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EVALUATION OF FARMERS' IRRIGATION PRACTICES IN EL-HAMMAMI SANDS

By:

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EGYPT WATER USE AND MANAGEMENT PROJECT

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Abstract

A study of three of the farms of El-Hammami area in El-Mansuriya region, Giza Governorate, was carried out to evaluate the irrigation of sandy soils. The on-farm irrigation practices in the area indicated that the farmers at the beginning of the canal apply more water than those at the end of the canal. The irrigation application efficiency of the farmers at the tail end of the canal was greater than that of the farmers at the beginning. The data also indicated that subsurface irrigation due to seepage from neighboring fields contributed substantially to crop water use. The study showed that surface irrigation might not be the best way to irrigate these sandy soils.

74 Pages, 12 Figures, 28 Tables

mh/

ملخـــــــص

تم القيام بدراسة لثلاث مزارع بمنطقة ترعة الحمامى بالمنصورية محافظة الجيزة ،لتقييم نظام الرى فى الأراضى الرملية .

وقد أوضحت دراسة نظام الرى الحقلى بالمنطقة أن المزارعين الذين تقع حقولهم على بداية الترعة يستخدمون مياه أكثر من الذين تقع حقولهم على نهايتها .. وأن كفاءة الرى الحقلى عند المزارعين فى نهاية الترعة تكون أكبر من كفاءة الرى عند المزارعين فى بداية الترعة .. وقد اتضح أيضا من الدراسة أن الرى الجوفى نتيجة التسرب من الحقول المجاورة يساهم فعليا فى احتياجات النبات وأنه من الممكن ألا يكون الرى السطحى أفضل طريقة لرى مثل هذه الأراضى الرملية .

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Table of Contents

Abstract (English) i
Abstract (Arabic) ii
Table of Contents iii
List of Tables v
List of Figures vii
Acknowledgements viii
Administrative Credits ix

I. INTRODUCTION 1

II. REVIEW OF IRRIGATION DESIGN AND OPERATIONS 2

A. Surface Irrigation 2
1. Flood Irrigation 2
a) Border Strip 3
b) Basin or Level Borders 3
2. Furrow Irrigation 3

B. Design Parameters Review 4
1. Soil Texture 4
2. Soil Intake Rate 4
3. Bulk Density 5
4. Water Holding Capacity (field capacity) 5
5. Flow Rates and Heads Available 6

III. MATERIAL AND METHODS 6

A. Farm Selection and Layout Description 6

B. Determination of Farm Irrigation Practices 9
1. Field Size and Depth Applied 9
2. Bed Size 9
3. Frequency of Irrigations 11
4. Estimation of Crop Requirements 11
5. EWUP's Influence on Irrigations 11

C. Data Collection Procedure 11

D. Determination of Irrigation Design Parameters 11
1. Soil Texture 11
2. Soil Intake Rate 11
3. Soil Bulk Density 12

4. Soil Moisture 12
5. Flow Rates and Heads Available 13
6. Topography 13

IV. RESULTS 13

A. Analysis of Irrigation Design Parameters 13
1. Soil Texture and Related Characteristics 13
2. Soil Intake Rate 15
3. Soil Bulk Density and Porosity 19
4. Water Holding Capacity 19
5. Water Discharge 22

B. Farmers' Irrigation Practices 22
1. Farm (01-01-01) 26
a) Wheat 26
b) Berseem 30
2. Farm (01-02-02) 30
a) Berseem 30
b) Cabbage 37
c) Watermellon 37
3. Farm (01-02-03) 40
a) Broad beans 40
b) Berseem 40
c) Wheat 44
d) Tomato 44
e) Hot pepper 52
f) Eggplant 52
g) Watermellon 57
h) Maize 57

V. DISCUSSION 62

A. Evaluation of Farmers' Irrigation Practices 62

B. Farmers' Design Criteria 65

C. Effect of Water Table 67

V. SUMMARY AND CONCLUSIONS 71

VI. REFERENCES 72

American Equivalents of Egyptian
Arabic Terms and Measures Commonly
Used in Irrigation Works 74

List of Tables

Table No.		Page
1	Recommended Border Irrigation Relationships (Adapted from Phelan and Criddle, 1955, Yearbook of Agriculture, P. 264)	7
2	Particle Size Distribution for Profiles Near the Selected Farms	14
3	Cylinder Infiltrometer Data (1981)	16
4	Bulk Density and Porosity Values (1981)	20
5	Soil Water Holding Capacity (1980-81)	21
6	Root Penetration for Groundnut and Hot Peppers in El-Hammami, Summer 1981	23
7	Root Penetration for Maize in El-Hammami, Summer 1981	24
8	Water Discharge (1980-81)	25
9	Averages of Different Irrigation Measurements Collected in Farm (01-01-01) (1980-81)	27
10	Soil Moisture Data Sheet, at the Beginning of El-Hammami Canal, Wheat Crop in Winter 1980-81	28
11	Soil Moisture Data Sheet, at the Beginning of El-Hammami Canal, Berseem Crop in Winter 1980-81	31
12	Averages of Different Irrigation Measurements Collected in Farm (01-02-02) (1980-81)	34
13	Soil Moisture Data Sheet, at the End of El-Hammami Canal, Berseem Crop in Winter 1980-81	35
14	Soil Moisture Data Sheet, at the End of El-Hammami Canal, Cabbage Crop in Winter 1980-81	38

Table No.		Page
15	Soil Moisture Data Sheet, at the End of El-Hammami Canal, Watermellon Crop in Summer 1980-81	39
16	Average of Different Irrigation Measurements Collected in Farm (01-02-03) (1980-81)	41
17	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Broad Bean Crop in Winter 1980-81	42
18	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Berseem Crop in Winter 1980-81	45
19	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Wheat Crop in Winter 1980-81	48
20	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Tomato Crop in Winter 1980-81	51
21	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Hot Pepper Crop, along the Season 1980-81	53
22	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Eggplant Crop along the Season 1980-81	56
23	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Watermellon in Summer 1980-81	58
24	Soil Moisture Data Sheet, at the Middle of *Mesqa* 2, Maize Crop in Summer 1980-81	59
25	The Influence of Farm Location on the Amount of Water Discharged (1980-81)	63
26	The Influence of Farm Location on the Application Efficiency (1980-81)	64
27	Average Infiltration Rate for the First 195 Minutes	66
28	Available Flow Rates and Maximum Basin Area	68

List of Figures

Figure No.		Page
1	The Three Selected Sites	8
2	Farm Layout Description	10
3	Intake Curve Plotted on Log-Log Paper	17
4	Solving Kostiakov's Equation for Values of c and n	18
5	Acutal Water Application vs. Estimated Consumptive Use for Wheat Crop	29
6	Actual Water Application vs. Estimated Consumptive Use for Berseem Crop	33
7	Actual Water Application vs. Estimated Consumptive Use for Berseem Crop	36
8	Actual Water Application vs. Estimated Consumptive Use for Broad Bean Crop	43
9	Actual Water Application vs. Estimated Consumptive Use for Berseem Crop	47
10	Actual Water Application vs. Estimated Consumptive Use for Wheat Crop	50
11	Actual Water Application vs. Estimated Consumptive Use for Corn Crop	61
12	Schematic Sketch for Water Table Fluctuation and Subsurface Irrigation of Adjacent Field	69

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EVALUATION OF FARMERS' IRRIGATION PRACTICES IN EL-HAMMAMI SANDS*

By
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I. INTRODUCTION

Water management is the primary concern of the Egypt Water Use and Management Project (EWUP). The Project's first goal is to increase land production, crop production and farmers' incomes through improved water management. The main idea is to minimize the amount of irrigation water applied by the Egyptian farmers without reducing crop yield.

EWUP's program covers three areas in Egypt which were selected to be representatives of the Egyptian irrigation system; these are (1) El-Mansuriya, Giza Governorate (in Middle Egypt), (2) Abu Raya, Kafr El-Sheikh Governorate (in Northern Egypt), and (3) Abyuha, El-Minya Governorate (in Southern Egypt).

Two watercourses were selected in El-Mansuriya area for intensive studies: Beni Magdul canal and El-Hammami canal. This paper deals with El-Hammami canal, which takes the water from El-Mansuriya main canal.

El-Hammami area is about 2000 *feddans* (Dotzenko et al., 1979). The area exhibits the sandy soil conditions found along the fringe of the Nile Valley.

Farmers irrigate their fields by lifting the water from the canal, *mesqa* or from the shallow aquifer. *Saqias* are used when irrigation water is available in the irrigation canals, while pumps are used to pump the groundwater, when there is insufficient water in the canals, or when the fields are too far from the canals.

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* This paper was submitted to Colorado State University, Agronomy Department, as a partial fulfillment of M. Sc. requirement.

a/ Former EWUP agronomist and present leader of the Agronomy Department in the Project Preparation Unit of the Irrigation Management Systems Project.

b/ EWUP Senior Agronomist and Associate Professor of Agronomy at Colorado State University.

This paper presents a summary of the data collected by EWUP from three selected farms.

The major objectives of this report are:

A) To Evaluate the irrigation application efficiency at the farm level;

B) To Study the farmers' design criteria;

C) To Estimate the water table contribution to the water uptake by plants.

The questions to be answered by these objectives are:

1. How much water did the farmers apply?
2. How much of that water was actually stored in the soil?
3. At which depth in the soil profile was the water stored?
4. How is the computed water use compared with the estimated water requirements?

II. REVIEW OF IRRIGATION DESIGN AND OPERATIONS

In general, there are three methods of applying irrigation water to land (surface irrigation, sprinkler irrigation, subsurface irrigation). In this study, the surface irrigation system will be discussed, being the only one used in the study area.

A. Surface Irrigation

The idea is to obtain uniform distribution of an adequate amount of water without excessive penetration. This should be accomplished with minimum expenses, labor, equipment and disfiguration of land surface.

Surface irrigation can be subdivided into flood irrigation, and furrow irrigation (Hart, 1975).

1. Flood Irrigation: Theoretically, water should stand in the soil at all points just long enough to allow sufficient water to enter and fill the root zone to field capacity. It is seldom possible to achieve this situation under practical field conditions. Flood irrigation includes several specific methods of application.

a) Border Strip: The objective is to advance a sheet of water over a narrow strip of land between borders consisting of low ridges. The strip must have a uniform grade. The border dikes should be low and well rounded so as to allow the crop to expand over the dikes.

This method is well adapted to close-growing crops. It can use large heads of water safely and has low labor and time requirements.

The field layout depends upon the soil intake rate, slope, and depth of irrigation water to be applied. Strip width is largely governed by the amount of water that may be safely carried through turnouts from the supply ditch and along the slope of the land. Larger streams are required if the soil intake rate is high, and shallow applications are required (Phelan & Criddle,1955).

b) Basin or Level Borders: The objective is to quickly fill a diked area to the desired depth and then allow the water to uniformly penetrate the soil. The method is especially adapted to flat lands and for close-growing crops. The method is good for sodicity and salinity control.

The dikes around the basin must be high enough to save the amount of water required for irrigation since the time of application is short. Generally, the dikes are too high to allow equipment to drive over them. The land must be quite level generally not greater than 0.1% slope. The stream size depends upon the size of basins, but, as a rule of thumb, the stream size should be twice that required on flat land for border strip irrigation with the same width as that of basin irrigation.

2. Furrow Irrigation: It is the most recommended method for row crops where the furrows are made between the rows. It is adapted to all row crops, on gentle slopes if intake rates are not too high, or for dead level. In Egypt, the farmers use small basins with small furrows inside every basin for their row crops. Small furrows are prepared and used chiefly for guiding the water rather than conveying it. Overtopping often occurs. The method is helpful where the land is not sufficiently leveled. It makes use of small discharges, and can be used for cover crops as well as row crops.

B. Design Parameters Review

In order to design an irrigation system and to have a good irrigation evaluation, some physical parameters need to be determined. The soil texture, soil intake rate, soil bulk density, water holding capacity and flow rate are of primary concern.

1. Soil Texture: It refers to the relative proportions of various sizes of particles in a given soil. The traditional method of characterizing particle sizes in soils is to divide these particles into three size ranges known as sand, silt and clay. The overall textural designation or class is determined on the basis of the mass ratios of these three fractions.

   The soil texture must be known before designing an irrigation system. According to soil texture classification, the amount of irrigation water to be applied can be closely estimated when used with some other parameters like the available stream size, slope and porosity.

2. Soil Intake Rate: It is a soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions, including the presence of an excess of water (Brady 1976).

   Soil intake rate is used in designing an irrigation system because it explains the relation between the depth of water entering the soil and the time needed. The intake rate depends mostly on the soil texture and gives an indication about the moisture distribution in the soil. Usually the intake rate decreases rapidly with time during an irrigation. This decrease is a logarithmic function of time that can be described by the Kostiakov equation (McCulloh, 1876).

$$D = c\,T^n$$

where,

D = depth of water infiltrated in time T,
c & n = constants (McCulloh, 1976).

If the log of the accumulated intake in "cm" is plotted as a function of log of time in "minutes", the resulting best fit straight line will have an intercept of c and a slope of n.

When $D = c\,T^n$

$I = (60)\ cn\ T^{(n-1)}$ where I = the intake rate (cm/hr);
$\bar{I} = (60)\ c\ T^{(n-1)}$ where $\bar{I}$ = the average intake rate (cm/hr) for the whole period of time (McCulloh, 1976).

3. Bulk Density: It is the mass of dry soil per unit bulk volume (including the air space)

$$B_d = M_s/V_b \qquad \text{(Marchall, 1979)}$$

Soil bulk density is important in converting the percent moisture by weight to percent moisture by volume.

The relation is:

Percentage of moisture by volume =
Percentage of moisture by weight x bulk density

4. Water Holding Capacity (field capacity): It is the amount of water held in the soil after excess water has drained away and the rate of downward movement has materially decreased, which usually takes place within 2-3 days after rain or irrigation in well drained pervious soils of uniform structure and texture.

Water holding capacity is used in calculating the irrigation application efficiency:

$$\text{Application Efficiency} = \frac{\text{Applied Water}}{\text{Field Capacity}} \times 100$$

In the absence of groundwater and provided the soil profile is sufficiently deep, the typical moisture profile at the end of the intake process consists of a wetted zone in the upper part of the profile, and a relatively dry zone beneath. The post-intake movement of water from the moist to the drier zones within the profile is called redistribution. This process is caused by matric suction gradients. The rate of redistribution generally decreases with time, as the suction gradients decrease and the hydraulic conductivity of the desorbing zone falls off. Thus, moisture loss from the upper zone, rapid at first, becomes slower and slower, and by time this loss becomes imperceptible. The seemingly stable wetness remaining has since long been termed "field capacity" and taken to represent the upper limit of moisture availability in the field.

The field capacity is not an equilibrium value or a true constant, since redistribution does not generally cease within a few days and can persist for very long periods of time. In any case, different soils vary greatly - sometimes by a factor of ten - in their ability to retain water after comparable periods following intake. Soil wetness at any given time after intake depends on the soil hydraulic properties and profile uniformity as well as on the quantity of water intake and the initial wetness (Hillel, 1971).

5. Flow Rate and Heads Available: Flow rates should be measured at the on-farm delivery point. Measurements should be taken before designing the irrigation system to use the estimated discharge with the other parameters, so higher irrigation application efficiency can be obtained under practical field conditions.

   Soil topography is important in surface irrigation design, because it describes the soil surface condition. If the topography is irregular and surface irrigation systems are to be used, it is essential to determine the elevations throughout the irrigated area (Hart, 1975).

   As soon as the parameters are determined, the farm layout can be obtained. This is usually done with the aid of some prepared tables and imperical equations (Table 1).

   This results in a "design efficiency", but the practical field conditions do not necessarily follow the design efficiency. The more accurate the parameters are determined and the more homogenous the area is the more the design efficiency should compare with the actual field efficiency.

III. MATERIAL AND METHODS

A. Farm Selection and Layout Description

Three fields were selected in the area for intensive studies (Figure 1). The selection was one field at the beginning, another at the end of the canal, and a third along *Mesqa* 2, beyond the end of the canal.

Initial field studies showed that the farmers' field layouts are about the same throughout the study area, no matter what the location is or how water lifting is done.

