	(1)	(1)	Corn	gravity	14.80	2.70	7.50
K.N.	(1)	(1)	Berseem		13.10	1.2	6.0
B.M.	(1)	(1)	Corn	Tambour	18.0	6.0	12.0
B.M.	(2)	(1)	Corn	Tambour	16.0	7.4	11.0
B.M.	(2)	(2)	Corn	Tambour	16.0	8.0	12.0
B.M.	(2)	(3)	Corn	Tambour	12.0	5.0	10.0
B.M.	(2)	(4)	Corn	Sakia	17.4	3.1	12.0
B.M.	(2)	(5)	Corn	Sakia	22.0	5.3	14.0
B.M.	(3)	(1)	Corn	Sakia	19.3	11.2	15.0
B.M.	(3)	(1)	Berseem	Sakia	13.5	6.8	11.0
B.M.	(4)	(1)	Corn	Sakia	29.4	6.2	18.2
B.M.	(5)	(2)	Corn	Sakia	23	8	16.0
B.M.	(5)	(1)	Veget.	Sakia	23	8	16.0
B.M.	(5)	(1&2)	Berseem	Sakia	20.4	5.5	17.0
B.M.	(6)	(1)	Veget.	Sakia	21.3	5.3	12.0
B.M.	(6)	(1)	Veget.	Tambour	12.6	5.2	8.7
B.M.	(7)	(1)	Corn & Veg.	Sakia	15.5	6.5	12.0
E.H.	(1)	(1)	Berseem & Corn	Sakia	50	20	40
E.H.	(1)	(2)	Corn & Veget.	Sakia	36	15	28
E.H.	(1)	(3)	Corn & Pepper	Sakia	61	27	40
E.H.	(1)	(4)	Corn	Sakia	50.5	28.5	35
E.H.	(1)	(5)	Corn & Pepper	Sakia	52	25	35
E.H.	(1)	(6)	Corn & Pepper	Sakia	38	16	29
E.H.	(1)	(7)	Corn & Pepper	Sakia	64	18.6	41
E.H.	(1)	(8)	Corn & Pepper	Sakia	65	26	45
E.H.	(1)	(1)	Squash	Sakia	38	13	28
E.H.	(1)	(7)	Squash	Sakia	54	20	35
E.H.	(1)	(8)	Squash	Sakia	46	25	35
E.H.	(1)	(6)	Squash	Sakia	58	25	35
E.H.	(1)	(5)	Squash	Sakia	38	15	28
E.H.	(1)	(3)	Squash	Sakia	37	13	25
E.H.	(6)	(1)	Veget.	Sakia	22	8	17
E.H.	(8)	(1)	Peanuts & Veget.	Pump	24	8	18

Tambour, or animals, when using the Saqia, must rest more often, otherwise there will likely be an overall reduction or variation in the flow rate as the lift increases and decreases.

At a given field in a particular area, flow rates vary widely over time. It is difficult for a farmer to regulate an application to a given amount without conidering explicitly the flow rates, wide variation in the amount of water applied to a bunded unit occurs and poor water management is the result.

Management - The farmer operates his water application system based on his perceived objectives and manages the water based on his knowledge and skills. His management of the system results from how he answers the question: When do I irrigate? How much water do I apply, and how?

A farmer irrigates in the Mansuriya District using level basins or bunded units ranging in area from 40 to 120 m^2 with length to width ratios ranging from 1 to 2 (see Figure 5). Depending on the crop, the basins may be flat or have furrows, but each is irrigated as a level irrigation unit. The farmer basically introduces water until the area is covered, perhaps to a given depth, and this determines how much water he applies. Thus, the decision of when to irrigate is his primary management variable and appears to be based on several considerations (Table 5). A farmer's objectives appear to be to manage his available water supply for adequate crop production including salinity control, for crop residue management, to facilitate tillage, to promote germination and emergence, to provide early seedling growth and to maintain adequate soil moisture.

The answers of farmers to how do I irrigate limit severely the level of effective water management they can achieve. The methodology for regulating flow rate and amount of water applied results in much

Table 5. Irrigation Frequency in El Mansuriya District.

Irrigation Frequency in days	Distribution							
	El Hammami		Beni Magdul		Kafret Nasar		All Canals	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1 ≤ 4	31	25					31	12
5 ≤ 8	17	14	25	21			42	16
9 ≤ 12	41	33	37	33	6	43	84	33
13 ≤ 16	19	16	23	20	5	36	47	19
17 ≤ 20	3	2	24	21	1	7	28	11
21 ≤ 24	8	7	6	5	1	7	15	6
25 ≤ 28			1	1	1	7	2	1
29 ≤ 32			1	1			1	0.5
33 ≤ 36	1	1					1	0.5
37 ≤ 40								
> 40	3	2					3	1
Total	123	100	117	100	14	100	254	100

variation of the amount. Methods for distributing water result in an extensive distribution system. Fields are unlevel to an unacceptable degree, bunds are of inadequate height and the size of each field varies by several magnitudes. The system of irrigation limits the potential level of water management for farmers.

Amounts of water applied by farmers during an irrigation are very variable. This variability results directly from their method of determining how much water to apply. The time to cover a given area with water depends on the flow rate, slope, geometry, infiltration rate, surface roughness and channel shape. Farmers' criteria for applying water, when combined with the system of applying water, limits good water management. Other factors influence the amount of water applied.

The amount of water applied during the first irrigation and all additional irrigations are given in Table 3. On all three branch canals the first irrigation results in a greater amount of water applied than do subsequent irrigations. The median amount of water applied for the first and subsequent irrigations for each branch canal was as follows:

	First	Subsequent
	(mm)	
B.M.	160 ≥ 180	60 ≥ 80
E.H.	120 ≥ 140	40 ≥ 60
K.N.	120 ≥ 140	60 ≥ 80

The results suggest the first irrigation is a large amount of water. The primary cause of the irrigation amount is probably the high infiltration rates after plowing for the irrigation. The estimates of soil moisture deficiency and observations of the water table both indicate the irrigation is excessive.

The median application for subsequent irrigations are much smaller and in the 60 to 80 mm interval for Beni Magdul and Kafret Nasar and 40 to 60 mm for El Hammami. The smaller median amount on El Hammami may not be statistically significant for the limited data collected but could be explained by the predominance of vegetables at El Hammami. Farmers' perceptions that vegetables need smaller irrigations may cause the result observed. A significant number of irrigations exceed 80 mm on all branch canals indicating considerable variability in the amount of water applied during an irrigation.

The next management decision farmers make is when do I irrigate. The frequency of irrigation for selected crops at Beni Magdul and El Hammami is shown in Table 5. The results are different for each site since at least both the rotation and soils are different.

Beni Magdul is provided water continuously. Thus, farmers may irrigate whenever they feel their crops need water. Under the "demand" system, the median irrigation frequency was 9 to 12 days (Table 5). Furthermore, no farmers irrigated during the interval of four days or less. The longer intervals between irrigation (28 percent of the irrigations were 17 or more days apart) represent irrigations early and late in the cropping season or during the interval between crops.

El Hammami was supplied water for four days and for eight days water was unavailable. Previous general observations had suggested that some farmers irrigated at the beginning and end of the four-day period when water was available. Twenty-five percent of the irrigations by study farmers came at a frequency of four or fewer days (Table 5). Fourteen percent at five to eight days and 39 percent were less than nine days. The median frequency was still 9 to 12 days with one-third

of the irrigations coming during this time interval. In principle, all irrigations at El Hammami should have come in the 9 to 12 or 21 to 24 day intervals since those are the intervals on the rotation. Since 57 percent of the irrigations came at intervals other than a multiple of 12 days, then the water came from canal storage, drains, ground water, water made available outside the official rotation or from more than one irrigation during the four days water is officially available.

Limited data on Kafret Nassar suggest the same pattern of irrigation frequency. However, no irrigations came at a frequency of 8 days or less. The median frequency for all canals was 9 to 12 days.

The short irrigation intervals at El Hammami suggest farmers apply water at more frequent intervals than desired in attempting to provide water to crops from rotations that are longer than preferred. The high frequency irrigations probably increase over-irrigation. The farmer probably thinks the succeeding interval without irrigation would affect crop growth and yield. On some portions of the branch canal water supplies are inadequate (Wolfe, Shahin and Issa, 1979). When water is available, the farmer continues to irrigate all crops to insure against future expected shortage.

Farmers also appear to irrigate for reasons other than to replenish soil moisture. Need for tillage, for example, may require that a field be irrigated. Removal of crop residue may require an irrigation. Sometimes removal of residue and tillage are both accomplished from the same irrigation. Providing water for germination and emergence and salinity control would appear to be the purpose of the preplanting irrigation. While considerable excess water may be applied, the irrigation is still necessary for crop production. Perhaps a more careful

inventory of why farmers give particular irrigations to particular crops at particular times may reveal additional reasons why farmers apply water in addition to soil moisture replenishment.