Table 1. Recommended Border Irrigation Relationships (Adapted from Phelan and Criddle, 1955, Yearbook of Agriculture, p. 264)

Soil Texture	Percent Slope	Applic. depth (inches)	Suggested Size of border strip (feet)		Size of Stream (c f s)
			Width	Length	
Coarse	0.25	2	50	500	8.0
		4		800	8.0
		6		1320	6.0
	1.00	2	40	300	2.75
		4		500	2.50
		6		900	2.50
	2.00	2	30	200	1.25
		4		300	1.00
		6		600	1.00
Medium	0.25	2	50	800	7.0
		4		1320	6.0
		6		1320	3.5
	1.00	2	40	500	2.5
		4		1000	2.5
		6		1320	2.5
	2.00	2	30	300	1.0
		4		600	1.0
		6		1000	1.0
Fine	0.25	2	50	1320	4.0
		4		1320	2.5
		6		1320	1.5
	1.00	2	40	1320	2.5
		4		1320	1.25
		6		1320	0.75
	2.00	2	30	660	1.0
		4		1320	1.0
		6		1320	0.67

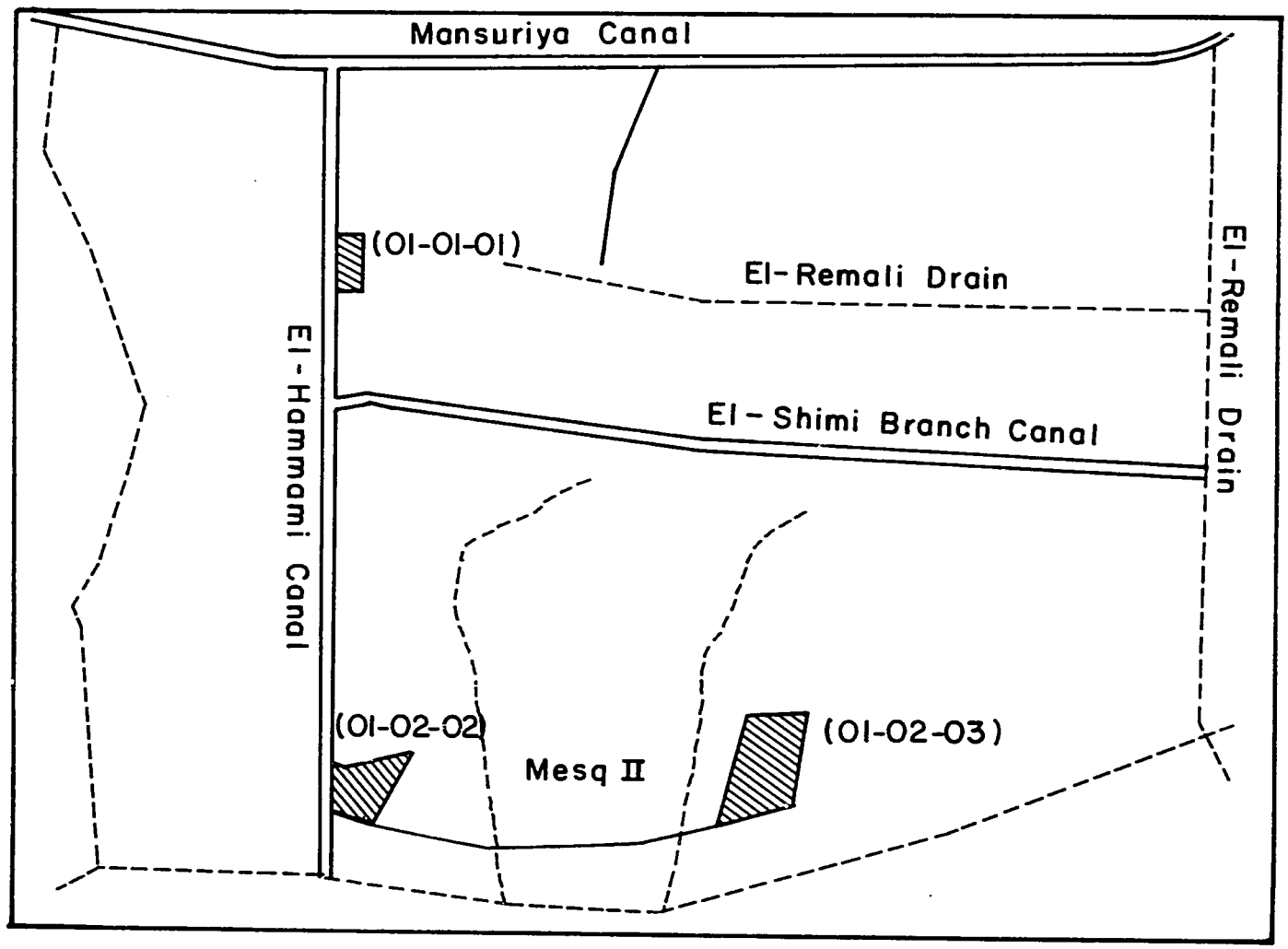

Figure 1. The Three Selected Sites

In general, a *saqia* lifting the irrigation water from the canal or a pump pumping the water from the shallow groundwater table is located by the head of the field. Water is directed to a narrow *marwa* which has cuts to allow water to enter every basin. One basin is irrigated at a time and then the next (Figure 2).

Despite similarity of farm layouts through the area, the amount of water available for irrigation was expected to be different according to farm location along the canal. For this reason, the selection procedure was to select farms under anticipated different amounts of available water.

The first selected farm (01-01-01) is located at the very beginning of El-Hamammi canal. As expected, there was always enough irrigation water, and the only method for lifting water was a *saqia* located by the corner of the field (Figure 1).

The second farm (01-02-02) is located at the end of El-Hammami canal and on the beginning of *Mesqa* 2 (Figure 1). Lifting water was done by a *saqia* at the head of the field. It was also expected that the farmer could always have enough water.

The third farm (01-02-03) is located at the middle of *Mesqa* 2 (Figure 1) where shortage of water was expected. The cross sectional area of the *mesqa* at the farm location was too small to convey enough water to the farm especially in summer. The farmer had a *saqia*, as well as a pump to use shallow groundwater table when water in the canal cannot meet his needs.

B. Determination of Farm Irrigation Practices

1. Field Size and Depth Applied: Fields were surveyed with 100 m tapes to measure basin sizes, *marwa* length and width and *saqia* locations.

   The area was used to get the depth applied from the equation.

$$\text{Depth of water applied (cm)} = \frac{\text{Total vol. of water applied } (m^3)}{\text{Area irrigated } (m^2)} \times 100$$

   The volume of water applied per irrigation was obtained directly from the flume measurement.

2. Bed Size: Bed size was measured by the tape. The distance between plants, the height of rows, the width of the bottom of the row and the distance between rows were all measured.

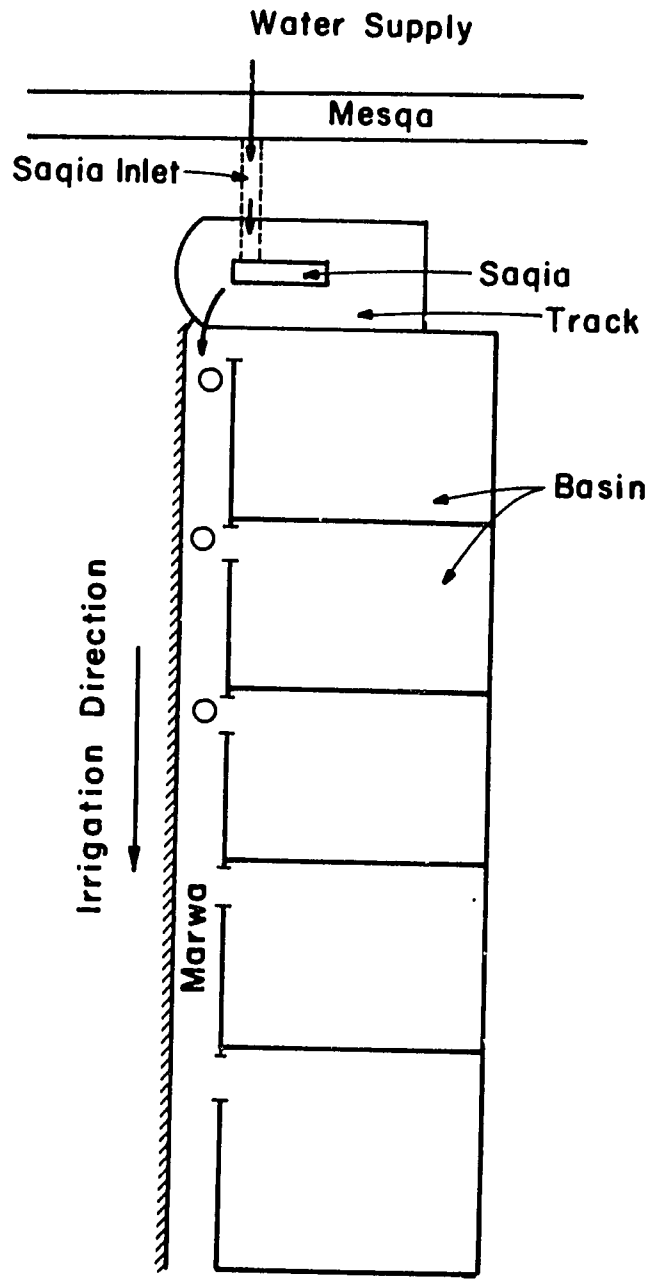

Figure 2. Farm Layout Description.

3. Frequency of Irrigations: The number of days between irrigations was recorded to get an average of the frequency of irrigation and to know the direct reason for each irrigation by questioning the farmers and monitoring the growth stage.

4. Estimation of Crop Requirements: The average daily water depletion (rate of depletion per day) was obtained by dividing the amount of moisture consumed (calculated with the gravimetrical method) between two successive irrigations by the number of days elapsed in that interval.

   The data obtained was compared with the recommended evapotranspiration estimated (Water Master Plan, 1981).

5. EWUP's Influence on Irrigations: The EWUP staff did not interfere at all during 1980. There was no influence on the following:

   - When the farmer irrigated his field.
   - How much water he applied.
   - The irrigation system design.
   - The time of planting, etc.

C. Data Collection Procedure

In order to evaluate the farmer's irrigation design ,to figure out how close the farmer's design relates to the fundamentals of surface irrigation design criteria, and to check how the practical field conditions govern the farmer's design, the previously discussed parameters need to be determined and analyzed. The study was conducted on those farmers' fields where some data collection could interfere with on-going farm activities. The data collection had to be frequently held to a minimum in order to minimize the interference with the farmers' regular operations.

D. Determination of Irrigation Design Parameters

1. Soil Texture: The soil survey done by EWUP (Dotzenko et al., 1979) was used to determine the soil texture characteristics and some other preliminary studies of some parameters.

2. Soil Intake Rate: Since the soil survey studies indicated that the soil characteristics in the whole area were quite uniform, it was expected that the soil intake rate could be

uniform over the whole area. Thus, the number of replicates used in determination of intake rate was limited to four. The intake rate was determined by four double ring infiltrometers placed on four spots in an area of about half a *feddan*. Cylinders were installed in the four selected locations that were examined carefully to avoid signs of unusual surface disturbance, animal burrows, and stones which might influence cylinder readings. Areas which might have been affected by unusual animal or machinery traffic were avoided. The water level was kept at 10 to 15 cm. When the water level had dropped 3 to 5 cm, sufficient water was added to return the water surface to its approximate initial elevation. In data analysis, refilling was assumed to be instantaneous. In the first five minutes, readings were recorded every minute. After the first five minutes, readings were recorded every five minutes until the end of the experiment, except for the reading before and after refilling. An average of those four replicates was taken as the soil intake rate curve.

3. Soil Bulk Density: As described in the determination of the intake rate, the uniform soil characteristics limited the number of samples needed to be taken to determine the soil bulk density. A representative location from each field was selected. The selected locations were examined for signs of unusual surface disturbances. The bulk density sampler was used to collect the undisturbed samples, the sampler tube was elongated vertically and hammered into the ground. Samples were collected vertically every 15 cm until 90 cm.

   An average of three groups of data was obtained to get the soil bulk density in the three soil layers 0-30, 30-60, and 60-90 cm.

4. Soil Moisture: In order to evaluate the farmers' irrigation application efficiency and the soil moisture depletion, soil moisture samples were collected before each irrigation and 24 to 72 hours after each irrigation. Samples were collectd in four different places in every irrigated field at depths of 0-10, 10-20, 20-30, 30-60 and 60-90 cm. The soil moisture content was determined gravimetrically. The difference between moisture contents before and after an irrigation from 0-90 cm was used as a base to determine the irrigation application efficiency. The difference in the moisture content after an irrigation and the moisture content before the following irrigation was used to calculate the water depletion.

Dividing the water depletion by the number of elapsed days between the two sampling dates, we obtain the rate of depletion.

Because of the highly fluctuating water table, which prevented the normal determination of field capacity, an average of the soil moisture content after irrigation was taken as the soil field capacity for every farm.

5. Flow Rates and Heads Available: To measure the amount of water used by the farmer, cutthroat flumes of 20 by 90 cm were placed directly at the outlet of the *saqia* or the pump. Flume readings were taken by EWUP's technicians every fifteen minutes (or less) during an irrigation. The cutthroat flume program developed by Helal et al. (1980) was used to calculate the discharge and the amount of water applied with the use of the HP-97 calculator. The amount of total water applied per irrigation was compared to the published estimated evapotranspiration.

6. Topography: Ground surface elevations were taken to determine the inside basin elevations to get general information about the degree of levelness.

IV. RESULTS

A. Analysis of Irrigation Design Parameters

To evaluate the farmers' irrigation practices in the area, it is quite important to evaluate the irrigation design parameters in a way that helps determine the present status of the irrigation practices applied by the Egyptian farmers in sandy soils of the study sites.

1. Soil Texture and Related Characteristics: According to the soil survey, the soils of El-Hammami area were found to be largely loamy sands in the surface and sands in the subsoil (Dotzenko et al., 1979). The coarse sand was the major particle size, it represents about 81% in the surface soils and 85% in the subsoils (Table 2), while the fine sand ranges from 0.7% to 9% in the subsurface soils and varies from 4.7% to 6.6% in the subsoils. The amounts of clay and silt are proportionally less, the clay content ranges from 7.1% to 7.6% in the surface soils and from 2% to a maximum of 6% in the subsoils, while the silt content varies from 1% to 10.6% in

Table 2. Particle Size Distribution for Profiles Near the Selected Farms a/

Profile No. b/	Depth cm	Coarse Sand %	Fine Sand %	Silt %	Clay %	Texture
28	0- 40	80.9	9.0	3.0	7.1	Loamy Sand
	40-150	85.7	4.7	3.5	6.0	Sand
35	0- 20	85.5	6.4	1.0	7.1	Sand
	20-150	85.3	6.6	6.1	2.0	Sand
56	0- 15	81.1	0.7	10.6	7.6	Loamy Sand
	15- 45	88.4	1.4	4.1	6.1	Sand
	45-150	84.2	5.2	6.6	4.1	Sand

a/ Adapted from EWUP Technical Report No. 2 , 1979.
b/ Profile No. 28 represented farm (01-01-01)
Profile No. 35 represented farm (01-02-02)
Profile No. 56 represented farm (01-02-03)

the surface soils and from 3.5% to 6.6% in the subsoils. The dominant sandy texture influences the other physical properties of the soil.

2. Soil Intake Rate: The average accumulated intake for the four double ring infiltrometers after 195 minutes was 92.1 cm as total depth applied under the experiment conditions (Table 3). The data obtained was plotted in a log-log paper (Figure 3). The equation developed by Kostiakov ($D = c\ T^n$) was used (McCulloh, 1976). In the equation:

D = accumulated intake of the soil
c = accumulated intake intercept at unit time
T = time at which water is on the soil surface
n = slope of the line

The time required to fill the soil with a given depth of water, D, is indicated by the formula

$$T = \frac{D}{c}^{1/n}$$

Kostiakov's equation was solved for c and n (Figure 4). The results were:

c = 1.41.
n = 0.79
thus $D = (1.41)\ T^{(0.79)}$
and $I = (60)\ (1.41)\ (0.79)\ T^{(-0.21)}$
where $\underline{I}$ = the intake rate (cm/hr)
then $\underline{I} = (60)\ (1.41)\ T^{(-0.21)}$ where,
where $\bar{I}$ = the avarage intake rate (cm/hr), for a period of 195 minutes.