Seasonal application of water to crops, farms, fields and canals are given in Table 6. For corn the range in seasonal water applied was from 401 to 1170 mm. Seasonal evapotranspiration is estimated at 600 mm. Thus 40 percent of the fields received less water applied than the estimated consumptive use. However, the highest corn yield occurred on a field that received only 480 mm. Average seasonal water applied by canal was as follows:

Canal	mm
Kafret Nasar	518
El Hammami	650
Beni Magdul	712

The small number of observations for K.N. limits any interpretation. The difference between E.H. and B.M. is small and could reflect an unavailability of water rather than a difference in farmer preference of use. The continuously available water on B.M. did not result in a greatly increased average seasonal application of water.

Water application to squash at El Hammami ranged between 388 and 590 mm. The highest yield was on 12 percent less water than the maximum and the minimum amount applied resulted in only 25 percent less yield.

Water Table Conditions

Depth to water in the project area ranges from 60 to 150 cm. The water table fluctuates during the season with a rise immediately after each irrigation, a decline between irrigations, but usually an overall gradual build up of the water table during the season occurs. The rate

Table 6. Seasonal Applications of Water to Corn and Squash.

Area	Farm No.	Field No.	Applied Water mm	Yield Ard/f	
CORN					
B.M.	5	2	749	11.92	
B.M.	2	3	481	14.4	
B.M. (1977)	2	5	810	10	Min. 401 mm
B.M. (1977)	2	4	690	10	Max. 1170 mm
B.M. (1977)	2	3	700	8	
B.M.	2	1	850	11.07	
B.M.	2	2	870	11.0	
B.M.	2	[illegible]	1170	6.0	
B.M.	7	2	500	12	
B.M.	2	4	634.9	12	
B.M.	2	2	870	6.29	
B.M.	3	1	525	6.55	
B.M.	4	2	411	10.5	
K.N.	1	1	536.9	8	
K.N. (1977)	1	1	500	8.5	
E.H.	1	8	839.1	8	
E.H.	1	7	535.7	9.5	
E.H.	1	6	599.8	10	
E.H.	1	5	401	9	
E.H.	1	3	864.0	9.2	
SQUASH				kg/f	
E.H.	1	1	417.1	257.9	Min. 380
E.H.	1	8	525.5	5618.9	Max. 590
E.H.	1	6	590.7	5254	
	1	5	419.7	5071.3	
	1	7	380.4	4348	

of decline of the water table during the season between irrigations is greatest during the period of higher consumptive use suggesting that declines occur both from lateral outflow and water use from the water table by plants. Figure 14 illustrates this phenomena.

Careful delineation of the relationships between water applied, water stored in the root zone, downward flow to the water table as deep percolation and subsequent use of water from the water table by the growing crop has not been quantitatively defined to date (1979). Careful, quantitative definition of these relationships is important to defining the exact effect of the application of irrigation water to the fluctuation of the water table. Approximate budgets based on estimates of consumptive use and published data on crop water use from a water table in a given soil at an approximate depth will now be used to develop a sample water budget for a field.

Clyma and Ali (1977) cited a study where the water table was within 90 cm of the surface, 80 percent of the consumptive use came from the water table. The water table in Mansuriya District is almost always 90 cm or less from the surface. This suggests that 80 percent or more of crop consumptive use may be met by upward flow from the water table.

When calculations of crop consumptive use are made, the results suggest that water applications definitely exceed consumptive use early and late in the growing season when actual evapotranspiration is less than maximum potential evapotranspiration. When an irrigation application is made, especially early and late in the season, the water table rises suggesting that the application exceeds the soil moisture deficiency and the excess goes to the water table. Soil moisture tensions in a limited number of sites also suggest that the water content is less