Note that if $D = c\ T^n$
$\underline{I} = (60)\ c\ n\ T^{(n-1)}$
$\bar{I} = (60)\ c\ T^{(n-1)}$ (McCulloh, 1976)

The "I" calculated is considered as the basic intake rate under experimental conditions of 195 minutes and 15 cm constant head of water.

The "I" value is 27.7 cm/hr. In practical field conditions, the average head of water applied by the farmers never reached the 15 cm head of water used in the experiment, but the value of 27.7 cm/hr can be used as a basis in evaluating the irrigation design of the farmer (McCulloh, 1976).

Elapsed Time (min)	Time of Reading (hr.min)	Cylinder #1 Accumulated Intake cm	Cylinder #2 Accumulated Intake cm	Cylinder #3 Accumulated Intake cm	Cylinder #4 Accumulated Intake cm	Average Accumulated Intake cm
0	11.00	00.0	00.0	00.00	00.0	00.00
5	11.05	07.2	04.2	06.50	03.1	05.25
10	11.10	12.5	06.4	11.00	05.2	08.78
20	11.20	22.9	10.4	15.00	08.7	14.25
30	11.30	33.4	13.6	22.50	11.5	20.25
45	11.45	43.6	19.6	32.50	13.7	27.35
75	12.15	63.3	30.5	50.90	22.9	41.90
105	12.45	82.0	40.0	69.10	30.8	55.23
135	01.15	97.7	50.0	85.80	38.9	68.10
165	01.45	112.7	61.0	101.80	46.9	80.60
195	02.15	123.7	72.0	117.80	54.8	92.10

Table 3. Cylinder Infiltrometer Data (1981).

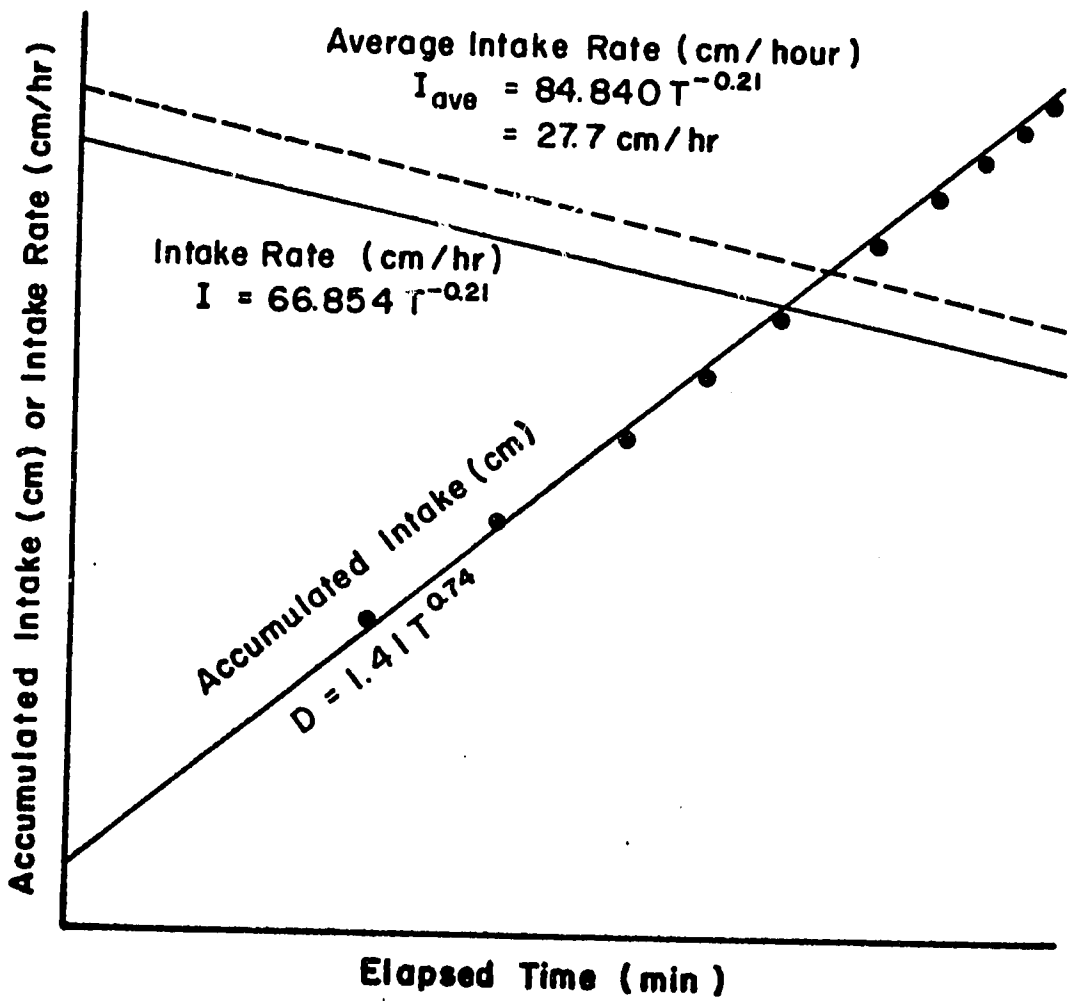

Figure 3. Intake Curve Plotted on Log-Log Paper.

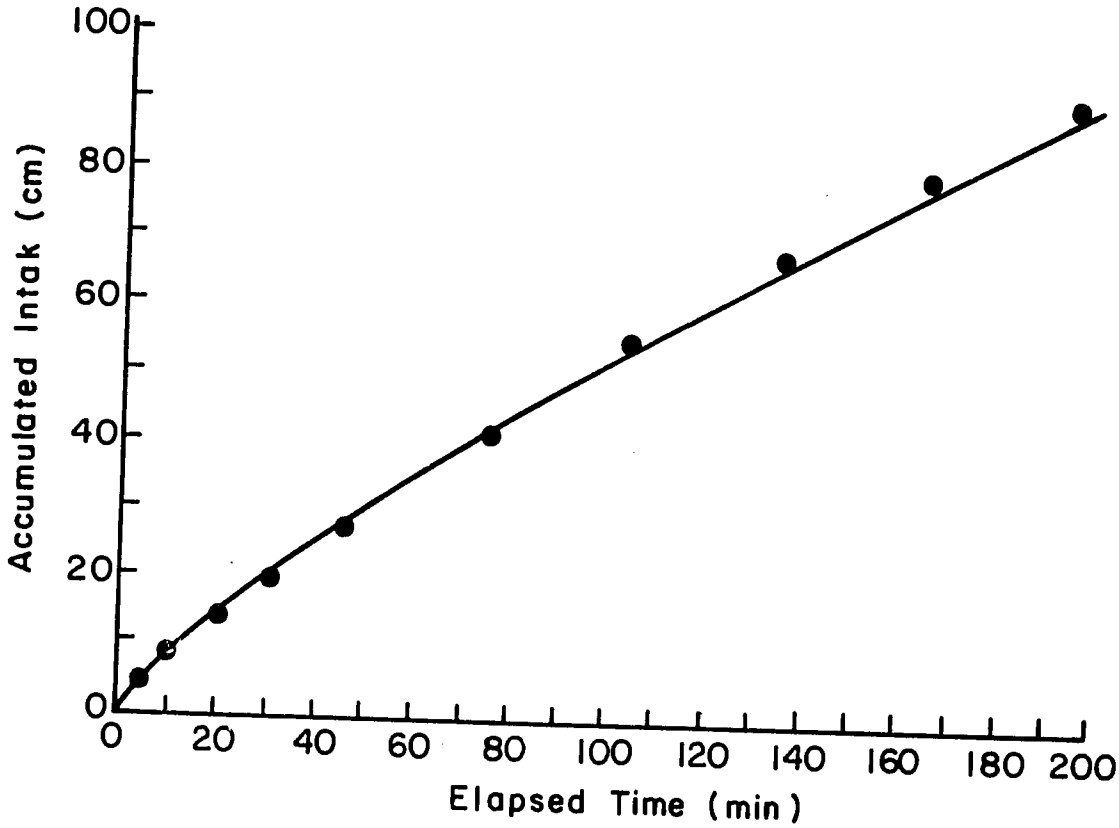

Figure 4. Solving Kostiakov's Equation for Values of c and n.

3. Soil Bulk Density and Porosity: The average of four soil bulk density values ranges from 1.6 g/cc at the upper 30 cm to 1.75 g/cc at the 60 to 90 cm. The values (Table 4) represent the higher range associates with sandy soil bulk density which usually has a variation from 1.2 to 1.8 g/cc (Marchall, 1979).

   These relatively high bulk density values might indicate a possible subsoil compaction which leads to low porosity values. The soil porosity was calculated using the bulk density values, assuming particle density 2.65 g/cc.

   The following equation was used

   $$\text{The percentage of porosity} = 1 - \frac{\text{bulk density}}{\text{particle density}}$$

   The calculated porosity values of 32 to 40% (Table 4) are quite appropriate for the soil texture and bulk density (Marchall, 1979).

4. Water Holding Capacity: The soil moisture samples collected in the area indicate a low water holding capacity, that is consistent and associated with the sandy texture of the soil. The upper 30 cm of the soil has the maximum percent of moisture stored from irrigation water while the change from 30-60 cm and from 60-90 cm is very small (Table 5). The big change in moisture content in the upper 30 cm is due to the small amount of water in the soil before irrigation (i.e. from 43.3 % to 55% of the total volume of voids), while from 30-60 cm it ranges from 84.9% to 94.3% which indicates that the soil voids are almost saturated and the air space is very small, and from 60-90 cm it ranges from 93.8% to 98.7% which also indicates that the soil voids are saturated with water, and most likely the sample is from below the water table.

   The only zone able to accept water was that of the 0-30 cm, where the volume of water held by the soil particles before irrigation varied from 17.3% to 22% and after irrigation it varied from 25% to 27%. The soil porosity from 0-30 cm was 40% (Table 5), which indicates a reasonable response for irrigation. A good soil aeration indicated that the concentration

Table 4. Bulk Density and Porosity values[a/] (1981).

Soil Layer cm	Bulk Density[b/] g/cc	Porosity %
0 -30	1.60	40
30-60	1.70	36
60-90	1.75	34

a/ Particle density taken as 2.65 g/cc.
b/ Average of four values.

Farm No.	Depth of Sampling (cm)	Moisture Content Before Irrig. (mm)	Moisture Content After Irrig. (mm)	Moisture Restored (mm)	Percent Stored Per Layer %	Soil Moisture as[b/] A Percent Volume		% Voids Filled Volume of Water		Soil Porosity %
						Before Irrig.	After Irrig.	Before Irrig.	After Irrig.	
(01-01-01)	0 - 30	52	75	23	64	17.3	25.0	43.3	62.5	40.0
	30 - 60	81	86	5	14	27.0	28.7	84.9	90.3	36.0
	60 - 90	90	98	8	22	30.0	32.7	43.7	100.0	34.0
(01-02-02)	0 - 30	66	81	15	83	22.0	27.0	55.0	67.5	40.0
	30 - 60	90	93	3	17	30.0	31.0	94.3	97.5	36.0
	60 - 90	94	92	- 2	0	31.3	30.7	97.8	95.9	34.0
(01-02-03)	0 - 30	53	76	23	66	17.7	25.3	44.3	63.3	40.0
	30 - 60	83	87	4	11	27.7	29.0	87.1	91.2	36.0
	60 - 90	91	99	8	23	30.3	33.0	94.7	100.0	34.0

Table 5. Soil Water Holding Capacity[a/] (1980-1981)

a/ The three represented samples are from the first irrigation of berseem in the three fields

b/ Soil bulk density values obtained from (Table 3)

of roots was highest from 0-40 cm, which might be due to optimum moisture content and soil aeration (Tinsley, 1982) (Tables 6 & 7). On the other hand, the volume of water held before irrigation from 30-60 cm was between 27% to 31.3% and 28.7% to 31% for after irrigation with soil porosity 36% which means that the percent water stored due to irrigation was very little and all voids were almost saturated before irrigation and consequently poor soil aeration which could restrict root penetration. The case was even worst in the 60-90 cm as the volume of water held was 30 to 31.3% before irrigation and 30.7 to 33% after irrigation with soil porosity 34% which indicates that all voids were completely filled with water.

The above discussion indicates that the high water table is usually in the 30-60 cm level.

5. Water Discharge: The average depth of water applied per irrigation was sometimes influenced by the average water discharge (Table 8). The data indicated that the higher the discharge, the higher the depth of water applied (i.e., with average water discharge 38.5 lps, the average depth of water applied was 179 mm, while with 15 ℓps water discharge, the average depth applied was 45 mm). This is in contradiction with the basic theory of water application efficiency where the higher the discharge, the lower the opportunity time for infiltration as there is a smaller amount of water applied.

The data also indicated that the farm location had a very great influence on the average discharge available and consequently on the depth of water applied (i.e. farmers at the beginning of the canal make use of greater discharges than those by the end of the canal).

B. Farmers' Irrigation Practices

The farmers' irrigation practices were evaluated from the data collected on:

- Frequency of Irrigation.
- Available discharge.
- Volume of water applied.
- Water depleted.
- Application efficiency.

Table 6. Root Penetration for Groundnut and Hot Peppers in El-Hammami[a/] Summer 1981.

Depth	Groundnut #1			Groundnut #2			Hot Peppers		
cm	g/seg	total %	accum. %	g/seg	total %	accum. %	g/seg	total %	accum. %
0-10	0.6	13.3	13.3	1.4	35.9	35.9	2.1	43.7	43.7
10-20	0.8	17.8	31.1	1.0	25.6	61.5	0.7	14.6	58.3
20-30	1.0	22.2	53.3	0.3	7.7	69.2	0.3	6.3	64.6
30-40	1.3	28.9	82.2	0.1	2.3	71.5	1.3	27.1	91.7
40-50	0.3	6.7	88.9	1.1	28.2	99.7	0.1	2.0	93.7
50-60	0.5	11.1	100.0				0.1	2.0	95.7
60-70							0.1	2.0	97.7
70-80							0.1	2.0	99.7
Total	4.5			3.9			4.8		

a/ Adapted from EWUP DWP # 92 "Evaluation of Root Penetration for Summer Crops 1981."

Table 7. Root Penetration for Maize in El-Hammami, Summer 1981[a].

Depth cm	Maize #1			Maize #2		
	g/seg	total %	accum. %	g/seg	total %	accum. %
0-10	5.7	68.7	68.7	4.0	66.7	66.7
10-20	2.0	24.1	92.8	1.4	23.3	90.0
20-30	0.2	2.4	95.2	0.2	3.3	93.3
30-40	0.2	2.4	97.6	0.2	3.3	96.6
40-50	0.1	1.2	98.8	0.2	3.3	99.9
50-60			98.8			
60-70			98.8			
70-80	0.1	1.2	100.0			
Total	8.3			6.0		

a/ Adapted from EWUP DWP # 96 "Evaluation of Root Penetration for Summer Crops 1981."

Table 8. Water Discharge (1980-1981).

Site	Crop	Season	Average Depth Applied per (Irrig.) (mm)	Average Discharge (lps)
01-01-01	Wheat	winter	113	36.3
	Berseem	winter	179	38.5
01-02-02	Berseem	winter	69	34
	Cabbage	winter	71	30
	Watermellon	summer	101	22
01-02-03	Broad beans	winter	37	16
	Wheat	winter	31	19
	Berseem	winter	75	19
	Tomato	winter	35	19.5
	Eggplant	wint.&sum.	45	15
	Hot peper	wint.&sum.	41	31
	Watermellon	summer	70	19.4
	Maize	summer	44	21

1. Farm (01-01-01): This farm is located at the beginning of El-Hammami canal, where a shortage of available irrigation water in the canal never occurred. Therefore the farmer was always able to use his *saqia* and have an average discharge of 37 *l*ps (Table 9). During the winter seasons of 1980-1981, he cultivated both wheat and berseem.

   a) Wheat: Wheat was planted on about 2100 m^2. It was planted in December and harvested in May. The wheat crop received 6 irrigations between January and April, with an average irrigation frequency of 15 days. The amount of water applied varied from 40 to 130 mm per irrigation (Table 10). This made the average depth of irrigation 113 mm, and the total depth of irrigation per season 679 mm. Of the 679 mm applied, only 91 mm were stored in the 0 to 90 cm depth, and only 74 mm were accounted for as depletion. In contrast, the estimated consumptive use for a wheat crop is 475 mm (Figure 5). Thus the application efficiency based on the water stored is calculated as follows:

$$(91/679)\ 100 = 14.1\%$$

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

$$(475/679)\ 100 = 60\ \%$$

If the data were correct, a major discrepancy exists in which a large amount of water was applied, but very little water stored, and the plants used several times the amount of water stored. The question then arises as to what actually happened to all the water that was applied, and from where did the wheat get the water it actually used? The unaccounted applied water amounted to 679 - 91 = 588 mm. At the same time the plant obtained 475 - 91 = 384 mm of water from non-irrigation sources.

Crop	Season	Area	Number of Irrigations	Average Irrigation Frequency	Total depth of water applied	Total depth of water stored	Total depth of water depleted	Average discharge	Average Application Efficiency	Estimated Evapotranspiration
		(m^2)		(days)	(mm)	(mm)	(mm)	(LPS)	(%)	(mm)[a/]
Wheat	Winter	2100	6	15	679	91	74	36.3	14.1	475
Berseem	Winter	2100	10	17	1791	226	198	38.5	14.0	677

Table 9. Average of Different Irrigation Measurements Collected in Farm (01-01-01) (1980-1981).

a/ Estimated E.T. obtained from Water Master Plan Technical Report 17, UNDP-EGY/73/024.

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0-30 (cm) (%)	Water stored 0-90	Water stored Total Depl/ day (mm)
1	7/1/81	0-30	52	74	22	209.7	100	42	34	-	64.7	34	-
	SMB 6/1	30-60	74	82	8								
	SMA 8/1	60-90	79	83	4								
2	12/2/81	0-30	67	75	8	258.9	123	42	8.1	0.20	80.0	10	0.22
	SMB 12/2	30-60	81	83	2					0.02			
	SMA 17/2	60-90	90	90	0								
3	10/3/81	0-30	68	75	7	241.6	115	38	9.6	0.33	63.6	11	0.42
	SMB 10/3	30-60	81	85	4					0.09			
	SMA 12/3	60-90	105	98	-7								
4	26/3/81	0-30	65	74	9	272.4	130	36	7.7	0.71	90.0	10	1.28
	SMB 26/3	30-60	90	88	-2								
	SMA 29/3	60-90	90	91	1					0.71			
5	11/4/81	0-30	63	75	12	189.4	90	32	14.4	0.85	92.3	13	2.15
	SMB 11/4	30-60	72	73	1					1.23			
	SMA 14/4	60-90	90	88	-2					0.07			
6	30/4/81	0-30	64	76	12	252.7	121	28	10.7	0.73	92.3	13	0.73
	SMB 29/4	30-60	73	74	1								
	SMA 2 /5	60-90	92	92	0								

Table 10. Soil Moisture Data Sheet.

Location: At the beginning of El-Hammami Canal
Site Numbers: (01-01-01)
Area: $2100m^2$

Crop: Wheat 1980-81
Season: Winter 1980-81

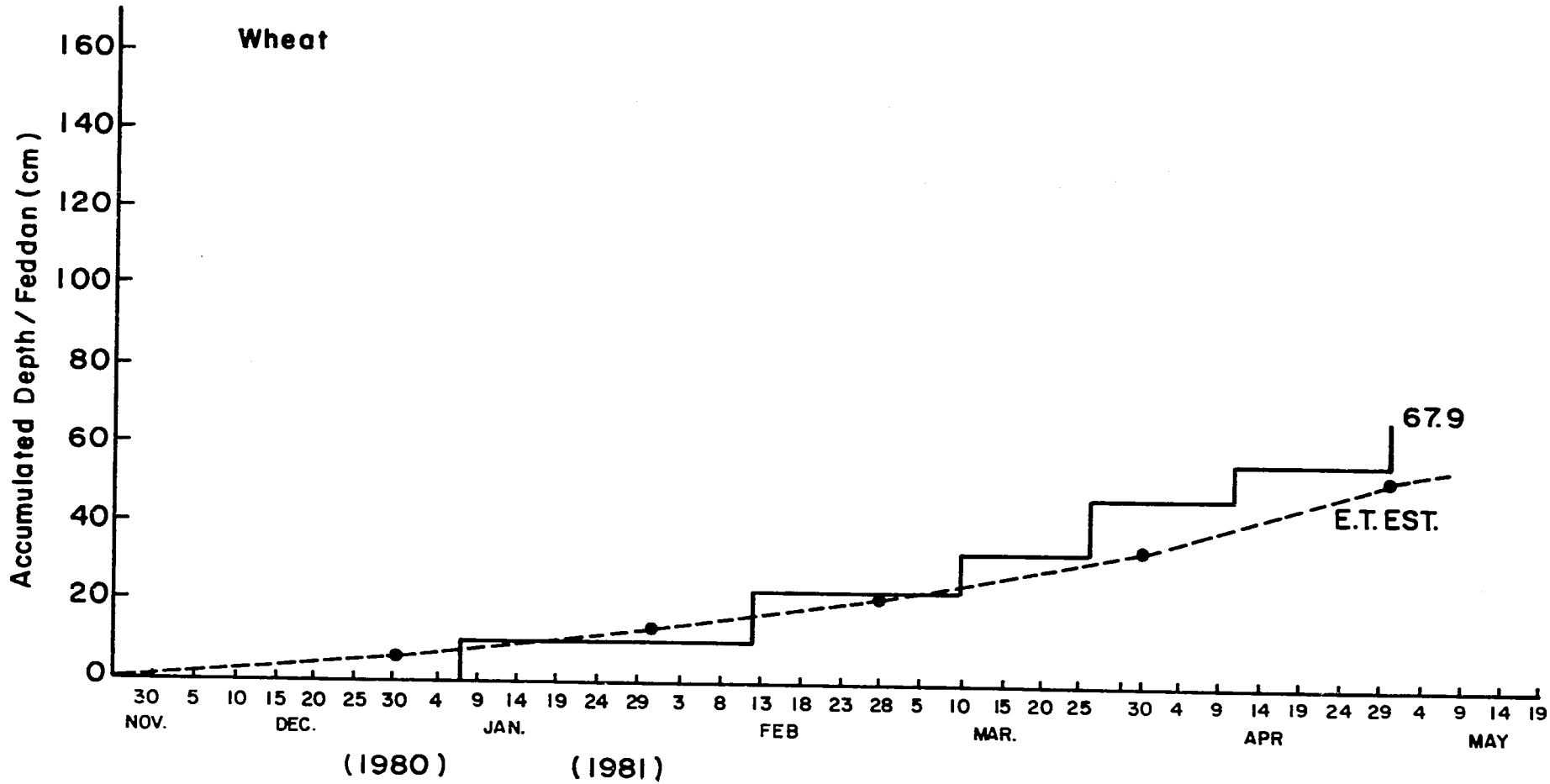

Figure 5. Actual Water Application vs. Estimated Consumptive Use for Wheat Crop.

b) Berseem: Berseem was planted on about 2100 m^2. It was planted in October with the final cut in May. The berseem crop received 10 irrigations between October and May, with an average irrigation frequency of 17 days. The amount of water applied varied from 100 mm to 202 mm per irrigation (Table 11). This made the average depth of irrigation 179 mm and the total depth of irrigation per season 1791 mm. Of the 1741 mm applied, only 226 mm were stored in the 0 to 90 cm depth and only 198 mm were accounted for as depletion. In contrast, the estimated consumptive use for a berseem crop of this duration is 677 mm (Figure 6). Thus the application efficiency based on the water stored is calculated as follows:

$$(198/1791)\ 100 = 14\%$$

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

$$(677/1791)\ 100 = 38\%.$$

2. Farm (01-02-02): This farm is located at the tail end of El-Hammami canal where irrigation water was usually available by the end of the on-period.

The farmer used his *saqia* when water was available in the canal when he wanted to irrigate; if not, he rented a pump taking water from a well. The average water discharge was about 28.; (Table 12) (for both pump and *saqia*). During winter 1980-81, the farmer cultivated his field with berseem and cabbage; and in summer 1981 he cultivated watermellon.

a) Berseem: Berseem was planted on about 2000 m^2. It was planted in November with the final cut in February. The berseem crop received 4 irrigations between November and February, with an average irrigation frequency of 25 days. The amount of water applied varied from 27 mm to 104 mm per irrigation (Table 13). This made the average depth of irrigation 69 mm, and the total depth of irrigation per season 276 mm. Of the 276 mm applied, only 53 mm were stored in the 0 to 90 cm depth and only 56 mm were accounted for as depletion. In contrast, the estimated consumptive use for a berseem crop of this duration is 170 mm (Figure 7).

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/ day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1	14/10/80	0-30	52	75	23	385.1	183.	36	20	-	64.0	36	-
	SMB 14/10	30-60	81	86	5								
	SMA 17/10	60-90	90	98	8								
2	26/10/80	0-30	53	74	21	424.5	202	31	12	2.44	87.5	24	1.76
	SMB 26/10	30-60	82	85	3					0.44			
	SMB 28/10	60-90	90	87	-3					0.88			
3	9/11/80	0-30	54	79	25	396.5	189	31	16.4	1.81	80.6	31	1.99
	SMB 8/11	30-60	83	87	4					0.81			
	SMA 12/11	60-90	91	93									
4	2/12/80	0-30	64	78	14	453.0	216	42	06.5	0.75	100.0	14	0.75
	SMB 2/12	30-60	91	87	-4								
	SMA 4/12	60-90	97	92	-5								
5	7/ 1/81	0-30	60	72	12	209.7	100	38	27	0.52	44.4	27	0.92
	SMB 7/ 1	30-60	79	86	5					0.23			
	SMA 9/ 1	60-90	86	96	10					0.17			
6	13/ 2/81	0-30	71	78	7	425.0	202	50	10.9	0.02	31.8	22	0.42
	SMB 13/ 2	30-60	77	87	10					0.26			
	SMA 16/ 2	60-90	91	96	5					0.14			

Table 11. Soil Moisture Data Sheet.

Location: At the beginning of El Hammami Canal
Site Number: (01-01-01)

Crop: Berseem "Egyptian Clover"
Season: Winter 1980-81

Area: 2100 m^2

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/ day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
7	9/ 3/81	0-30	66	74	8	407.6	194	45	4	0.40	100	8	0.56
	SMB 9/ 3	30-60	83	83	0					0.16			
	SMA 12/ 3	60-90	96	92	-4					0.00			
8	25/ 3/81	0-30	65	73	8	406.6	194	45	5.7	0.69	72.7	11	0.76
	SMB 25/ 3	30-60	82	84	2					0.07			
	SMA 27/ 3	60-90	94	95	1								
9	10/ 4/81	0-30	64	70	6	366.2	174	32	3.4	0.64	100	6	0.64
	SMB 10/4	30-60	89	84	-5								
	SMA 13/ 4	60-90	101	92	-9								
10	1 / 5/81	0-30	44	71	27	287.5	137	35	34.4	1.44	57.4	47	2.46
	SMB 1/ 5	30-60	71	85	14					0.72			
	SMA 4/ 5	60-90	86	92	6					0.33			

Table 11. Soil Moisture Data Sheet (Continued)

Location: At the beginning of El-Hammami Canal
Site Number: (01-01-01)
Area: 2100 m^2

Crop: Berseem "Egyptian Clover"
Season: Winter 1980-81

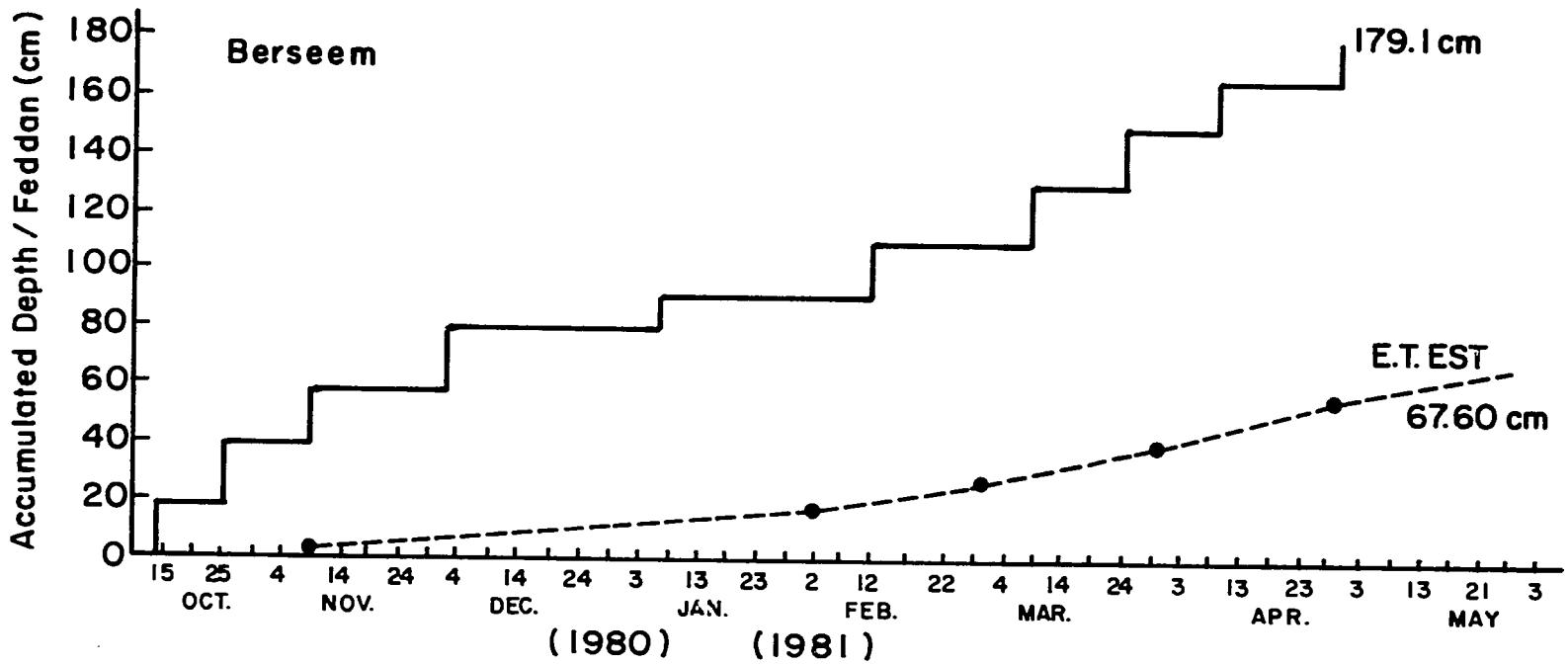

Figure 6. Actual Water Application vs. Estimated Consumptive Use for Berseem Crop.

Crop	Season	Area (m^2)	Number of Irri-gation	Average Irrigation Frequency (days)	Total Depth of water applied (mm)	Total Depth of water stored (mm)	Total Depth of water depleted (mm)	Average Discharge (LPS)	Average Applicat-ion effic-iency (%)	Estimated Evapotrans-piration (mm) %
Berseem	Winter	2002	4	25	276	53	56	34	18.5	170
Cabbage	Winter	2485	6	18	424	141	115	30	36.5	(-)
Water Mellon	Summer	2002	4	30	404	203	162	22	65	(-)

a/ Estimated E.T. from Water Master Plan Technical Report 17, UNDP-EGY/73/042.

b/ Berseem for one cut only (Nov. - Feb.)