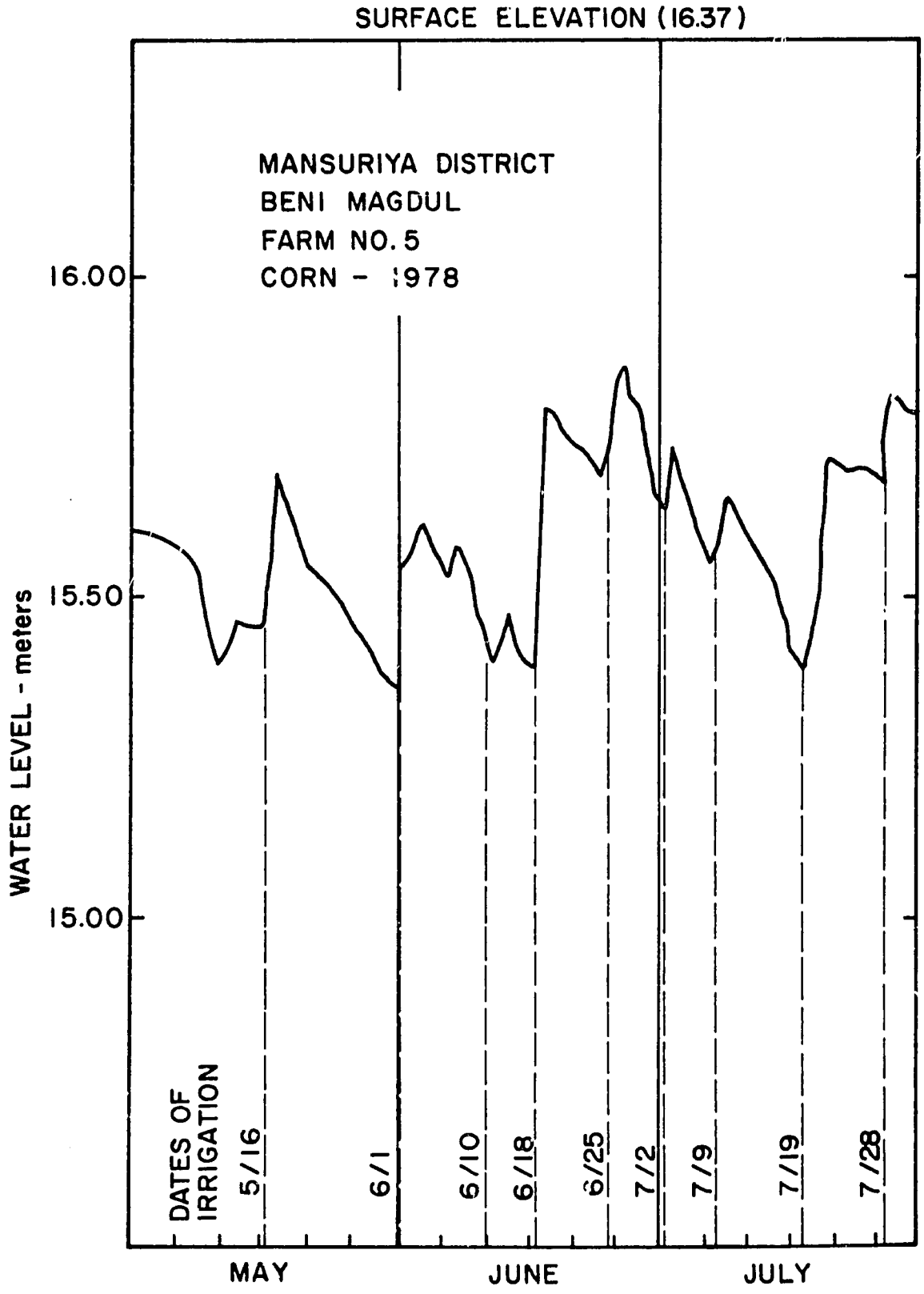
SURFACE ELEVATION (16.37)
MANSURIYA DISTRICT
BENI MAGDUL
FARM NO. 5
CORN - 1978
16.00
15.50
15.00
WATER LEVEL - meters
DATES OF IRRIGATION
5/16
6/1
6/10
6/18
6/25
7/2
7/9
7/19
7/28
MAY
JUNE
JULY

Figure 14

than field capacity only to the 15 cm depth. At 30 and 45 cm depths, soil moisture tensions are less than one-third bar indicating the soil moisture content is greater than field capacity.