Table 12. Averages of Different Irrigation Measurements Collected in Farm (01-02-02) (1980-81)

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1	23/11/80	0-30	66	81	15	164.1	82	30	22	-	83.3	18	-
	SMB 23/11	30-60	90	93	3								
	SMA 25/11	60-90	94	92	-2								
2	2/12/80	0-30	69	76	7	54.0	27	35	13	1.71	100	7	1.71
	SMB 30/11	30-60	94	86	-8								
	SMA 4/12	60-90	102	89	-13								
3	12/11/81	0-30	71	79	8	125.5	63	31	30.2	0.13	42.1	19	0.13
	SMB 12/1	30-60	88	94	6								
	SMA 14/1	60-90	93	98	5								
4	12/2/81	0-30	82	85	3	207.3	104	40	8.7	0.96	33.3	9	1.39
	SMB 11/2	30-60	90	93	3					0.14			
	SMA 14/2	60-90	90	93	3					0.29			

Table 13. Soil Moisture Data Sheet

Location: By the end of El-Hammami Canal
Site Number: (01-02-02)

Area: 2002

Crop: Berseem "Egyptian Clover"
Season: Winter (1980-81)

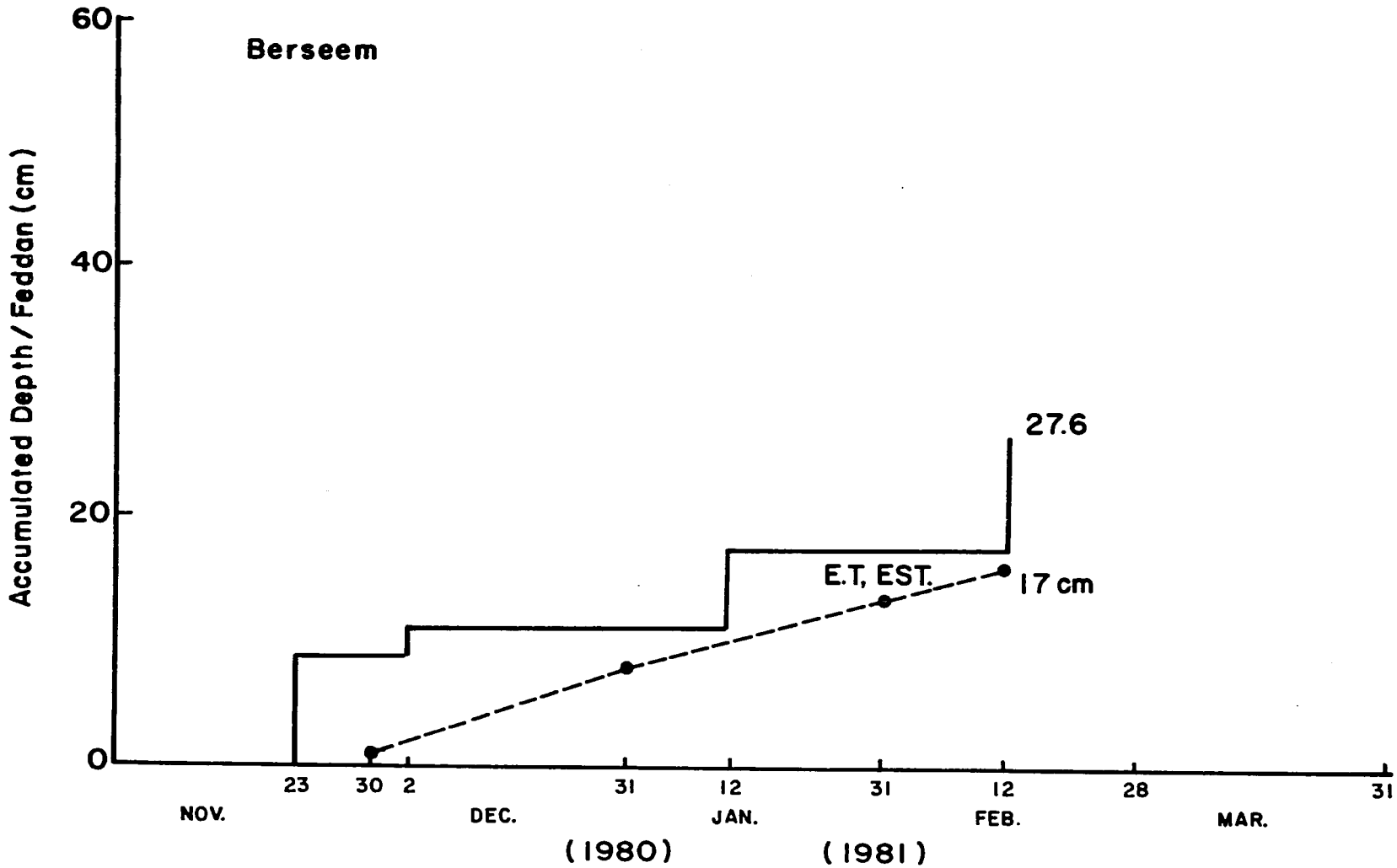

Figure 7. Actual Water Application vs. Estimated Consumptive Use for Berseem Crop.

Thus, the application efficiency based on the water stored is calculated as follows:

(53/276) 100 = 18.5%

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

(170/276) 100 = 62%

b) Cabbage: Cabbage was planted on about 2485 m^2. It was planted in October and collected in March. The cabbage crop received 6 irrigations between October and March, with an average irrigation frequency of 18 days. The amount of water applied varied from 54 mm to 85 mm per irrigation (Table 14). This made the average depth of irrigation about 71 mm, and the total depth of irrigation per season 424 mm. Of the 424 mm applied, only 141 mm were stored in the 0 to 90 cm depth and only 115 mm were accounted for as depletion. The estimated consumptive use for the cabbage crop was not available.

Thus, the application efficiency was calculated based on the water stored only.

(141/424) 100 = 36.5%

c) Watermellon: Watermellon was planted on about 2000 m^2. It was planted in May and stayed until July.

The watermellon crop received irrigations between March and June, with an average irrigation frequency of about 30 days. The amount of water applied varied from 36 mm to 250 mm (pre-planting irrigation) per irrigation (Table 15). This made the average depth of irrigation about 101 mm, and the total depth of irrigation per season 404 mm. Of the 404 mm applied, only 203 mm were stored in the 0 to 90 cm depth and only 162 mm were accounted for as depletion.

The estimated consumptive use for the watermellon crop was not available. Thus, the application efficiency was calculated based on the water stored only.

(203/404) 100 = 65%

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/ day	Water stored 0 30 (cm) (%)	Water stored 0- 0 (cm) (%)	Water stored Total Depl./day (mm)
1	15/10/80	0-30	N.A	N.A	-	N.A	70/e	-	-	-	-	-	-
	SMB N.A	30-60	N.A	N.A	-								
	SMA N.A	60-90	N.A	N.A	-								
2	17/11/80	0-30	69	75	6	133.5	54	16	24.1	-	46	13	-
	SMB 17/11	30-60	81	82	1								
	SMA 19/11	60-90	83	89	6								
3	7/ 1/81	0-30	77	77	0[a/]	170.2	69	28	8.7		0	6	0.06
	SMB 6/ 1	30-60	88	89	1								
	SMA 10/ 1	60-90	86	91	5					0.06			
4	27/ 1/81	0-30	54	65	11	165.8	67	35	22.4	1.15	73.3	15	1.70
	SMB 27/ 1	30-60	84	85	1					0.25			
	SMA 29/ 1	60-90	85	88	3					0.30			
5	11/ 2/81	0-30	57	82	25	211.8	85	35	73	0.53	40.3	62	2.06
	SMB 11/ 2	30-60	71	93	22					0.93			
	SMA 14/ 2	60-90	79	94	15					0.60			
6	4/ 3/81	0-30	66	74	8	205.6	83	36	54	0.76	17.8	45	1.38
	SMB 4/3	30-60	87	92	5					0.29			
	SMA 7/3	60-90	87	119	32					0.33			

a/ The Zero in the upper layer might be because of raining or some sampling error.

Table 14. Soil Moisture Data Sheet

Location: By the end of El-Hammami Canal
Site Number: (01-02-02)

Crop: Cabbage
Season: Winter 1980-81

Area: 2485 m^2

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/ day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1[a/]	28/ 3/81	0-30	54	76	22	495.8	250	18	26.0	-	34	65	-
	SMB 28/ 3	30-60	60	86	26								
	SMA 31/ 3	60-90	74	91	17								
2[b/]	8/ 6/81	0-30	58	61	3	71.5	36	30	66.7	0.27	12.5	24	0.82
	SMB 8/ 6	30-60	65	78	13					0.34			
	SMA 11/ 6	60-90	77	85	8					0.21			
3	15/ 6/81	0-30	58	79	21	158.8	75	20	68.0	0.75	41.2	51	2.25
	SMB 15/ 6	30-60	71	92	21					1.50			
	SMA 17/ 6	60-90	85	94	9					0.00			
4	27/ 6/81	0-30	46	59	13	86.2	43	20	100+	3.30	20.6	63	11.90
	SMB 27/ 6	30-60	50	75	25					4.20			
	SMA 30/ 6	60-90	50	75	25					4.40			

a/ The first irrigation is pre-planting irrigation, where the farmer planted his watermelon seeds about 60 days later.

b/ The planting irrigation was that of 8/6/81.

Table 15. Soil Moisture Data Sheet

Location: By the end of El-Hammami Canal
Site Number: (01-02-02)

Crop: Watermelon
Season: Summer 1980-81

Are: 2002 m^2

3. Farm (01-02-03): This farm is located by the middle of *Mesqa* 2 at the end of El-Hammami canal.

The actual *mesqa* cross-section at the farm location is very narrow and shallow. The *mesqa* is rather guiding the irrigation water than conveying it. There was no actual problem of water shortage during the winter season, while in summer, the availability of irrigation water was a severe problem. In summer, the farmer used a pump for all irrigations. During winter 1980-81, the farmer cultivated broad beans, wheat, berseem, tomato, eggplant and hot pepper; the last two stayed through the summer season. In summer, he cultivated watermellon and maize (Table 16).

a) Broad beans: The broad bean crop was planted on about 1650 m^2. It was planted in late November and harvested at the end of March. The broad bean crop received 7 irrigations between December and March, with an average irrigation frequency of 15 days. The amount of water applied varied from 11 mm to 83 mm per irrigation (Table 17). This made the average depth of irrigation 37 mm, and the total depth of irrigation per season 261 mm. Of the 261 mm applied, only 110 mm were stored in the 0 to 90 cm, and only 150 mm were accounted for as depletion. In contrast, the estimated consumptive use for a broad bean crop is 373 mm (Figure 8). Thus the application efficiency based on the water stored is calculated as follows:

$$(110/261)\ 100 = 55\ \%$$

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

$$(373/260) = 143\ \%.$$

It was found that the farmer applied 112 mm less than the estimated consumptive use (Figure 9).

b) Berseem: The berseem crop was planted on about 2100 m^2. It was planted in November and removed in May. The berseem crop received 12 irrigations between November and May, with an average irrigation frequency of 15 days. The amount of water applied varied between 48 mm and 128 mm

Crop	Season	Area (m^2)	Number of Irrigations	Average Irrigation frequency (days)	Total Depth of water applied (mm)	Total Depth of water stored (mm)	Total Depth of water Depletion (mm)	Average Discharge (LPS)	Average Application Efficiency (%)	Estimated a/ Evapotranspiration (mm)
Broad Beans	Winter	1669	7	15	261	110	150	16	55	373
Wheat	Winter	3780	9	17	278	128	155	19	57	475
Berseem	Winter	2100	12	15	894	282	261	19	33	677
Tomato	Winter	2580	5	21	177	75	74	19.5	58	-
Egg plant	Winter Summer	1408	6	30	270	131	114	15	58	-
Hot Pepper	Winter Summer	1655	13	14	540	263	386	31	55	-
Water Mellon	Summer	1204	5	26	352	116	212	14.4	34	-
Maize	Summer	2100	7	14	308	115	156	21	35	622

Table 16. Averages of Different Irrigation Measurements Collected in Farm (01-02-03) (1980-81).

a/ Estimated ET obtained from Water Master Plan Technical Report 17, UNDP-EGY/73/024.

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/ day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1	6/12/80	0-30	63	68	5	40.3	24	14	37.5	-	55.6	9	-
	SMB 6/12	30-60	83	86	3								
	SMA 8/12	60-90	91	92	1								
2	4/ 1/81	0-30	67	77	10	88.9	53	33	28.3	0.03	66.7	15	0.20
	SMB 4/ 1	30-60	81	86	5					0.17			
	SMA 7/ 1	60-90	110	106	- 4								
3	21/ 1/81	0-30	65	76	11	23.9	14	8	100+	0.70	52.4	21	1.64
	SMB 20/ 1	30-60	85	91	6					0.06			
	SMA 24/ 1	60-90	91	95	4					0.88			
4	7/ 2/81	0-30	65	76	11	17.3	11	3	100.0+	0.69	39.3	28	1.45
	SMB 7/ 2	30-60	81	88	7					0.63			
	SMA 9/ 2	60-90	93	103	10					0.13			
5	22/ 2/81	0-30	63	67	4	137.9	83	20	25.3	1.00	19.1	21	3.15
	SMB 22/ 2	30-60	81	85	4					0.53			
	SMA 24/ 2	60-90	82	95	13					1.62			
6	10/ 3/81	0-30	69	78	9	63 e	38 e	17 e	42.1		56.3	16	0.23
	SMB 9/ 3	30-60	82	85	3					0.23			
	SMA 12/ 3	60-90	99	103	4								
7	16/ 3/81	0-30	N.A	69	-	63	38	17	-	-	-	-	-
	SMB N. A	30-60	N.A	118	-								
	SMA 18/3	60-90	N.A	102	-								

Table 17. Soil Moisture Data Sheet

Location: By the middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Broad Beans
Season: Winter 1980-81

Area: $1669m^2$

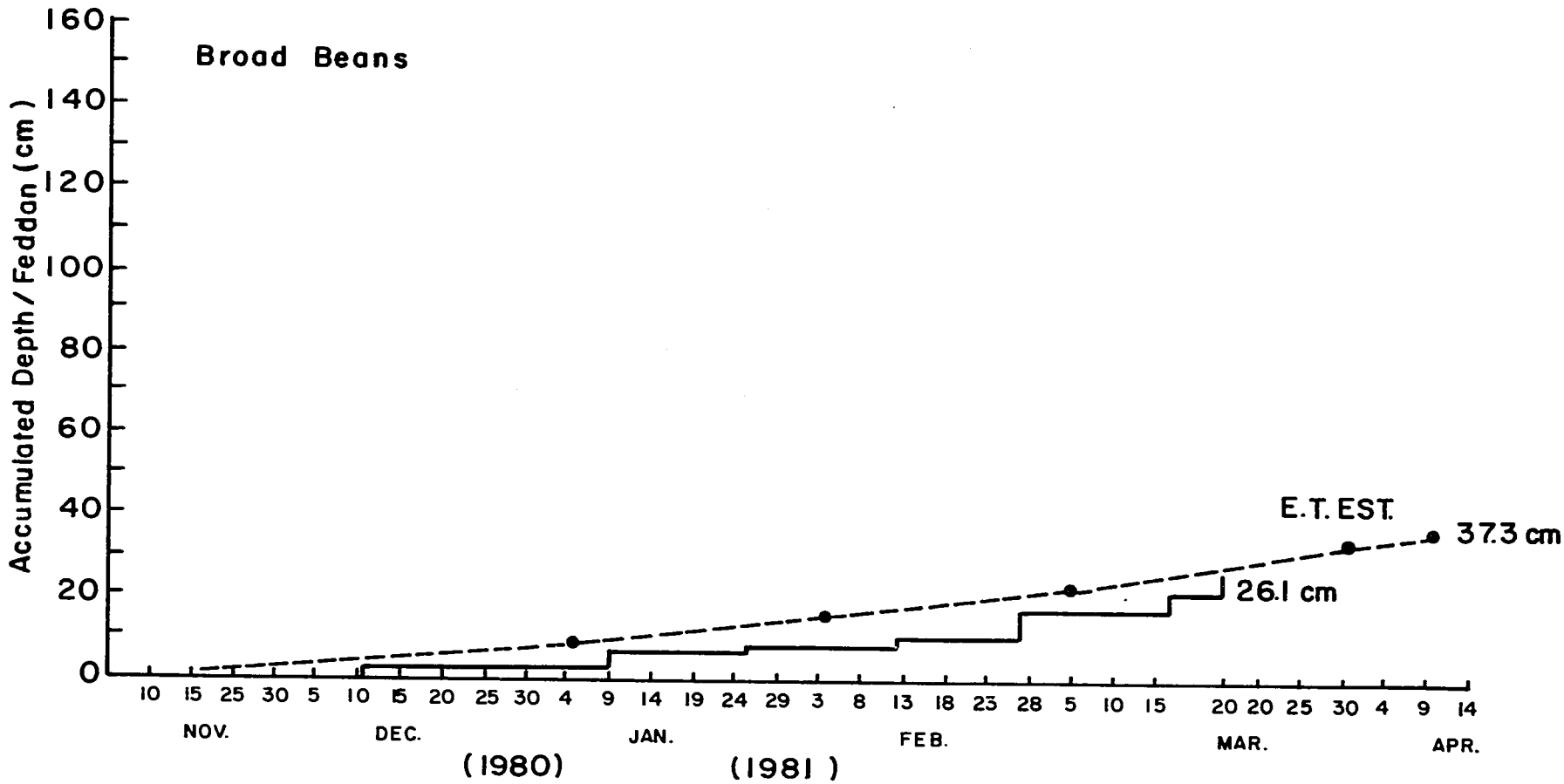

Figure 8. Actual Water Application vs. Estimated Consumptive Use for Broad Bean Crop.

per irrigation (Table 18). This made the average depth of irrigation 23 mm and the total depth of irrigation per season 884 mm. Of the 884 mm applied, only 282 mm were stored in the 0 to 90 cm, and only 261 mm were accounted for as depletion. In contrast, the estimated consumptive use for a berseem crop is 677 mm (Figure 9). Thus the application efficiency based on the water stored is calculated as follows:

$$(282/894)\ 100 = 33\%$$

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

$$(677/844)\ 100 = 71\%$$

c) Wheat: The wheat was planted on about 3750 m^2. It was planted in late November and harvested in May. The wheat crop received 9 irrigations between December and April, with an average irrigation frequency of 17 days. The amount of water applied varied between 12 and 47 mm per irrigation (Table 19). This made the average depth of irrigation 30 mm and the total depth of irrigation per season 278 mm. Of the 278 mm applied, only 128 mm were stored in the 0 to 90 cm, and 155 mm were accounted for as depletion. In contrast, the estimated consumptive use for a wheat crop is 475 mm (Figure 10). Thus, the application efficiency based on the water stored is calculated as follows:

$$(128/278)\ 100 = 57\%$$

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

$$(475/278)\ 100 = 170\%$$

d) Tomato: The tomato was planted on about 2500 m^2. It was planted on the beginning of November and stayed till mid February. The tomato crop received 5 irrigations between November and February, with an average irrigation frequency of 21 days. The amount of water applied varied from 14 mm to 50 mm per irrigation (Table 20).