A scenario on the dynamics of on-farm use of water is as follows. Farmers apply the early preplanting irrigation where 80 percent or more goes to deep percolation and raises the water table. Subsequent early irrigations are also excessive because crop consumptive use is much less than potential evapotranspiration. The low consumptive use rate is easily supplied through an upward moisture gradient by movement of water up from the water table. During the period of peak water use, upward flow from the water table still supplies major amounts of consumptive use. Reduced amounts of water applied and the higher use rate during this time result in increased soil moisture deficiency which causes reduced deep percolation to the water table. Thus, water tables generally decline during the period of peak water use and the rise after an irrigation is usually less. Sometimes an unusually heavy irrigation causes a major rise in the water table (June 18, Figure 14). Seasonally, much of the consumptive use is met from the water table which is replenished by each successive irrigation. Some water travels laterally to drains and out of the area. The resulting water balance is achieved through water application, consumptive use and drain outflow as there appears to be limited net changes in the water table on an annual basis. Past excess sources of water that raised the water table to present levels have been reduced, drainage flow or consumptive use have increased or a combination of these have occurred.

Figure 15 and Table 7 present the data from which a water balance was computed as a sample analysis. Computation of the changes in

groundwater storage and measurement of the drainage outflow would permit an overall check on the water balance for a field. Accurate, consistent soil moisture data would also improve the accuracy of the balance. The soil moisture deficiency was assumed to be 25 mm at each irrigation. For the season, this results in 60 percent of consumptive use being met from groundwater. Seasonally, an 18 percent surplus of water application occurred as drainage flow, non-beneficial consumptive use or a change in the water table.

Circumstantial evidence of the rise in the water table and basic data on contributions of the water table to consumptive use both suggest that excess water is applied during each irrigation. This excess water causes the fluctuating water table and is very effective at leaching fertilizer out of the crop root zone. The presence of the water table at a shallow depth assures the upward migration of salts and salinization of the soil while preventing the leaching of salts past the water table. Areas that presently are rapidly becoming saline could be controlled or reclaimed if the water table were lowered. Preliminary data suggest that the fluctuating water table effectively restricts the root zone of crops to the minimum depth of the water table or less. This is 30 to at most 50 cm. During periods of peak consumptive use, the crop is stressed from the lack of an adequate root system. Crop stress can significantly reduce yields.

Factors Affecting Crop Yield

In connection with the study of on-farm irrigation practices, the yield of the crop and a number of factors that influence yield were measured. These variables and their values for each site are listed in Table 8. Because the number of sites were inadequate to provide sufficient accuracy for a step-wise multiple linear regression analysis, the