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1	25/11/80	0-30	53	76	23	78.5	75	20	46.7	-	65.7	35	
	SMB 24/11	30-60	83	87	4								
	SMA 27/11	60-90	91	99	8								
2	26/11/80	0-30	53	75	22	90.6	86	15	27.9	-	91.6	24	
	SMB 24/11	30-60	83	85	2								
	SMA 29/11	60-90	91	88	- 3								
3	14/12/80	0-30	64	78	14	168.4	80	30	17.5	0.73	100	14	0.73
	SMB 14/12	30-60	91	87	- 4								
	SMA 16/12	60-90	97	93	- 4								
4	3/ 1/81	0-30	60	77	17	201.4	96	25	17.7	1.06	100	17	1.06
	SMB 2/ 1	30-60	91	77	-14								
	SMA 5/ 1	60-90	98	91	- 3								
5	21/ 1/81	0-30	61	72	11	122.2	58	17	50	1.07	37.9	29	1.40
	SMB 20/ 1	30-60	79	86	7								
	SMA 24/ 1	60-90	86	97	11					0.33			
6	5/ 2/81	0-30	71	79	8	116.1	55	10	38.2	0.07	38.1	21	1.93
	SMB 5/ 2	30-60	78	86	8					0.53			
	SMA 7/ 2	60-90	92	97	5					0.33			
7	22/ 2/81	0-30	60	75	15	269.8	128	13	12.5	1.12	93.8	16	1.12
	SMB 22/ 2	30-60	81	82	1								
	SMA 24/ 2	60-90	95	88	- 8								

Table 18. Soil Mositure Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Berseem
Season: Winter (1980-81)

Area: 2100 m^2

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture .to (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0.30 (cm) (%)	Water stored 0-.0 (cm) (%)	Water stored Total Depl./day (mm)
8	16/ 3/81	0-30	66	74	8	116	55	10	16.4	0.45	88.9	9	0.45
	SMB 16/ 3	30-60	83	84	1								
	SMA 21/ 3	60-90	96	92	- 4								
9	1/ 4/81	0-30	64	80	16	162.8	78	26	20.5	0.67	100	16	0.67
	SMB 1/ 4	30-60	89	85	- 4								
	SMA 5/ 4	60-90	101	98	- 3								
10	12/ 4/81	0-30	64	70	6	101.8	48	14	12.5	2.29	100	6	3.43
	SMB 12/ 4	30-60	90	84	- 6								
	SMA 15/ 4	60-90	90	90	0					1.14			
11	26/ 4/81	0-30	49	73	24	161	77	20	68.8	1.50	45.3	53	2.43
	SMB 26/ 4	30-60	78	90	12					0.43			
	SMA 29/ 4	60-90	83	100	17					0.50			
12	6/ 5/81	0-30	44	70	26	122	58	17	72.4	4.83	61.9	42	9.83
	SMB 5/ 5	30-60	73	86	13					2.83			
	SMA 7/ 5	60-90	87	90	3					2.17			

Table 18. Soil Moisture Data Sheet (Continued)

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Berseem
Season: Winter 1980-81

Area: 2100m^2

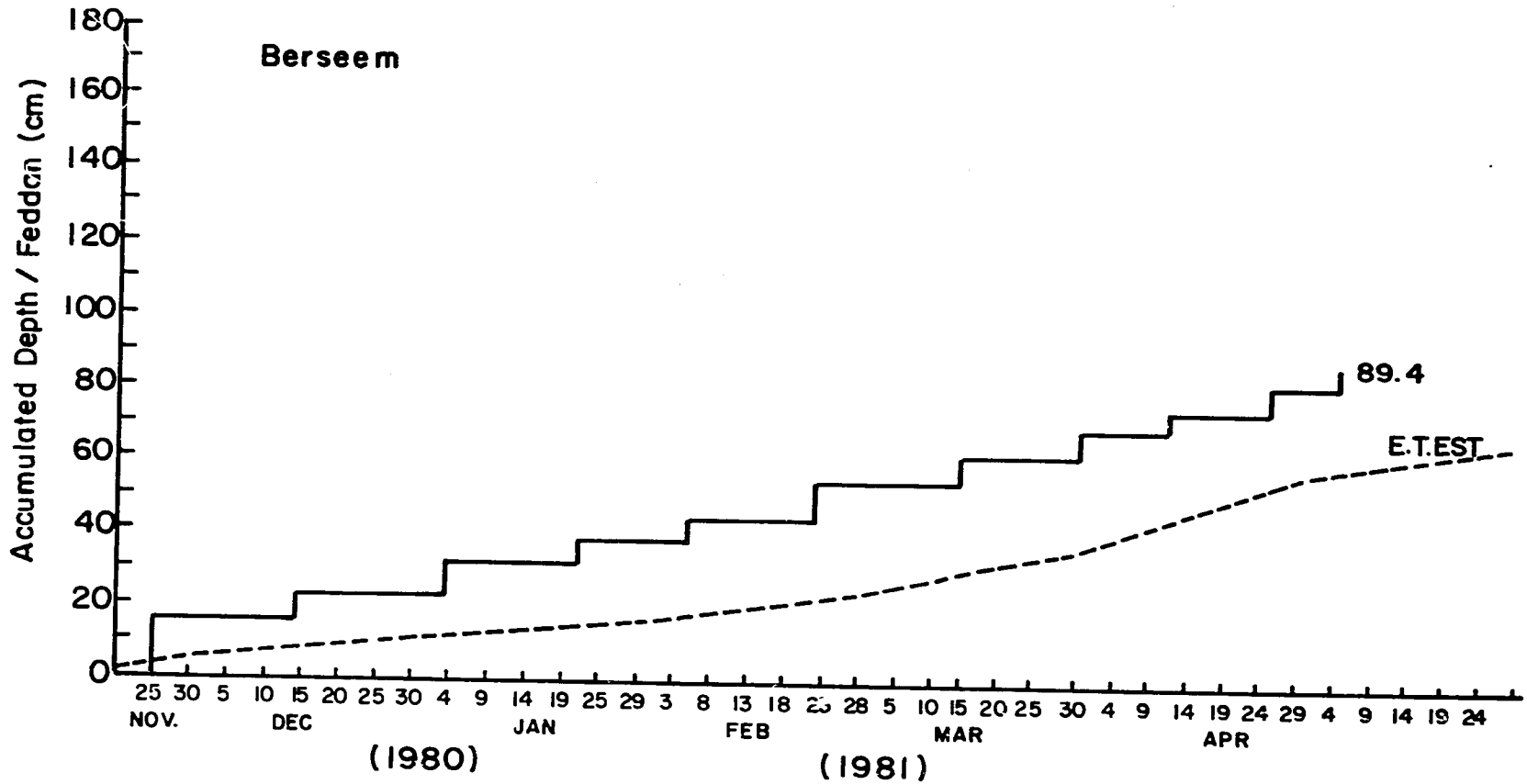

Figure 9. Actual Water Application vs. Estimated Consumptive Use for Berseem Crop.

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0-30 (cm) (%)	Water stored 0-90 (cm) (%)	Water stored Total Depl./day (mm)
1	6/12/80	0-30	63	68	5	80	20	14	45	-	55 ≤	9	-
	SMB 6/12	30-60	83	86	3								
	SMA 8/12	60-90	91	92	1								
2	4/ 1/81	0-30	67	77	10	177	47	33	32	0.03	66.7	15	0.20
	SMB 4/ 1	30-60	81	86	5					0.17			
	SMA 7/ 1	60-90	110	106	- 4								
3	21/ 1/81	0-30	65	76	11	47	12	8	100+	0.70	52.4	21	1.64
	SMB 20/ 1	30-60	85	91	6					0.06			
	SMA 24/1	60-90	91	95	4					0.88			
4	4/ 2/81	0-30	60	71	11	145	38	23	34	1.14	84.6	13	1.93
	SMB 3/ 2	30-60	80	82	2					0.79			
	SMA 7/ 2	60-90	105	92	-13								
5	23/2/81	0-30	56	69	13	161.3	43	19	44	1.00	68.4	19	1.47
	SMB 22/2	30-60	75	81	6					0.47			
	SMA 25/2	60-90	108	93	-15								
6	9/ 3/81	0-30	64	78	14	98.4	26	15	73.1	0.46	73.7	19	1.01
	SMB 8/ 3	30-60	82	84	2								
	SMA 11/ 3	60-90	87	90	3					0.55			

Table 19. Soil Mositure Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Wheat
Season: Winter 1980-81

Area: 3780m^2

Irr. No.	Sampling date	Depth (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water applied Volume (m^3)	Water applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)/day	Water stored 0.30 (cm) (%)	Water stored 0-0 (cm) (%)	Water stored Total Depl./day (mm)
7	16/ 3/81	0-30	N.A	66	N.A	150	39	15	N.A	N.A	N.A	N.A	N.A
	SMB N.A	30-60	N.A	82	N.A								
	SMA 21/ 3	60-90	N.A	108	N.A								
8	31/ 3/81	0-30	69	73	4	86.2	23	23	100+		15.4	26	1. 9
	SMB 31/ 3	30-60	81	85	4					0.10			
	SMA 2/ 4	60-90	90	108	18					1.80			
9	13/ 4/81	0-30	64	70	6	114.6	30	22	20	0.64	100	6	1.93
	SMB 12/ 4	30-60	90	84	- 6								
	SMA 15/ 4	60-90	90	90	0					1.29			

Table 19 Soil Moisture Sheet (Continued)

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Wheat
Season: Winter 1980-81

Area: 3780m^2

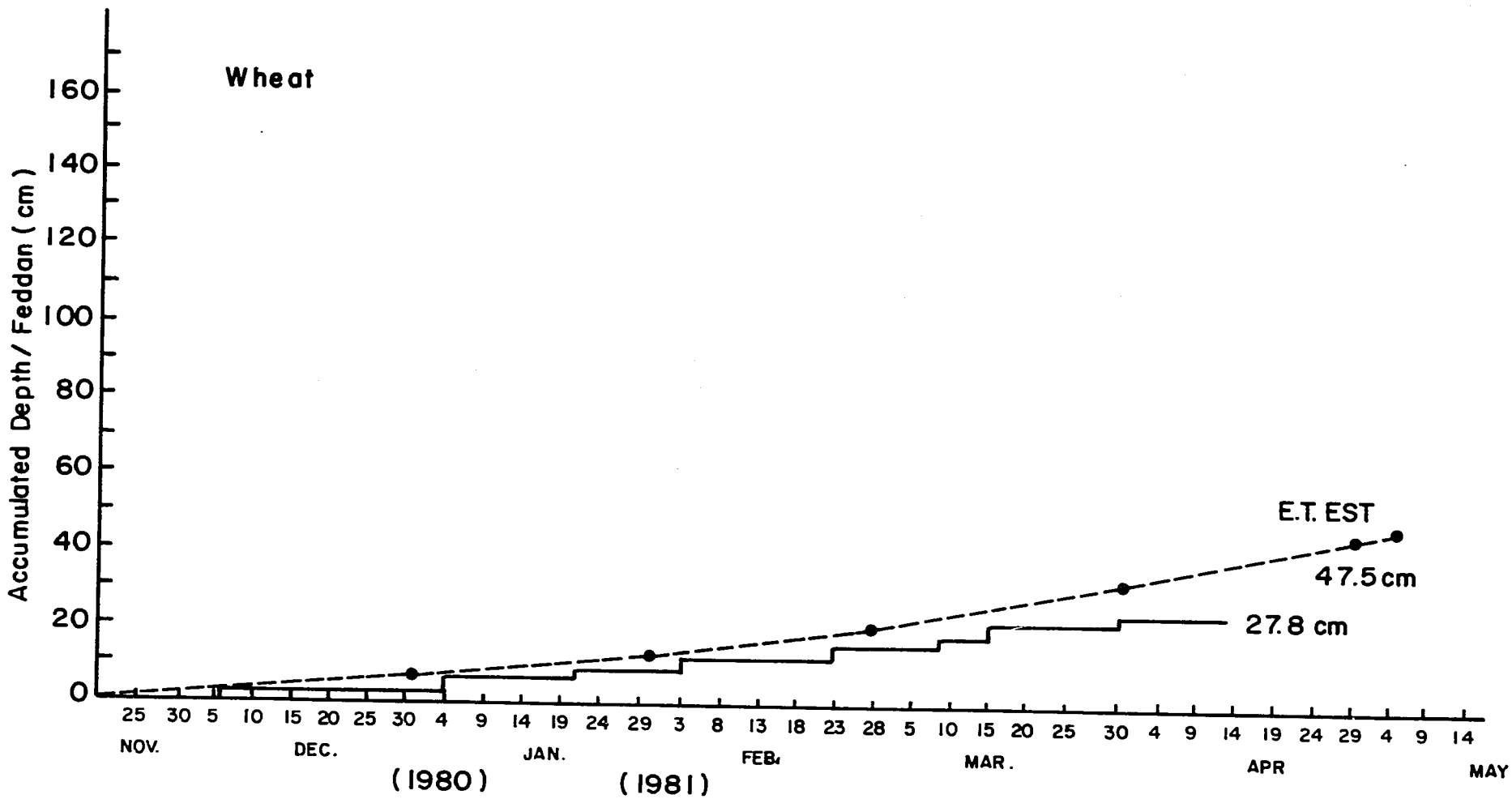

Figure 10. Actual Water Application vs. Estimated Consumptive Use for Wheat Crop.

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	(mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/ day)
1	12/11/80 SMB N.A. SMB N.A.	0-30 30-60 60-90	N.A.	N.A.	N.A.	217.5 e	41 e	23 e	---	---	---	N.A.	---
2	6/12/80 SMB 6/12 SMA 8/12	0-30 30-60 60-90	63 83 91	68 86 92	5 3 1	166	31	14	29	N.A.	55.6	9	N.A.
3	4/1/81 SMB 4/1 SMA 7/1	0-30 30-60 60-90	67 81 110	77 86 106	10 5 -4	267	50	33	30	0.03 0.17	66.7	15	0.20
4	21/1/81 SMB 20/1 SMA 24/1	0-30 30-60 60-90	65 85 91	76 91 95	11 6 4	71.6	14	8	100+	0.70 0.60 0.88	52.4	21	1.6
5	4/2/81 SMB 3/2 SMA 7/2	0-30 30-60 60-90	60 77 91	73 85 100	13 8 9	217.5	41	23	73.2	1.60 1.40 0.40	43.3	30	3.4

Table 20. Soil Moisture Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Tomato
Season: Winter 1980-81

Area: 2580 m^2

This made the average depth of irrigation 35 mm, and the total depth of irrigation per season 177 mm. Of the 177 mm applied, only 75 mm were stored in the 0 to 90 cm, and only 74 mm were accounted for as depletion. As the estimated consumptive use for a tomato crop is not available, the application efficiency is calculated based on the water stored. The efficiency is:

(75/177) 100 = 58%

e) Hot Pepper: The hot pepper was planted on about 1600 m^2. It was planted on the first week of December 1980 and stayed in the land until the beginning of August 81. The crop received 13 irrigations between December and July 81, with an average irrigation frequency of 14 days. The amount of water applied varied from 23 mm to 67 mm per irrigation (Table 21). This made the average depth of irrigation 41 mm, and the total depth of irrigation per season 540 mm. Of the 540 mm applied, only 263 mm were stored in the 0 to 90 cm, and only 386 mm were accounted for as depletion. As the estimated consumptive use for the hot pepper is not available, the application efficiency is calculated based on the water stored only. The efficiency is:

(203/540) 100 = 55%

Eggplant: The eggplant was grown on about 1400 m^2. It was planted in December and harvested in May 81. The eggplant received 6 irrigations between December and May, with an average irrigation frequency of 30 days. The amount of water applied varied from 32 mm to 87 mm per irrigation (Table 22). This made the average depth of irrigation 45 mm, and the total depth of irrigation per season was 270 mm. Of the 270 mm applied, only 131 mm were stored in the 0 to 90 cm, and only 114 mm were accounted for as depletion. As the estimated consumptive use for an eggplant crop is not available, the application efficiency is calculated as follows:

(131/270) 100 = 58%

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	(mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/day)
1	6/12/80	0 - 30	63	68	5	43.6	26	22	34.6	---	55.6	9	---
	SMB 6/12	30 - 60	83	86	3								
	SMA 8/12	60 - 90	91	92	1								
2	21/01/81	0 - 30	65	76	11	48.3	29	22	72.4	0.07	52.4	21	0.11
	SMB20/1	30 - 60	85	91	6					0.02			
	SMA24/1	60 - 90	91	95	4					0.02			
3	09/03/81	0 - 30	59	71	12	70.7	43	38	74.4	0.39	37.5	32	1.03
	SMB 8/3	30 - 60	74	83	9					0.39			
	SMA11/3	60 - 90	84	95	11					0.25			
4	12/04/81	0 - 30	64	70	6	37.7	23	17	26.1	0.21	100	6	0.33
	SMB12/4	30 - 60	90	84	-6								
	SMA15/4	60 - 90	90	90	0					0.12			
5	26/04/81	0 - 30	49	73	24	73.6	45	38	100 +	1.50	45.3	53	2.43
	SMA26/4	30 - 60	78	90	12					0.43			
	SMA29/4	60 - 90	83	100	17					0.50			
6	06/05/81	0 - 30	44	70	26	59.9	36	38	100 +	2.90	62	42	5.90
	SMB 5/5	30 - 60	73	86	13					1.70			
	SMA 9/5	60 - 90	87	90	3					1.30			

Table 21. Soil Moisture Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-02)
Area: 1655 m^2

Crop: Hot Pepper
Season: Along the Season 1980-81

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	(mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/day)
7	18/05/81 SMB SMA	0 - 30 30 - 60 60 - 90	n.a.	n.a.	n.a.	73.6	45	38	100^+ e		45 e		
8	01/06/81 SMB 1/6 SMA 4/6	0 - 30 30 - 60 60 - 90	63 74 78	69 97 101	6 23 23	110.4	67	38	77.6	n.a.	11.5	52	n.a.
9	11/06/81 SMB 11/6 SMA 13/6	0 - 30 30 - 60 60 - 90	61 75 81	72 82 82	11 7 1	62.5	38	38	50	0.80 2.20 2.00	58	19	5.00
10	26/06/81 SMB 25/6 SMA 28/6	0 - 30 30 - 60 60 - 90	60 67 102	67 76 80	7 9 -22	73.6	45	38	35.6	0.80 1.00	43.8	16	1.80
11	05/07/81 SMB 4/7 SMA 7/7	0 - 30 30 - 60 60 - 90	35 51 63	41 51 63	6	62.4	38	38	16	3.56 2.78 1.89	100	6	8.23
12	17/07/81 SMB 17/7 SMA	0 - 30 30 - 60 60 - 90	n.a.	n.a.	n.a.	62	38	38	16 e				8.2

Table 21 Soil Moisture Data Sheet (Continued)

Location: By the middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Are: 1655 m^2

Crop: Hot Pepper
Season: Along the Season 1980-81

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	(mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/day)
13	28/07/81	0 - 30	51	57	6	110.4	67	38	10.5	n.a.	85.7	7	n.a.
	SMB 28/7	30 - 60	71	72	1								
	SMA 28/7	60 - 90	77	76	-1								
		0 - 30											
	SMB	30 - 60											
	SMA	60 - 90											
		0 - 30											
	SMB	30 - 60											
	SMA	60 - 90											
		0 - 30											
	SMB	30 - 60											
	SMA	60 - 90											
		0 - 30											
	SMB	30 - 60											
	SMA	60 - 90											
		0 - 30											
	SMB	30 - 60											
	SMA	60 - 90											

Table 21 Soil Moisture Data Sheet (continued)

Location: By the middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Area: 1655m ^{2}

Crop: Hot Pepper
Season: Along the Season 1980-81

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture Before (mm)	Soil Moisture After (mm)	Soil Moisture Δ (mm)	Water Applied Volume (m^3)	Water Applied Depth (mm)	Q (LPS)	E (%)	Depl. (mm)	Water Stored 0-30 (cm) (%)	Water Stored 0-40 (cm) (%)	Water Stored Depl. (mm/day)
1	14/12/80	0-30	61	78	17	122.1	87	26	48.3	—	40.5	42	--
	SMB 13/12	30-60	81	90	9								
	SMA 16/12	30-90	83	99	16								
2	24/2/81	0-30	60	76	16	47.7	34	10	85.3	0.23	55.2	29	0.42
	SMB 22/2	30-60	81	90	9					0.13			
	SMA 26/2	60-90	95	99	4					0.06			
3	23/3/81	0-30	83	84	1	66.1	47	14	2.1		100	1	
	SMB 22/3	30-60	94	85	-9								
	SMA 26/3	60-90	117	92	-25								
4	12/4/81	0-30	64	70	6	53.7	38	14	15.8	1.00	100	6	1.10
	SMB 12/4	30-60	90	84	-6								
	SMA 15/4	60-90	90	90	0					0.10			
5	26/4/81	0-30	49	73	24	44.2	32	14	100^+	1.50	45.3	53	2.43
	SMB 26/4	30-60	78	90	12					0.43			
	SMA 29/4	60-90	83	100	17					0.50			
6	18/5/81	0-30	N.A.	N.A.	N.A.	44	32	14	100^+				2.43
	SMB N.A	30-60							e				e
	SMA N.A	60-90											

Table 22. Soil Moisture Data Sheet.

Location: By the middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Area: 1408 m^2

Crop: Egg Plant
Season: Along the Season 1980-81

g) Watermellon: The watermellon was planted on about 1200 m^2. It was planted in April and stayed until July. It received 5 irrigations between April and July, with an average irrigation frequency of 26 days. The amount of water applied varied from 42 mm to 123 mm per irrigation (Table 23). This made the average depth of irrigation 70 mm, and the total depth of irrigation per season 352 mm. Of the 352 mm applied, only 166 mm were stored in the 0 to 90 cm, and only 212 mm were accounted for as depletion. As the estimated consumptive use is not available, the application efficiency is calculated based on the water stored, as follows:

(116/352) 100 = 34%

h) Maize: The maize crop was planted on about 2100 m^2. It was planted in late May and harvested in late August. The maize crop received 7 irrigations between June and August, with an average irrigation frequency of 14 days. The amount of water applied varied from 28 mm to 79 mm per irrigation (Table 24). This made the average depth of irrigation 44 mm, and the total depth of irrigation per season 308 mm. Of the 308 mm applied, only 115 mm were stored in the 0 to 90 cm depth and only 212 mm were accounted for as depletion. In contrast, the estimated consumptive use for maize is 622 mm. Thus the application efficiency based on the water stored is calculated as follows:

(115/308) 100 = 35%

However, when the water applied is expressed as a percent of estimated consumptive use, the result is:

(622/308) 100 = 202%

It was found that the farmers applied 314 mm less than the estimated consumptive use (Figure 11).

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	Δ (mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/day)
1	13/4/81	0-30	55	74	19	50.2	42	13	54.8	---	82.6	23	---
	SMB 12/4	30-60	83	83	0								
	SMA 13/4	60-90	87	91	4								
2	2/6/81	0-30	63	69	6	148.5	123	19	42.3	0.22	11.5	52	0.62
	SMB 1/6	30-60	74	97	23					0.22			
	SMA 4/6	60-90	78	101	23					0.18			
3	11/6/81	0-30	61	72	11	59.9	50	18	38	0.89	57.9	19	5.55
	SMB 11/6	30-60	75	82	7					2.44			
	SMA 13/6	60-90	81	82	1					2.22			
4	26/6/81	0-30	60	67	7	63.5	53	17	30.2	0.73	43.8	16	1.73
	SMB 25/6	30-60	67	76	9					0			
	SMA 28/6	60-90	102	86	-16								
5	5/7/81	0-30	36	41	5	101.5	84	30	7.2	3.1	83.3	6	6.9
	SMB 4/7	30-60	51	51	0					2.1			
	SMA 7/7	60-90	63	64	1					1.7			

Table 23. Soil Moisture Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Watermelon
Season: Summer 1980-81

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	(mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/ day)
1	1/6/81	0-30	71	84	13	132.7	63	20	27	-	76.5	17	-
	SMB 1/6	30-60	83	85	2								
	SMA 4/6	60-90	90	92	2								
2	11/6/81	0-30	61	72	11	67.5	32	14	59	3.3	57.9	19	6.3
	SMB11/6	30-60	75	82	7					1.4			
	SMA 13/6	60-90	81	82	1					1.6			
3	25/6/81	0-30	60	67	7	74.8	36	15	44	1.1	43.8	16	2.4
	SMB 25/6	30-60	67	76	9					1.3			
	SMA 28/6	60-90	102	80	-22								
4	5/7/81	0-30	36	41	5	58.2	28	21	21.5	3.5	83.3	6	8.2
	SMB 4/7	30-60	51	51	0					2.8			
	SMA 7/7	60-90	63	64	1					1.9			
5	17/7/81	0-30	51	[illegible]	6	72.7	35	25	20		85.7	7	
	SMB 16/7	30-60	71	72	1								
	SMA 19/7	60-90	77	71	-6								
6	28/7/81	0-30	51	55	4	72.7	35	25	17	0.5	66.7	6	0.7
	SMB 28/7	30-60	70	72	2					0.2			
	SMA 29/7	60-90	77	76	-1								

Table 24. Soil Moisture Data Sheet

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crops: Maize
Season: Summer 1980-81

Area: 2100 m^2

Irri. No.	Sampling date	Depth of Sampling (cm)	Soil Moisture			Water Applied		Q	E	Depl.	Water Stored		
			Before (mm)	After (mm)	Δ (mm)	Volume (m^3)	Depth (mm)	(LPS)	(%)	(mm)	0-30 (cm) (%)	0-40 (cm) (%)	Depl. (mm/ day)
7	5/8/81	0-30	53	66	13	165.8	79	30	55.7	0.3	29.6	44	0.6
	SMB 5/8	30-60	70	80	10					0.3			
	SMA 7/8	60-90	79	100	21								
	SMB	0-30											
	SMA	30-60											
		60-90											
	SMB	0-30											
	SMA	30-60											
		60-90											
	SMB	0-30											
	SMA	30-60											
		60-90											
	SMB	0-30											
	SMA	30-60											
		60-90											
	SMB	0-30											
	SMA	30-60											
		60-90											

Table 24. Soil Moisture Data Sheet (continued

Location: By the Middle of Mesqa 2 at the End of the Canal
Site Number: (01-02-03)

Crop: Maize
Season: Summer 1980-81

Area: 2100 m^2

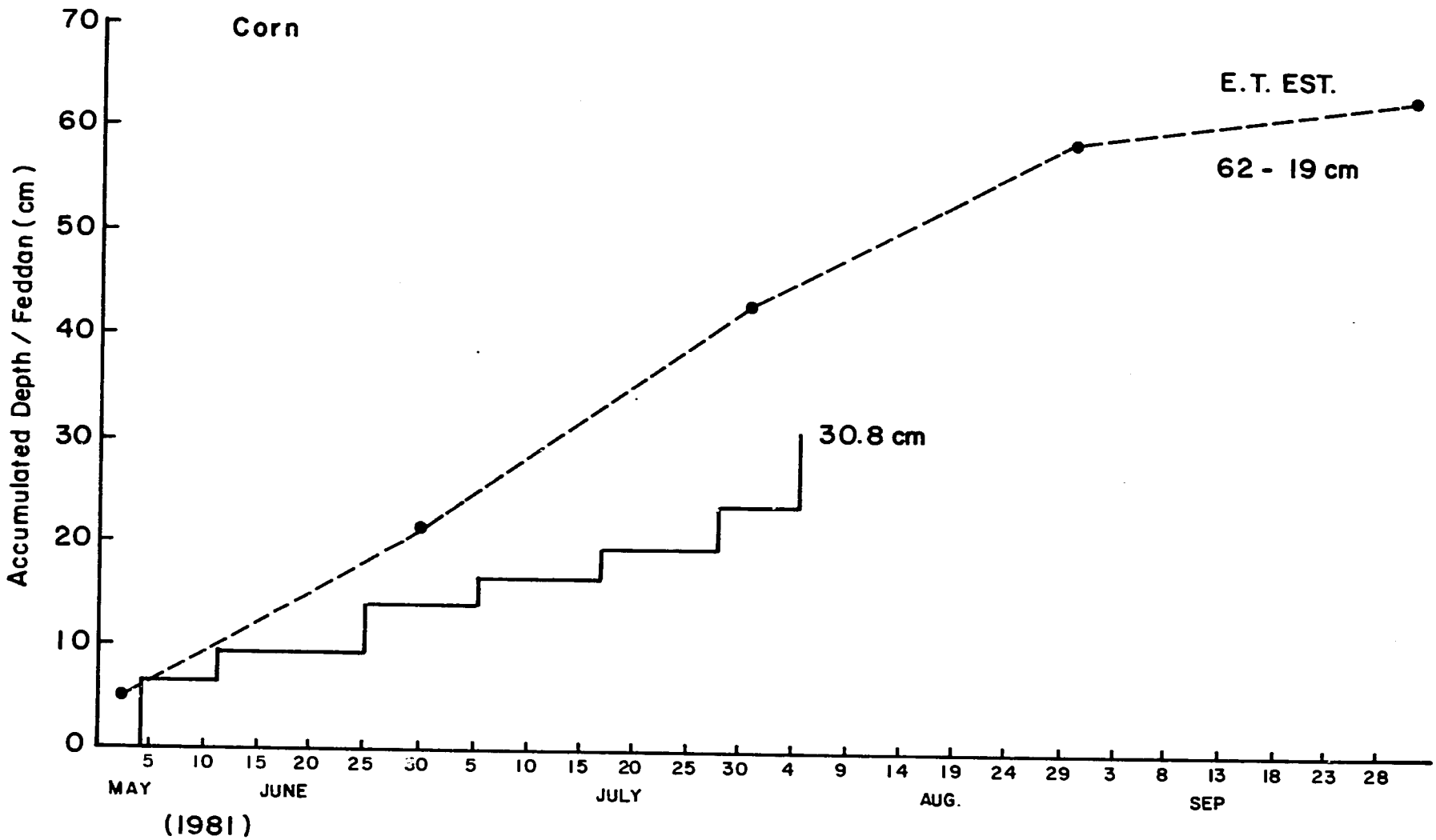

Figure 11. Actual Water Application vs. Estimated Consumptive Use for Corn Crop.