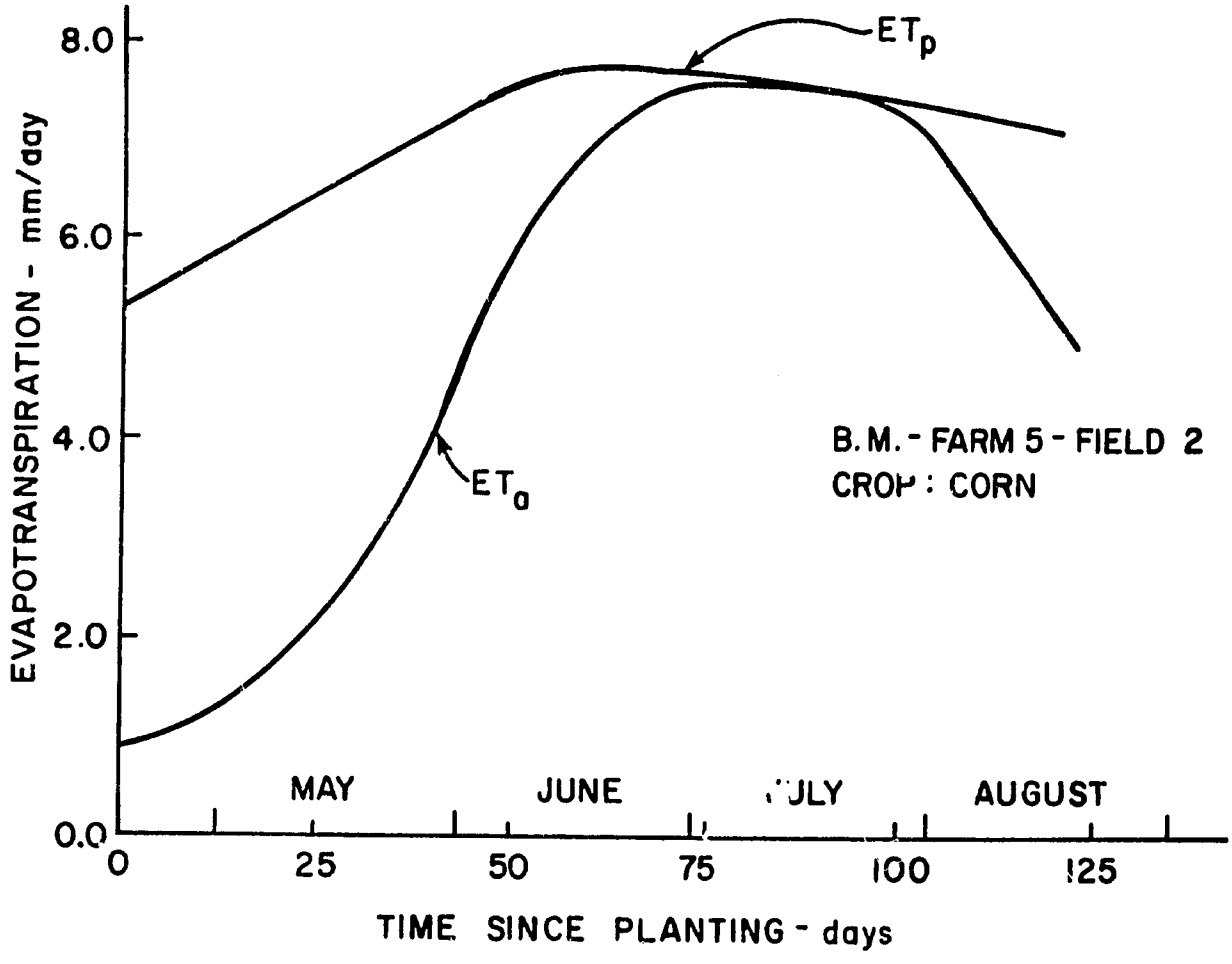

Figure 15. Seasonal Consumptive Use (ETa) and Potential Evapotranspiration (ETp) for a Corn Field at Beni Magdoul.

Table 7. Sample Water Balance for the Corn Field in Figure 7 (amounts in mm).

Irrigation	Preplant	1	2	3	4	5	6	7	8	9	10
	Water Application Budget										
Depth Applied	166	81	50	60	62	70	60	50	80	70	
Deficiency (SMD)	25	25	25	25	25	25	25	25	25	25	25
Storage (SMS)	25	25	25	25	25	25	25	25	25	25	
Deep Percolation (DP)	141	56	25	35	37	45	35	25	55	45	
	Consumptive Use Budget										
Consumptive Use (CU)	---	44	53	48	50	48	50	52	73	64	133
Source:											
Soil Moisture (SM)	---	25	25	25	25	25	25	25	25	25	25
Water Table (GW)	---	19	28	23	25	23	25	27	48	39	108
Application Efficiency (EA)	15	31	50	42	40	36	42	50	31	36	
	Seasonal Summary										
Total Applied	749	EA (seasonal) = 33%									
CU	615										
SM	250 (41%)										
GW	365 (59%)										
	Water Table Rie After Irrigation										
Well 7		24	30	--	40	20	--	12	34	14	

Table 8. Regression Variables for Corn Yield.

	(1) K.N. 1978	(2) K.N. 1977	(3) BM78 F7	(4) BM78 F4F2	(5) BM78 F3	(6) BM78 F2F4	(7) BM78 F2F2	(8) BM78 F2F3	(9) BM78 F5	(10) BM77 F2F3	(11) BM77 F2F5	(12) BM77 F2F4
Yield (Ard/F)	8.0	8.5	12.0	10.5	6.6	12.0	6.3	14.4	11.9	8.0	10.0	10.0
Seed Rate (kg/f)	42.00	42.00	17.57	26.98	26.67	22.44	33.71	28.67	23,68	28.67	23.95	22.44
No. of Irrigations	6	6	9	5	6	10	7	6	10	8	8	7
Area (f)	1.90	1.90	0.34	0.44	0.44	0.52	0.09	0.21	0.55	0.21	0.49	0.52
Manure (dℓ/F)	200	230	250	0	220	300	200	250	0	0	200	200
Fertilizer N (kg/f)	66	57.75	105.5	118.8	33	33	132	82.5	138.5	66	33	66
Total Water Applied (m^3/m^2)	0.54	0.51	0.61	0.40	0.52	0.45	0.87	0.47	0.60	0.69	0.70	0.68
Pre-plant Irrigation	Yes	Yes	No	No	No	Yes	No	No	No	No	No	No
Planting Date 1/	39	8	13	56	45	27	18	18	-17	9	12	10
Plowing Date 2/	39	8	-42	47	41	27	12	18	-19	9	5	9
Harvest Date 3/	10	1	0	30	31	15	3	10	-13	7	6	7
Frequency of Irrigation (days) 4/	12.5	12.0	12.5	17.5	16.5	12.5	14.0	14.5	13.5	14.0	13.5	14.5