V. DISCUSSION

A. Evaluation of Farmers' Irrigation Practices

The description of farmers' irrigation practices presented in the previous section indicated that:

1. The farm location influenced the amount of water applied by the farmers in a way that the farmers at the tail end of the canal applied less water than those at the beginning of the canal. In farm (01-01-01), the average depth of water applied for wheat was about 113 mm per irrigation, while in farm (01-02-03), the average was 37 mm per irrigation. The berseem crop received an average of 179 mm per irrigation in farm (01-01-01) and 75 mm only per irrigation in farm (01-02-03) (Table 25).

2. Locations applying less water had the highest application efficiency (Table 26). The average application efficiency for wheat crop was about 14% in farm (01-01-01) and about 57% in farm (01-02-03). For *berseem* crop, the average application efficiency was 14% in farm (01-01-01) and 33% in farm (01-02-03).

3. Farmers at the end of the canal sometimes applied less water than the estimated consumptive use (Table 27).

   In farm (01-02-03), the farmer applied 261 mm for the broad beans while the estimated consumptive use was 373 mm per season. Also for wheat, the farmer applied only 278 mm and the estimated consumptive use was 475 mm per season, but in farm (01-01-01), the farmer applied about 200 mm more than the estimated consumptive use. For maize, the farmer in (01-02-03) applied 308 mm while the estimated consumptive use was 622 mm per season.

Table 25. The Influence of Farm Location on the Amount of Water Discharged (1980-1981).

Site	Crop	Season	Average Depth Applied Per Irrigation (mm)	Number Of Irrigation	Average Discharge (lps)	Location By The Canal
01-01-01	Wheat Berseem	Winter Winter	113 179	6 10	36.3 38.5	By the beginning of the canal.
01-02-02	Berseem Cabbage Watermellon	Winter Winter Summer	69 71 101	4 6 4	34 30 22	By the end of the canal at the beginning of *Mesqa* 2.
01-02-03	Broad beans Wheat Berseem Tomato Eggplant Hot pepper Watermellon Maize	Winter Winter Winter Winter Wint.&Sum. Wint.&Sum. Summer Summer	37 31 75 35 45 41 70 44	7 9 12 5 6 13 5 7	16 19 19 19.5 15 31 19.4 21	By the end of the *Mesqa*.

Table 26. The Influence of Farm Location on the Application Efficiency (1980-1981).

Crop	Farm Location	Total Depth of Water Applied (mm)	Total Depth of Water Stored (mm)	Total Depth of Water Depleted (mm)	Estimated[a/] Evapotranspiration (mm)	Average Application Efficiency %
Wheat	By the beginning of the canal.	679	91	74	475	14.1
Berseem		1791	226	198	677	14.0
Berseem	By the end of of the canal by the beginning of the *mesqa*.	276	53	56	170[b/]	18.5
Broad beans	By the end of the canal at the middle of the *mesqa*.	261	110	150	373	55
Wheat		278	128	155	475	57
Berseem		894	282	261	677	33
Maize		308	115	156	622	35

a/ Estimated E.T. from Water Master Plan T.R. 17, UNDP-EGY/73/042.
b/ Berseem for one cut only (November - February).

B. Farmers' Design Criteria

In order to have surface irrigation system design on El-Hammami sands, we need first to answer the following question: What basin size can be irrigated given infiltration characteristics and available flow rates at El-Hammami?

The data indicated that the available flow rate ranges between 10 lps and 30 lps. The infiltration characteristics determined indicated that the Kostiakov equation (McCulloh, 1976) will be:

$$D\ (cm) = 1.41\ T^{0.79}$$

Where D = cumulative infiltrated depth (cm)
T = time (minutes).

$$I\ (cm/hr) = (1.41)\ (0.79)\ (60)\ T^{-0.21} = 66.83\ T^{-0.21}$$

Where I = infiltration rate (cm/hr)
T = time (minutes).

$$\bar{I}\ (0 \rightarrow T_e) = D(T_e)/T_e = \frac{1.41\ (T_e)^{0.79}}{T_e} \times 60$$

$$\bar{I}\ (0 \rightarrow T_e) = 84.60\ (T_e)^{-0.21}$$

Where $\bar{I}\ (0 \rightarrow T_e)$ = average infiltration rate from T = 0 to T = T_e

Evaluating the intake rate using the 8 intake family curves of the SCS was not possible because the infiltration curve of El-Hammami soils was off the scale. For this reason, to completely answer the above question, a solution technique relating advance to infiltration characteristics is required.

An example is the "zero inertia model", the following analysis is a simplification.

Assuming that the advancing front has covered the basin, what flow rate is required to keep it there? This flow rate will be less than that required to cause water to cover the basin.

Assume that the infiltration rate in effect is the average rate for the first 195 minutes (27.95 cm/hr) (Table 27).

As this assumption seems realistic,

$$\sum \text{inflow} = \sum \text{outflow} + \text{storage}$$

Assume storage = 0

Table 27. Average Infiltration Rate for the First 195 Minutes

Time	D	I
0	0.00	0
5	5.03	47.67
10	8.69	41.21
20	15.03	35.63
60	35.81	28.29
120	61.91	24.46
180	85.29	22.46
195	90.85	22.08
	$\bar{I}$ $(0-T_e)$	27.95

$$\Sigma \text{ inflow} = Q \text{ lps}$$

$$\Sigma \text{ outflow} = I \text{ (cm/hr) } wl \text{ (m}^2) \frac{m}{100 \text{ cm}} \frac{1000 \text{ l}}{m^3} \frac{hr}{3600 \text{ sec}}$$

$$= \frac{I \ wl \ (1000)}{(100)3600)} \text{ l/sec} = 2.78 \times 10^{-3} \ I \ wl \text{ l/sec}$$

For equilibrium:

$$\Sigma \text{ inflow} = \Sigma \text{ outflow}$$

$$Q = 2.78 \times 10^{-3} \ I \ wl$$

$$\text{Given } \bar{I} = 27.95 \text{ cm/hr}$$

$$wl = Q/2.78 \times 10^{-3} \ (27.95)$$

From the results obtained using the above technique, we can answer why basins are small at El-Hammami area. The analysis indicates the existing field layouts are the only efficient surface design the farmers can have (Table 28).

C. Effect of Water Table

The data analysis indicated that in all cases a major discrepancy exists in which a large amount of water was applied, but very little water stored and the plants used several times the amount of water stored. The question then arises as to what happened to all the water that was applied and from where did the plants get their water requirements?

In some cases the water applied was actually less than the estimated consumptive use. The plants must have obtained their water requirements from other sources than the water applied.

It is suspected that the discrepancies between water applied and water stored and between water stored and water used is a result of interaction with the high water table found in the area. This could cause extensive subsurface water movement. It may be possible in El-Hammami that much of the irrigation water infiltrates to the water table and spreads laterally so that it raises the water table under both the field receiving irrigation and the adjacent fields (Figure 12). This provides some subsurface irrigation to the neighboring fields. Likewise, when a neighboring field is irrigated, some water flows under the farmer's fields raising his water table and providing subsurface irrigation for his crops. It is also possible for additional horizontal movement of water to take place directly from El-Hammami canal.

Table 28. Available Flow Rates and Maximum Basin Area.

Available Flow Rate Q lps	Maximum Basin Area (wl)	Maximum Basin Area (m^2)
5	8 x 8	64
10	11 x 11	128
15	14 x 14	193
18	15 x 15	231
20	16 x 16	257
25	18 x 18	322
30	20 x 20	386
40	23 x 23	515
50	25 x 25	644

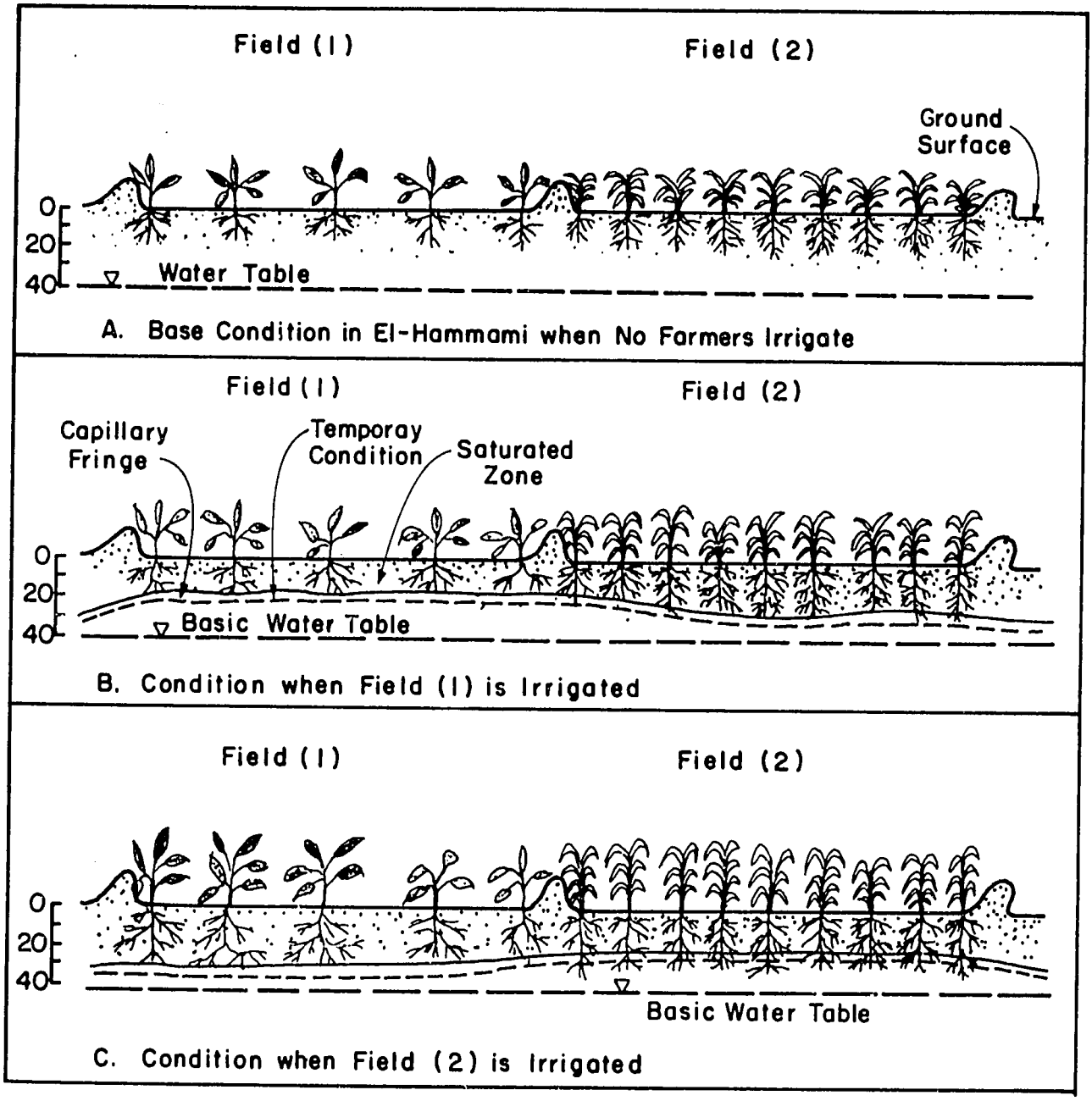

Figure 12. Schematic Sketch for Water le Fluctuation and Subsurface Irrigation of Adjacent Field.

That type of horizontal movement resulting from possible neighboring irrigations and canal seepage can account for some of the negative depletion values found in some of the soil moisture data. (soil moisture data sheets).

VI. SUMMARY AND CONCLUSIONS

The application efficiencies in the area were 14% in the first farm, 18 to 36% in the second and 33 to 58% in the third one. The consumptive use efficiencies were much bigger than the application efficiencies. The big differences between the two efficiencies might be a function of the water table fluctuation and the subsurface irrigation of adjacent fields.

The farm location by the canal appeared to influence the amount of water applied by the farmers and consequently the farmers' application efficiency. It is found that the less the water is available, the higher the application efficiency is.

It is too difficult to conclude from the low values of application efficiencies calculated that the farmers overirrigate their fields because of the high influence of the water table. However, the data indicated that some farmers over apply irrigation water, it may not all be overirrigation because some could be reused by some other farmers through subsurface irrigation of the neighboring fields. More intensive studies need to be made for the different factors affecting the application efficiency calculations and the on-farm irrigation practices in general.

A complete water budget study is of primary importance before making any conclusions or recommendations concerning the on-farm irrigation practices in any area.

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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	100×10^4	247.105	238.048	100.000
1 sq. mile	259×10^6	640.000	616.400	259.000

WATER MEASUREMENTS	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 rainfall)	23.809	0.781	9.372
420 m^3 /Feddan (= 100 mm rainfall)	10.00	0.328	3.936

OTHER CONVERSION		METRIC	U.S.
1 ardab	=	198 liters	5.62 bushels
1 ardab/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 OF 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
Broadbeans	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.)

EGYPT WATER USE AND MANAGEMENT PROJECT

PROJECT TECHNICAL REPORTS

NO.	TITLE	AUTHOR
PTR#1	Problem Identification Report for Mansuriya Study Area, 10/77 to 10/78.	Egyptian and American Field Teams.
PTR#2	Preliminary Soil Survey Report for the Beni Magdul and El-Hammami Areas.	A. D. Dotzenko, M. Zanati, A. A. Abdel Wahed, & A. M. Keleg.
PTR#3	Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt.	American and Egyptian Field Teams.
PTR#4	On-farm Irrigation Practices in Mansuriya District, Egypt.	M. El-Kady, W. Clyma & M. Abu-Zeid
PTR#5	Economic Costs of Water Shortage Along Branch Canals.	A. El Shinnawi M. Skold & M. Nasr
PTR#6	Problem Identification Report For Kafr El-Sheikh Study Area.	Egyptian and American Field Teams.
PTR#7	A Procedure for Evaluating the Cost of Lifting Water for Irrigation in Egypt.	H. Wahby, G. Quenemoen & M. Helal
PTR#8	Farm Record Summary and Analysis for Study Cases at Abu Raya and Mansuriya Sites, 1978/1979.	F. Abdel Al & M. Skold
PTR#9	Irrigation & Production of Rice in Abu Raya, Kafr El-Sheikh Governorate.	Kafr El-Sheikh Team as Compiled by T. W. Ley & R. L. Tinsley
PTR#10	Soil Fertility Survey in Kafr El-Sheikh, El Mansuriya and El-Minya Sites.	M. Zanati, P. N. Soltanpour, A.T.A. Mostafa, & A. Keleg.
PTR#11	Kafr El-Sheikh Farm Management Survey Crop Enterprise Budgets and Profitability Analysis.	M. Haider & F. Abdel Al
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PTR#25	Problem Identification Report for El-Minya	R. Brooks

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PTR#33	Soil Survey Report for Abyuha Area Minya Governorate.	A. A. Selim, M. A. El-Nahal, & M. H. Assal
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PTR#58*	Cotton Field Trials, Summer, 1980 Abu Raya.	Kafr El-Sheikh Team as compiled by M. Awad & A. El-Kayal
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MAN.#1	Trapezoidal Flumes for the Egypt Water Use Project.	By: A. R. Robinson.
MAN.#2	Programs for the HP Computer Model 9825 for EWUP Operations.	By: M. Helal, D. Sunada, J. Loftis, M. Quenemoen, W. Ree, R. McConnen, R. King, A. Nazr and R. Stalford.
MAN.#5	Precison Land Leveling Data Analysis Program for HP9825 Desktop Calculator	T. W. Ley
MAN.#8	Thirty Steps to Precision Land Leveling	A. Bayoumi, S. Boctor & N. Dimick
MAN.#9	Alphabetical List of Some Crops and Plants with Their English, Egyptian, Botanical & Arabic Names and Vocabulary of Agricultural and other Terms Commonly Used.	G. Ayad
MAN.#10	EWUP Farm Record System	Farouk Abdel Al, David R. Martella, and Gamal Ayad

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