1/ Days from May 15 2/ Days from May 15 3/ Days from September 1 4/ Median value of range

number of independent variables were limited to three and a regression analysis conducted. Nineteen different combinations of three independent variables were evaluated. The results suggested that seeding rate, total water applied, and harvest data were the most significant variables (Table 9). That model and three additional ones are shown in Table 9. The coefficients for all variables were negative except manure and nitrogen fertilizer applied. Only the coefficient for total water applied appears to not include zero in the confidence interval which suggests that as the water applied increases, the yield decreases. Nearly 75% of the variation in yield can be explained by seeding rate, total water applied and harvest data and is significant at the .009 level. This effect is supported by the previous sections which suggested over-irrigation was the practice. A study by Johnson and Khan (1979) suggested that when a number of factors are limiting, yield is not significantly affected by many of the factors of production.

Additional data and analyses are needed to identify the factors that affect production under traditional farming practices. The identification of these factors is important in determining those factors which limit crop production and would identify the priority problems needing solution.

Summary and Conclusions

Irrigation practices in the Mansuriya District of Egypt were studied during the summer season of 1978. The principal crop was corn although a number of vegetable crops were also grown.

The state-of-the-art of farmer irrigation practices related to the state variables for water application were as follows:

Table 9. Results of 4 3 - Variable Models.

Model	Variables In Model	Value of Coefficient / std. error	F-Value / Significance	Beta / Elasticity	Overall r^2	Overall F / Significance	(for) eqn.
	Seed Rate	-0.17/0.58	9.00/0.017	-0.54/-0.50			
1	Total Applied Water	-14.11/3.79	13.82/0.006	-0.76/-0.84	0.746	7.82/0.009	
	Harvest Data	-0.12/0.41	8.34/0.02	-0.59/-0.11			
	(Constant)	24.08/3.01	64.14/0.00	--			
	Seed Rate	-0.17/0.82	4.33/0.071	-0.53/0.49			
2	Total Applied Water	-8.67/4.70	3.40/0.102	-0.47/-0.52	0.489	2.55/0.129	
	Manure Applied	0.0021/0.0058	0.13/0.73	0.09/0.04			
	(Constant)	19.4/3.85	25.44/0.001	--			
	Seed Rate	-0.17/0.078	4.49/0.067	-0.51/-0.48			
3	Total Applied Water	-9.73/4.60	4.46/0.068	-0.52/-0.58	0.533	3.04/0.093	
	N-Fert Applied	0.015/0.016	0.89/0.37	0.23/0.12			
	(Constant)	19.07/3.62	27.76/0.001	--			
	Seed Rate	-0.20/0.074	7.05/0.029	-0.61/-0.56			
4	Total Applied	-10.23/4.23	5.85/0.042	-0.55/-0.61	0.605	4.08/0.050	
	Freq. of Irrigation	-0.55/0.35	2.52/0.15	-0.37/-0.78			
	(Constant)	29.06/6.70	18.83/0.002	--			

1. Field geometry - Farmers irrigated small basins (0.0008 to 0.014 ha) with row crops on ridges or broadcast crops on the flat. The number and size of bunded units irrigated simultaneously vary. From 8 to 14 percent of the field area is consumed by field distribution ditches. The size of the basin does not appear to vary with the water supply rate.

2. Slope - The bunded units in a field were irrigated without regard to slope (assumed zero or level). Elevation variations within a basin ranged from 5 to 20 cm while the maximum range specified (USDA, 1979) for level basins is 3 cm.

3. Infiltration rate - Early season infiltration rates appear to result in excessive applications of irrigation water at the first irrigation. Terminal intake rates ranged from 1.2 cm/hr on a clay loam soil to 6 to 12 cm/hr on a sandy loam soil.

4. Surface roughness - No significant effects of surface roughness on irrigation practices were observed.

5. Channel shape - Furrows were used with crops that are sensitive to inundation. Farmers appear to attempt to regulate rate and amount of water applied to control inundation but are not always successful.

6. Water supply rate - Variable flow rates and variable areas for bunded units limit farmers ability to apply a specified amount of water to a field. Tambour flow rates range from 5 go 18 l/s and Saqia flow rates range from 3 to 61 l/s. The maximum flow rate is frequently twice the mean.

7. Management - Farmers appear to irrigate field systems which do not permit good water management because they are unlevel, and the area

irrigated and flow rates are variable. His decision on when to irrigate is influenced by the canal rotation with 25 percent of his irrigations on a four day interval. When water is continuously available, no frequencies less than four days occurred and the median frequency was 9 to 12 days. The amount of water applied appears excessive with the seasonal average application estimated to be more than twice as much as can be stored in the soil. The result is leaching of fertility and a fluctuating water table. Both limit crop production.

8. The factors which affect crop yield were evaluated but inadequate data did not permit quantification. Preliminary results suggest that increased water application decreased yields suggesting that excess water was applied. No factors except fertilizer had a positive affect on yield out of 10 factors evaluated. More data are needed to define the cause and effect relationships but results from other studies suggest one or more factors are limiting with the result that supplying the traditional factors of production do not result in positive increases in yield (Johnson and Khan, 1979). Level borders were recommended for improvement of the on-farm system. Evaluation of the new system is presently (1979) being conducted in Egypt.

Recommendations

The authors recommend the following activities be evaluated as potential solutions to the above defined problems.

1. Design an improved, precision leveled, water application system for a farm on both Beni Magdul and El Hammami branch canals using the criteria defined by USDA (1974) for level borders.

2. Construct the irrigation system and provide irrigation advisory assistance to the farmers on the operation and management of the system.

3. Collect evaluation data on the social, economic, crop production and engineering aspects of the operating irrigation system The results for the improved system will be compared with the traditional system to evaluate appropriateness of the new system and further understand the farmer's management decisions. Final recommendations must await these results before suggesting solutions to the above defined problems.

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AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

Land Area	in *sq meters*	in *acres*	in *feddans*	in *hectares*
1 acre	4,046.856	1.000	0.963	0.405
1 *feddan*	4,200.833	1.038	1.000	0.420
1 hectare(ha)	10,000.000	2.471	2.380	1.000
1 *sq* kilometer	100 x 104	247.105	238,048	100.000
1 *sq* mile	259 x 106	640.000	616.400	259.000

Water Measures	*feddan*-cm	*Acre*-feet	*Acre*-inches
1 billion m^3	23,809,000.000	810,710.000	
1,000 m^3	23.809	0.811	9.728
1,000 m^3/*feddan* (= 238 mm of rainfall)	23.809	0.781	9.372
420 m^3/*feddan* (= 100 mm of rainfall)	10.00	0.328	3.936

Other Conversions

1 *ardeb* = 198 liters = 5.62 bushels (U.S)
1 *ardeb/feddan* = 5.41 bushels/acre
1 kg/*feddan* = 2.12 lb/acre
1 donkey load = 100 kg
1 camel load = 250 kg
1 donkey load of manure = 0.1 m^3
1 camel load of manure = 0.25 m^3

Egyptian Units for Field Crops

Crop	Eg. Unit	in kg	in lbs	in bushels
Lentils	*ardeb*	160.0	352.42	5.87
Clover	*ardeb*	157.0	345.81	5.76
Broad beans	*ardeb*	155.0	341.41	6.10
Wheat	*ardeb*	150.0	330.40	5.51
Maize, Sorghum	*ardeb*	140.0	308.37	5.51
Barley	*ardeb*	120.0	264.32	5.51
Cottonseed	*ardeb*	120.0	264.32	8.26
Sesame	*ardeb*	120.0	264.32	
Groundnut	*ardeb*	75.0	165.20	7.51
Rice	*dariba*	945.0	2081.50	46.26
Chick-peas	*ardeb*	150.0	330.40	
Lupine	*ardeb*	150.0	330.40	
Linseed	*ardeb*	122.0	268.72	
Fenugreek	*ardeb*	155.0	341.41	
Cotton(unginned)	*metric qintar*	157.5	346.92	
Cotton(lint or ginned)	*metric qintar*	50.0	110.13	

Egyptian Farming and Irrigation Terms

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat," A land measure of 1/24 *feddan*, 175.03 m^2
qaria = village
sahm = 1/24th of a *qirat*, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also *masraf*, (n.)